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An interaction effect between young children's field dependence-independence and order of learning with glass-box and black-box simulations: Evidence for the malleability of cognitive style in computer-supported learning

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ABSTRACT

A counterbalanced measures design was used to examine whether the order of learning with a glass-box simulation about the life cycle of butterflies, and, a black-box simulation about the life of bees, differentially affected field-dependent and field-independent children's performance on two related knowledge tests. The children aged from 5 to 6.5 years old were classified into a field type based on their Children's Embedded Figures Test scores. Subsequently, they were assigned into Group A and Group B. Group A learned first with the glass-box simulation followed by the black-box simulation, while Group B used the tools in the reverse order. A statistically significant interaction effect was found between field type and order of learning with the simulations on the butterfly post-test performance, showing that learning first with the black-box simulation facilitated field-dependent children's subsequent learning with the glass-box simulation. The results tap on the issue about whether field dependence-independence is a cognitive ability or cognitive style, and the issue of the malleability of cognitive styles as well. Implications and future research directions are discussed.

1. Introduction

Today's children constitute a new generation of learners known as "*digital natives*" (Prenksy, 2001). This new generation of learners is surrounded by a multitude of technological tools and uses computers ubiquitously in daily life (Plowman, Stevenson, Stephen, & McPake, 2012). Accordingly, the integration of computers in preschool education has become an issue of great concern for researchers, who emphasize the need to develop technology-enhanced curricula that are developmentally appropriate for young children (Blackwell, Lauricella, & Wartella, 2014; Fridin, 2014; Keren & Fridin, 2014; McManis & Gunnewig, 2012). In view of that, the internationally acclaimed organization National Association for the Education of Young Children (NAEYC), having as its main concern children's overall development, published in 2012 specific guidelines for the use of computers in the preschool classroom (NAEYC, 2012). These guidelines raised important concerns for research and practice, and especially about whether young children, irrespective of individual cognitive differences, were able to learn from certain types of computer tools and their affordances.

In particular, the use of simulation tools in education is an area of study that has greatly attracted the interest of the research community since the 1980s (Jungck & Calley, 1985; Plass, Homer, & Hayward, 2009; van der Meij & de Jong, 2006; de Jong, 1998; Rutten, van Joolingen, & van der Veen, 2012; Ward et al., 2015; Leutner, 1993; Swaak, van Joolingen, & de Jong, 1998; Hobson, Cabe, & Sackes, 2010). Succinctly, simulations provide many advantages to support calls for inquiry-based and learner-centered instruction, and have the most potential in making abstract content more concrete, accessible, and understandable to learners (Smetana & Bell, 2012). In addition, they allow learners to experiment with ideas that would otherwise be too complex, time-consuming, and adventurous to pursue in a conventional classroom environment (Akpan, 2002).

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Researchers have also recognized that an important factor influencing learners' understanding of the content, when taught with the use of any technological tool, is individual cognitive differences, and, in particular, learners' cognitive style of field dependence-independence (FD-I) (Burnett, 2010; Dragon, 2009). FD-I has a direct effect on how learners perceive, process, and organize data and information (Morgan, 1997; Price, 2004; Thomas & McKay, 2010; Witkin, Moore, Goodenough, & Cox, 1977). As a result, FD-I may potentially lead to a better, or worse, learner performance during learning with a computer tool (Angeli & Valanides, 2004; Burnett, 2010; Dragon, 2009;).

The cognitive style of FD-I has received more attention from researchers in education and psychology than any other cognitive style (Evans, Richardson, & Waring, 2013). It is characterized as a dipole, with the one end including field-independent (FI) learners and the other end field-dependent (FD) learners (Riding, 1997; Witkin et al., 1977). The main difference between the two ends relates to the ways that individuals perceive and process complex visual and/or textual information (Chen & Macredie, 2002; Morgan, 1997; Price, 2004).

Research, however, about the role of FD-I on young children's performance during learning with simulations is scarce (Satici, 2006), while, at the same time, it is acknowledged that there is recent research evidence showing the effects of FD-I on undergraduate students' performance during learning with simulations (Burnett, 2010; Dragon, 2009). For example, researchers have examined the effects of learning with glass-box (model-transparent) simulations, and, found that FI learners outperformed FD learners during learning with this type of simulation (Angeli & Valanides, 2004, 2013; Dragon, 2009).

These findings have important implications for undertaking future research work in this area and raise a number of important questions, such as: Do researchers accept that only FI learners can learn with simulations and that FD learners cannot, simply because their cognitive style impedes them from learning with these tools? Or, do researchers continue to explore ways of how all school children, irrespective of cognitive style differences, can benefit from learning with simulations? If one considers the fact that the percentage of FD learners in a school classroom is usually much higher than the percentage of FI learners (Brownlee, Schraw, & Berthelsen, 2011), then ongoing research efforts about how to scaffold FD students' learning with simulations are fully warranted.

In the study herein, the authors sought to further advance this line of research by examining whether the order of using a black-box (model-opaque) simulation and a glass-box (model-transparent) simulation would differentially affect young children's performance on knowledge tests, taking into consideration their FD-I. Thus, two computer simulation systems were specifically designed and implemented for the purposes of this research. The first computer system simulated the life cycle of butterflies, and, the second, the life of bees in the hive. The system about the life cycle of butterflies used a glass-box simulation, which provided a learner-controlled sequential presentation of the underlying model in a graphical form, exemplifying all nodes (variables) and the connections (relationships) between them. The system about the life of bees in the hive used a black-box simulation, which provided simultaneous presentations of information, but with no model transparency. The two topics were randomly selected among several other possible topics. The most important thing was to select topics with abstract content that required some form of transformation (in this case using the affordances of simulations) in order to be better understood by the children.

Undoubtedly, empirical evidence in favor of order effects between the two types of simulations, and learners' FD-I in terms of their performance on the knowledge tests about the life cycle of butterflies and the life of bees in the hive, will have both practical and theoretical significance. Regarding the practical significance, the results of the study can be used to guide the integration of simulation tools in the education of young children, taking into consideration possible differences in their cognitive style. Regarding the theoretical significance, the research will provide evidence about the extent to which the order of learning with glass-box and black-box simulations can compensate for cognitive style differences between FD and FI learners. The study will also add to the existing body of research about the nature of cognitive style, and, it will contribute to the continuing discussion about whether FD-I is an ability or a style (Evans et al., 2013; Kozhevnikov, Evans, & Kosslyn, 2014; Rittschof, 2010), as well as about the malleability of cognitive styles (Zhang, 2013).

2. Literature review

Simulations include expert models that learners explore by observing how changes in the values of an independent/input variable of the model affect the values of a dependent/output variable of the model (Clariana, 1989; Clariana & Strobel, 2008). Models constitute external representations of a phenomenon, comprising the (independent) variables that can be handled by learners for hypothesis testing, in order to study causal relations between one or more dependent variables and a number of independent variables (Gilbert, 2004; Jonassen & Strobel, 2006).

Bliss (1994) identified two types of modeling - explorative modeling and expressive modeling. Although, in both types of modeling, the students are called to explore a model, i.e., to examine cause and effect relations, their main difference is that in explorative modeling students have to test an existing model designed by someone else and draw their own conclusions in the end. In expressive modeling, students create their own model based on their experiences and knowledge. Then, they test the model, and, depending on the results, they proceed with the improvement and/or modification of the model if necessary.

Simulations are tools that promote explorative modeling. They allow students to test or explore models, but not to create their own models or modify existing ones (Clariana & Strobel, 2008). According to Landriscina (2013), simulations are distinguished into black-box or model-opaque simulations, and, glass-box or model-transparent simulations. In black-box or model-opaque simulations learners explore a system's behavior, but the underlying conceptual and computational model of the simulation remains hidden. Thus, learners can only observe the results of the causal relationships between the variables (Landriscina, 2013). Glass-box or model-transparent simulations, on the other hand, make the structure of the model underlying the simulation visible to the learners in the form of a diagram with nodes and connecting links between them (Landriscina, 2013). The use of glass-box simulations has been proposed in the literature to obviate the problem that may arise when students learn in a free exploration style with black-box simulations, that is, the development of misconceptions (i.e., misinterpretations of the model and the causal relations between the variables) that may interfere with later learning.

Nonetheless, learning with glass-box simulations always involves additional information provided by the transparent model, which can benefit only those learners who can correctly understand and interpret the model (Landriscina, 2013). Indeed, Bliss (1994) and Bliss et al. (1992) showed in their studies that most students found it hard to understand and test a model in its entirety. These results corroborate with the findings of more recent research studies (e.g., Angeli, 2013; Angeli & Valanides, 2013; Angeli, Valanides, & Kirschner, 2009), which also showed that students were not always successful in exploring a model as a