ORDER EFFECTS OF LEARNING WITH MODELING AND SIMULATION SOFTWARE ON FIELD-DEPENDENT AND FIELD-INDEPENDENT CHILDREN'S COGNITIVE PERFORMANCE: AN INTERACTION EFFECT

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ABSTRACT

The study examined the interaction between field dependence-independence (FD/I) and learning with modeling software and simulations, and their effect on children's performance. Participants were randomly assigned into two groups. Group A first learned with a modeling tool and then with simulations. Group B learned first with simulations and then with a modeling tool. A statistically significant interaction was found between FD/I and the order of using the two types of software. FI children in group A outperformed FD children in the same group on the modeling task. However, these results were not observed with the FD children in group B indicating that learning first with simulations facilitated the subsequent learning with the modeling tool of FD children only.

KEYWORDS

Modeling tools, simulations, field-dependence/independence, interaction effect, problem solving

1. INTRODUCTION

The use of computers in pre-school education is an issue of great concern for the research community (Chen & Chang, 2006). The objective and aim of every relevant research is to understand the way in which computers should be used, so as to facilitate the learning of young children (Haugland, 2000). In 2012, the internationally acclaimed organization National Association for the Education of Young Children (NAEYC), having as its main concern the overall development of children, and more specifically of infants, published guidelines according to which pre-primary teachers are expected to use computers in the classroom. One of these guidelines states that the use of computers should only be done when used in a correct pedagogical way aiming at the children's overall development. Since children can use computers with ease (Clements, 1999), the use of such tools in organized learning environments (e.g., in classrooms) is considered necessary in order to encourage students to investigate, create, solve problems and think critically. To maximize, however, the benefits for the children, computers have to become an integral part of teaching and learning throughout the curriculum (Chen & Chang, 2006) and always within an organized framework where computers are used in a developmentally suitable manner aiming at the children's overall development.

In particular, the use of modeling and simulation tools in young children's education is a research field of great interest (Dimitracopoulou, Komis, Apostolopoulos, & Politis, 1999; Jacobson & Wilensky, 2006; Sterman, 2006; Hmelo, Holton, & Kolodner, 2000; Ayersman, 1995; Moreno & Meyer, 1999). Modeling tools are powerful mental tools for the creation and understanding of systems through a process of studying the relations among the variables of the entities comprising the system (Jonassen, 2000, 2004). Simulation tools constitute software dynamically visualizing the relations among entity variables (Clariana & Strobel, 2008). As Rieber (1996) states, simulations are governed by the environment determined mainly by the content. Their design includes the mental models of their creators (e.g., teachers), and the students have to handle the variables and observe the relations between them (Clariana, 1989). As Linn et.al (2010) mention, interactive simulations as intermediate models facilitate the learning of abstract phenomena in authentic contexts and the understanding of the relations between variables. The modeling software represents a complex phenomenon showing the quantitative or qualitative relations between variables, without however offering the rich authentic dynamic representations of the simulation software.

Another factor influencing the understanding of the content when taught with the use of any technological tool is directly related to the cognitive characteristics of the students themselves (Hmelo & Azevedo, 2006). For example, Dragon (2009) argues that individuals with a different cognitive style process data and information in a different way. In Educational Technology, the cognitive style of field-dependence/independence (FD/I) has been quite popular among the researchers. The term cognitive style refers to individuals' different abilities to absorb and process information from their environment (Burnett, 2010; Chen & Macredie, 2002; Morgan, 1997; Witkin, Moore, Goodenough, & Cox, 1977). FD/I is characterized as a dipole, with the one end including individuals whose characteristics refer to the field-independent (FI) cognitive style, and the other end including individuals whose characteristics refer to the field-dependent (FD) cognitive style (Morgan, 1997). The main difference between the two ends, according to researchers, is found in the way that individuals process complex representations (Morgan, 1997; Chen & Macredie, 2002; Davis, 1991; Snowman & Biehler, 1993; Canelos, Taylor, & Gates, 1980; Liu & Reed, 1994).

Although there is insufficient research in the literature regarding the examination of the role of the cognitive style on young children's cognitive performance during their learning using simulations and or modeling software, there is recent research evidence showing the effects of FD/I on undergraduate students' ability to solve a complicated problem using modeling tools (Angeli & Valanides, 2004; Angeli, Valanides, & Kirschner, 2009; Angeli, 2013; Angeli & Valanides, 2013) and simulation software (Trees, Doyle, & Radzicki, 1996). Specifically, the research evidence thus far shows that FI learners outperform FD learners during problem solving with modeling tools. Within the pre-primary education context, there is only one study conducted by Polemitou (2013), which also showed that FI children outperformed FD children when they worked with a modeling tool.

In the early 1990s, there were many concerns, which even led to a debate to some extent, about the order in which types of software should be integrated in the education of young children. More specifically, the debate related to the order of use of modeling and simulation software; that is to say if children of a young age should learn using modeling software first followed by simulation software or the other way around (Nichol, 1988; Webb, 1994; Bliss et al., 1992; Bliss, 1994; Polemitou, 2013). There has been no conclusion to this dispute, because, up until today, the research community has not examined this issue systematically through empirical research.

Therefore, to remedy for this lack of research, the study herein examined whether the type of software (simulation/modeling) and FD/I affected the performance of children aged between 5 and 6.5 years, as well as whether there was any interaction between the order of use of the software (that is to say, the use of modeling software first followed by simulation software or the other way around) and children's cognitive style.

2. METHOD

2.1 Participants

Children between 5 to 6.5 years of age participated in the research. The Children's Embedded Figures Test (CEFT; Karp & Konstadt, 1971) was used to measure children's cognitive style. The CEFT test was used with 140 children who were recruited for participating in this research study. Only 59 out of the 140 children managed to achieve the required grade on the CEFT in order for the researchers to be able to classify them in one of the two cognitive styles (i.e., FD or FI). The remaining 81 children were excluded from the research.

2.2 Data Collection Instruments

2.2.1 Pretest/Posttest: The Life Cycle of Butterflies

The test consisted of four exercises. In the first exercise, the children were asked to match pictures of a caterpillar, a butterfly, eggs, and a chrysalis with the correct words. In the second exercise, they were asked to put the life stages of a butterfly in order. In the third exercise, the children were given four life cycles of a butterfly and four weather conditions, namely, sunny, cloudy, rainy, and snowy, and they were asked to match each life cycle with a weather condition. In the fourth and last exercise four levels of sunlight were presented. The children had to circle the chrysalis or the butterfly for each level of sunlight, depending on what they believed would happen, that is to say if the chrysalis would turn into a butterfly or whether it would remain a chrysalis, based on the given level of sunlight.

2.2.2 Pretest/Posttest: The Life Cycle of Bees

The test consisted of five exercises. The first exercise included pictures of three bee types (e.g., worker, queen, drone bees), and asked the children to match them with the correct words. Subsequently, in the second, third, fourth and fifth exercises they were given pictures of various weather conditions (e.g., sunny, cloudy, rainy, snowy), as well as pictures of the tasks performed by bees; the children had to circle the task they believed would take place under each weather condition.

2.2.3 Children's Embedded Figures Test (CEFT)

The CEFT test (Karp & Konstadt, 1971) is specifically designed for children between 5-9 years of age. Karp and Konstadt (1971) reported that the internal reliability of the test, which was measured using Cronbach's alpha, was 0.87. The test consists of 38 questions. In the first part of the test the children are asked to locate a simple shape in the form of an equilateral triangle embedded in 19 other complex shapes. In the next 19 questions, the children are asked to locate a small house. The time the children have at their disposal to locate the simple shape embedded in each one of the complex shapes is 30 seconds.

2.3 Modeling Software: “The Life Cycle of Butterflies”

The software was designed to represent the life cycle of butterflies in the form of a model, and included the main factors influencing their survival and the continuation of the species. The child selects one of the four weather conditions (i.e., sunny, cloudy, rainy, snowy) first, and, then, the software models the life cycle of a butterfly according to the weather condition selected by the child. The variables of the model constitute: (a) the quantity of eggs laid, (b) the existence of adequate food quantity for the caterpillar, (c) the size of the caterpillar after four days of continuous food consumption, and (d) the quantity of sunlight required for the final metamorphosis of the caterpillar from chrysalis to butterfly. The child eventually has to select all four weather conditions in order to understand the factors influencing the growth of a butterfly under each condition.

2.4 Simulation Software: “The Life of Bees and their Role in Honey Production”

Using the simulation software, the child selects one of four weather conditions (i.e., sunny, cloudy, rainy, snowy), first, and, then, the software simulates the life of bees inside and outside the hive through a series of dynamic visualizations. In this way, the children observe the bees coming out of the hive, gathering pollen and returning, as well as the mating process between the queen and the drones. They can also observe, through a series of animated images, the different tasks being carried out in the hive (i.e., placing nectar in the cells, placing wax in the cells, cell purification, and larvae birth). Gradually, the children have to check all four weather conditions, in order to understand how weather conditions affect the work and lifestyle of bees in different ways.

2.5 Research Procedure

During the first stage, each child was given the CEFT test individually (Karp & Konstadt, 1971). Based on the children’s performance on this test, the researchers classified them in one of the two cognitive styles, namely, FI or FD. The total duration of the CEFT test was 20 minutes. Each cognitive style classification was then randomly divided into two sub-groups; group A worked with the modeling software first followed by the simulation software, and group B worked with the simulation software first followed by the modeling software.

Fifteen days after the first stage, the second stage followed. In the second stage, the children of group A were given a pretest to assess their prior knowledge regarding the life cycle of butterflies, while the children of group B were given a pretest about the life cycle of bees. The assigned time for each pretest was 10 minutes. After the children completed the pretest, they were asked to work on the computer for the next 30 minutes, using the modeling software (Group A) or the simulation software (Group B).

During the first 10 minutes of the third stage, the posttest was administered. Then, the children had a 10-minute break, and those who worked with the modeling software in the second stage were given a 10-minute pretest to assess their prior knowledge regarding the life of bees, while the children who worked with the simulation software in the second stage took a 10-minute pretest to assess their prior knowledge regarding the life cycle of butterflies. After the tests were completed, the children were asked to work on the computer for the next 30 minutes, using either the simulation or the modeling software. Children who in the second phase worked with the modeling tool they were asked to work with the simulation software, and those who worked with the simulation software in the second phase worked with the modeling tool during the third phase. The posttests were administered two days after the third stage.

3. RESULTS

Table 1 presents descriptive statistics of FD and FI children's performance on the pretests.

Table 1. Descriptive statistics of FD and FI children's performance on the pretests

	Modeling pretest			Simulation pretest		
	Mean	SD	N	Mean	SD	N
FD	65.75	19.57	34	52.94	12.76	34
FI	75.42	15.82	25	57.26	14.36	25

The performance of FD children on the modeling pretest was not particularly high (M = 65.75, SD = 19.57). Similarly, their performance on the simulation pretest was also low (M = 52.94, SD = 12.76). FI children had a higher performance, M = 75.42, SD = 15.82 and M = 57.26, SD = 14.36, on the modeling and simulation pretests, respectively. Nevertheless, while FI children performed better on both pretests, the difference between FI children's performance on the simulation pretest and FD children's performance on the same test was small.

Table 2 presents descriptive statistics of FD and FI children's performance on the posttests.

Table 2. Descriptive statistics of FD and FI children's performance on the posttests

	Modeling posttest			Simulation posttest		
	Mean	SD	N	Mean	SD	N
FD	93.93	7.91	34	68.42	16.89	34
FI	98.00	5.91	25	86.31	13.93	25

The FD children's performance on the modeling posttest (M = 93.93, SD = 7.91) was higher compared to their performance on the pretest (M = 65.75, SD = 19.57). The same was observed with the performance of FI children (M = 98.00, SD = 5.91). However, FI children's scores on the modeling posttest were higher than the scores of the FD children. Regarding the simulation posttest, scores of both the FD and FI children, M = 68.42, M = 86.31, respectively, were much higher than their pretest scores.

Table 3 presents descriptive statistics on children's performance on the modeling and simulation posttests for each cognitive style (FI/FD) and the order of use of the software.

Table 3. Descriptive statistics of children's performance on the modeling and simulation posttests per cognitive style and group

	Modeling posttest			Simulation posttest		
	Mean	SD	N	Mean	SD	N
FD						
Group A	90.97	8.89	18	86.55	15.76	18
Group B	97.26	5.08	16	88.49	18.55	16
FI						
Group A	99.10	3.34	14	87.59	10.03	14
Group B	96.59	8.08	11	84.68	18.15	11

Notes: Group A = modeling-simulation, Group B = simulation-modeling

As evidenced by the descriptive statistics above, the FI children of group A, namely, those who learned using modeling software first followed by simulation software, had a higher average performance than the FD children of group A on both the modeling and simulation posttests. On the other hand, FD children in group B, namely those who learned using simulation software first followed by modeling software, performed better than the FI children in group B on both posttests. Furthermore, the average performance of FD children in group B (M = 97.26, SD = 5.08) had a better performance than the FD children in group A on the modeling posttest (M = 90.97, SD = 8.89), and better performance than FI children in group B on the same test (M = 96.59, SD = 8.08).

To examine whether the order of use of the software affects FD and FI children's performance in a different way, taking into consideration their prior knowledge, a 2X2 Multivariate analysis of covariance (MANCOVA) was carried out. The results showed that the children's performance on the modeling pretest did not affect their performance on the modeling ($F_{(1,53)} = .43$, $p = .51$) and simulation ($F_{(1.53)} = 1.56$, $p = .21$) posttests to a statistically significant extent. The performance of children on the simulation pretest affected their performance to a statistically significant extent only on the simulation posttest ($F_{(1.53)} = 7.23$, $p < .05$), but not their performance on the modeling posttest ($F_{(1.53)} = .00$, $p = .95$). The results also showed a statistically significant interaction between the cognitive style and the order of use of the software, regarding the performance of students on the modeling posttest ($F_{(1,53)} = 5.17$, $p < .05$). Specifically, FI children in group A outperformed FD children in group A on the modeling task, however, these results were not observed with the FD children in group B indicating that learning first with simulations facilitated the subsequent learning with the modeling tool of FD children only.

4. DISCUSSION AND SIGNIFICANCE

According to the results, there is a statistically significant interaction between cognitive style and the order of using the two types of software. More specifically, FI children, who first used the modeling tool and then the simulation software, had a statistically higher performance on the modeling posttest, than FD children, who also used the computer tools in the same order. These results, however, were not observed when FD children first used the simulation software and then the modeling tool, which means that, learning using simulation software facilitated the subsequent learning with modeling software of FD children only. The results of this study are significant, because they show that FD learners can also learn about complex systems with modeling software if they learn first with simulation software and then with modeling software. This is highly important and significant for both the research community, as it informs the long time debate regarding the order of using the two types of software, but also the classroom teacher in terms of deciding about what tool (simulation of modeling) to integrate first in the education of young children.

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