Hemispheric Processing of Metaphors in Genetics among High School Students

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Abstract

The literature is replete with studies dealing with the importance of integration and understanding of metaphors in everyday life as well as in teaching (Aubusson, Harrison, & Ritchie, 2006; Baker & Lawson, 2001; Duit, 1991; Fredriksson & Pelger, 2016; Glynn, 2008; Guerra-Ramos, 2011; Niebert, Marsch, Treagust, 2012; Orgill & Bodner , 2005; Paris & Glynn, 2004; Pintrich, Marx, & Boyle, 1993).

However, the topic of the cognitive and hemispheric processing of metaphors with a different familiarity level in the field of teaching biology, as explored by us in the current study, has not yet been studied. A number of psycholinguistic theories address the issue of metaphorical processing. According to the "Career of Metaphor" theory (Bowdle & Gentner, 1999), the processing of metaphors with a different familiarity level (familiar versus unfamiliar), is accompanied by various cognitive processes (categorization versus comparison). Other theories, such as the "Graded Salience Hypothesis" (GSH) by Giora (Giora, 2003), claims that metaphors are processed according to the order of salience and the “Fine-Coarse Semantic Coding Model” by Beeman and Jung-Beeman, (Beeman, 1998; Jung-Beeman, 2005), predict changes in the hemispheric processing of metaphors with a different familiarity level (familiar metaphors are processed in the left hemisphere (LH) while unfamiliar metaphors are processed in the right hemisphere (RH)). The current study examined the hypotheses of these theories, for the first time, by metaphors in the field of genetics. It should be noted that the decision to integrate metaphorical processing in the brain with genetics education, was based on both the complexity of its teaching and learning on one hand and on its centralism in the studies of biology, on the other (Chu & Reid, 2012; Dikmenli, 2010; Duncan, Rogat, & Yarden, 2009; Duncan & Tseng, 2010; Knippels et al., 2005). Therefore, it is important to research it from unexplored directions and attempt to comprehend what would happen during the learning process.

In the current study, a three months intervention program for learning genetics through metaphors was developed according to "Teaching With Analogies" model (= TWA) by Glynn (Glynn, 1994, 2007). With the aid of this intervention program, the familiarity process of metaphors was implemented and its effect on the cognitive and hemispheric processing of the metaphors learned, was examined. In addition, we examined the program's efficacy on educational indicators that are unique for science, such as the level of knowledge and

misconceptions in genetics, the level of motivation towards science learning and the level of scientific creative thinking among 12th grade biology students.

Study goals: The main goal of the current study was to examine the effects of the intervention program for teaching genetics through metaphors according to TWA model, on cognitive and hemispheric processing of metaphors and on the advancement of educational indicators in teaching biology among 12th grade biology students. The study focused on the following six main targets: 1) To examine the effect of the intervention program on preference of different linguistic structures (categorization versus comparison) in understanding metaphors in genetics with a different familiarity level (familiar versus unfamiliar). 2) To examine the effect of the intervention program on the processing of metaphors in genetics with a different familiarity level (by reaction times and accuracy rates measurements) in the intervention group versus the control group. 3) To examine the effect of the intervention program on the hemispherical processing of metaphors with a different familiarity level represented by different linguistic structures (categorization versus comparison) in the intervention group versus the control group. In particularly, to examine whether LH would be faster or more accurate in processing familiar metaphors in a categorization structure ("A is B") in the intervention group versus the control group. In addition, to examine whether RH would be faster or more accurate in processing unfamiliar metaphors in a comparison structure ("A is like B") in both groups equally. 4) To examine the effect of the intervention program on the students' motivation level towards science learning and its components in the intervention group versus the control group. 5) To examine the effect of the intervention program on the level of knowledge and misconceptions in genetics in the intervention group versus the control group. 6) To examine the effect of the intervention program on the level of creative scientific thinking and its components in the intervention group versus the control group.

Method: In the study participated 214 12th grade biology students (ages 17-18), who were all native Hebrew speakers with normal development and without any learning disabilities. All of the participants attended state secular high schools in central Israel and majored in biology. Three experiments were conducted. In the first experiment participated 43 12th grade students who learned genetics with the help of the intervention program. Following the intervention, the participants answered a *Preference questionnaire to categorization form for understanding metaphors in genetic with a different familiarity level,* in order to identify the involvement of various thought processes in processing metaphors in genetics with a different familiarity level. In the second experiment participated 34 12th grade students who took part in the intervention group and 25 students who served as a control group. In this experiment the students completed a central computerized metaphorical test in which response times and accuracy rates were collected for semantic judgment of metaphors with a different familiarity level, in order to examine differences in the cognitive processing between both groups. In addition, the students answered the *Students' Motivation toward Science Learning (SMTSL)* questionnaire prior to learning genetics and following it. In the third experiment participated 72 12th grade students who took part in the intervention group and 40 students who served as a control group. In this experiment, the students completed a computerized hemispheric metaphorical test, which used the technique of divided visual field (DVF) that permits to test hemispheric lateralization in the processing of metaphors with a different familiarity level represented by different linguistic structures. Finally, the students were tested in standardized knowledge tests, misconceptions test and scientific creative thinking test, after learning genetics.

Results: the results of the current study indicated that for the first time in genetics instruction, various cognitive processes are involved in understanding metaphors in genetics with a different familiarity level. While in the processing of an unfamiliar metaphor, a comparison process is conducted, in the processing of a familiar metaphor, a categorization process is conducted, among 12th grade biology students who learned genetics with the intervention program. In addition, it was found that familiar metaphors were processed more rapidly and accurately than unfamiliar metaphors in the intervention group compared to the control group. More importantly, the findings indicated that the familiarity level of metaphors affected the different hemispheric involvement. It was found that in the intervention group, familiar metaphors in a linguistic structure of categorization ("A is B") were processed faster than in the comparison structure ("A is like B") in the LH. On the contrary, unfamiliar metaphors in a comparison structure were processed faster than in the categorization structure in the RH. Furthermore, the intervention program was found to be effective from an educational standpoint. The results indicate that the more metaphors are learned by using the instructions developed by us based on the TWA model (Glynn, 1994, 2007), they lead to an increase in the genetics knowledge level, without inducing further misconceptions as well as to an increase in the level of motivation toward science learning in general and in its components:

self-efficacy, active learning strategies and stimulating the learning environment). Furthermore, it leads to an increase in the level of creative scientific thinking in general and in its components: fluency, flexibility and originality, among students in the intervention group versus the control group.

Conclusions and importance of the study: The results suggest that when teaching new concepts through metaphors, teachers should resort more to using a language that promotes comparison processes (i.e., through similes) rather than a language that promotes categorization processes. This information can raise the teacher's awareness of the language spoken in class. Moreover, the results further indicate that learning genetics through exposure to metaphors led to changes in the hemispheric processing of metaphors. According to the findings, a familiarization process (conventionalization) of unfamiliar metaphors to familiar metaphors occurred with the help of the intervention program and a movement was detected from right to left hemispheric processing. These findings support, for the first time in learning genetics, the hypotheses of the psycholinguistic theories: the "Career of Metaphor" theory (Bowdle & Gentner, 1999, 2005), the "Graded Salience Hypothesis" (GSH) (Giora, 2003), and the “Fine-Coarse Semantic Coding Model” (Beeman, 1998; Jung-Beeman, 2005). These findings further contribute to the understanding of the cerebral mechanisms and the cognitive processes involved in understanding metaphors in science. Presently, there is scarcely any information on this topic, despite the vast literature on the processing of metaphors. These results provide the teacher with a deeper understanding of the thinking and learning processes which involve both hemispheres in the student's brain during the course of learning science through metaphors. Information on the normal cerebral mechanism in processing metaphorical language in populations without neurological and development disturbances, can also implicate on tracing the neuro-anatomical source of irregular students – both those with difficulties in sciences and those who are gifted. Future studies may examine whether new topics learned in school, among various populations of students of different ages, first engage the right hemisphere and when assimilated, are mainly processed by the left hemisphere.

The finding of the current study further broaden the educational knowledge in this field, since the study implemented, for the first time, a three months program for learning genetics through metaphors among 12th grade students by using the TWA model. Its results led to a higher level in educational measurements related to science education (motivation toward science learning, level of knowledge and level of scientific creativity), unexplored so far. These findings broaden and knowledge of studies that found that TWA model pedagogically effective (Glynn, & Takahashi, 1998; Paris & Glynn, 2004) and mostly support the importance of integrating metaphors in science education (Aubusson et al., 2006; Baker & Lawson, 2001; Duit, 1991; Fredriksson & Pelger, 2016; Glynn, 2008; Guerra-Ramos, 2011; Niebert et al., 2012; Orgill & Bodner , 2005; Paris & Glynn, 2004; Pintrich et al., 1993).In addition, the results refute the concern for an increase in misconceptions following the use of metaphors, as was noted in several studies (Marcelos & Nagem, 2011; Ornek & Saleh, 2012).

Our study demonstrates that the first time integration of psycholinguistic and cerebral aspects to educational aspect in biological education can be productive. With the findings of this study, it is possible to continue to learn and develop the field of science education as an alloy of pedagogical knowledge integrated with psycholinguistic knowledge.