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The effects of an animation-based on-line learning environment on transfer of knowledge and on motivation for science and technology learning

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Abstract

The study described here is among the first of its kind to investigate systematically the effect of learning with integrated animations on transfer of knowledge and on motivation to learn science and technology. Four hundred eighteen 5th and 7th grade students across Israel participated in a study. Students in the experimental group participated at least once a week in science and technology lessons that integrated the animation environment. The experiment was continued for two to three months. The findings showed a significant impact of animation-based on-line learning environment on transfer of knowledge and on learning motivation. Additionally, the findings showed that students changed their perception of science and technology learning as a result of teaching and learning with integrated animations. Students perceived themselves as playing a more central role in classroom interactions, felt greater interest in learning, and emphasized more the use of technology and experiments during lessons.

Keywords: Animation, transfer of knowledge, learning motivation.

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Introduction

BrainPOP is an animation-based on-line learning environment that includes a variety of animation videos and accessory tools for teachers and learners. The educational-scientific rationale behind BrainPOP has a high potential to enhance students’ understanding and learning motivation. Beginning in 2006-2007, tens of Israeli schools have implemented teaching and learning based on BrainPOP’s animation videos. The main objective of this study was to examine the effect of integration of the animation-based environment into the learning process on transfer of knowledge and student motivation to learn science and technology. Alongside several studies that examined the effects of technology-enriched learning environments on higher-order thinking skills (e.g. Hopson, Simms, & Knezek, 2001-2002), the present study is one of the first to examine systematically the effects of animation-based learning environment on higher-order thinking skills, with a focus on development of transfer abilities.

Background and Rationale

Animation as an educational tool

Information and communications technology (ICT) has opened new possibilities for increasing the effectiveness of teaching and learning processes (e.g. Bransford, Brown, Cocking, 1999; Salomon, 2002). One of the most promising is the animation-based learning environment. Animation is a dynamic representation that can be used to make change and complex processes explicit to the learner (Schnotz, & Lowe, 2003). Series studies have shown that learning in computer-based animations environments enhanced the understanding of complex concepts and systems compared with traditional learning environments that concentrate on verbal explanations (Park, 1994; Rieber, 1991; Tversky, Bauer-Morrison, & Betrancourt, 2002). For example, in traditional teaching settings it is difficult to describe the movement of electrons in an electric system, or chemical reactions between substances (e.g. Williamson & Abraham, 1995). Animation supports a creation of mental representations of phenomena, promoting better understanding. Computer animation is highly effective in demonstration of processes that cannot be viewed naturally or that are difficult to demonstrate in the classroom or even in the laboratory (Fleming, Hart, & Savage, 2000). Animation-based technology-enhanced learning environments were found to be highly effective in developing algorithmic thinking in computer science (e.g. Ben-Bassat Levy et. al., 2003; Esponda-Arguero, 2008), constructing knowledge in geometry and algebra (Reed, 2005; Rubio Garcia et. al., 2007), understanding abstract concepts in chemistry and biology (Kelly, & Jones,

2007; Rotbain, Marbach-Ad, & Stavy, 2008), and biotechnology learning (Good, 2004; Yarden & Yarden, 2006).

Studies that examined the effectiveness of animation-based learning environments, compared with static pictures produced mixed and even contradictory results. On one hand, several studies showed that by and large animation-based learning has no significant advantage over static pictures (e.g. Tversky et al., 2002; Betrancourt, 2005). On the other hand, a meta-analytic findings show that dynamic animations have significant advantages in promoting of learning success (Hoeffler, & Leutner, 2007). Other studies have shown that giving learners control over an animation and cooperative learning can increase the effect of animation-based learning environments (Betrancourt, 2005; Mayer, & Chandler, 2001; Schwan, & Riempp, 2004). Nevertheless, it was found that within the context of complex systems, there is no advantage to the user control over the animation (e.g. Lowe, 2004; Boucheix, 2007), so that the effectiveness of the animation is not limited to the cases in which the learner is required to carry out specific actions in addition to watching the animation.

The challenge of evaluation criteria

Evaluation criteria are one of the main challenges of studies that examine effectiveness of innovative learning environments. Specifically, the challenge is to find measures and tools that can represent appropriately the psychological-pedagogical characteristics of technology-intensive and traditional learning environments. In most cases, criteria for the evaluation of learning success are homogeneous and based on traditional measures. The effect of learning in technology-intensive learning environment

was assessed mostly with traditional achievement evaluation measures. But technology-intensive learning environment serve unique educational goals. Evaluation measures that can express the effect of technology-intensive learning environments must take into account the unique educational goals of the innovative environments (Rosen, & Salomon, 2007). These goals include the ability to explain problems, creative problem solving, transfer of knowledge to new unfamiliar situations, tendency for challenges, collaborative problem solving and motivation for learning. In the studies, Brown and Campione (1994) used non-traditional evaluation measures such as creativeness of learner's suggestions and solutions, analogies and methods of argumentation. In their CSILE project, Scardamalia, Bereiter and Lamon (1994), developed and implemented a measure for thinking level. The main measures used in the Jasper project assessed information explanation, creative problem solving, and learning motivation (Hickey, Moore & Pellegrino, 2001).

Examination of the effects of animation-based learning

The new educational measures developed in the course of different research projects dealing with technology-intensive learning environments are appropriate for assessing the educational goals unique to these environments. These measures serve as a basis for the present study. The objective of this study was to expand the knowledge about the effects of teaching and learning with animations. More specifically, the study examined the effect of animation-based learning environment on transfer of knowledge and on motivation to learn science and technology. Regarding transfer of knowledge, the study focused on the effect of the learning experience on the students' ability to

implement knowledge to new and unfamiliar situations, a conscious and directed transfer of abstract concepts that can be widely implemented in other fields and new situations (e.g. Salomon & Perkins, 1989; Bransford & Schwartz, 1999; Halpern, 1998). This ability is of great importance for learned knowledge and it provides a thinking tool for learning and understanding new topics.

Several previous studies showed a tendency of effectiveness of animation-based learning on problem-solving transfer compared with text-based learning (e.g. Chandler & Sweller, 1991; Mayer & Anderson, 1991, Mayer & Sims, 1994, Mayer, Steinhoff, Bower, & Mars, 1995). Animation is assumed to be promising teaching and learning tool, yet its efficacy in fostering transfer and learning motivation is inconclusive (Park & Gittelman, 1992; Rieber, 1989; Tversky et al., 2002). This study was designed to expand the knowledge about the effect of animation-based learning on transfer and learning motivation.

Research Questions

The study addressed the following questions regarding the effect of the BrainPOP animation-based learning environment:

1. What is the effect of the environment on transfer of knowledge, within the context of science and technology learning?
2. What is the effect of the environment on motivation for science and technology learning?

Method

Research Population

The study was conducted in Israel during the 2007-2008 school years, in five elementary and three secondary schools. All participating schools integrated teaching and learning based on the BrainPOP animation environment in their standard curriculum on a subject matter ‘Science and technology’ (See the Hebrew version: <http://www.brainpop.co.il>; English version: <http://www.brainpop.com>). The following inclusion criteria were used to select the participating schools:

- a. The presence of same-grade control groups where science and technology instruction was conducted with traditional methods (without the use of BrainPOP animations or some other technology-enhanced learning environment).
- b. Willingness of the administrative and pedagogical staff to cooperate fully with the research staff.
- c. The presence of the technological infrastructure required by BrainPOP learning environment.

Table 1 summarizes the grade and gender distribution of participating students between the experimental and control groups.

Table 1: Research population by grade and gender

Group	Male	Female	Elementary	Secondary	Overall
Experimental	81(36%)	132(58.7%)	128(56.9%)	97(43.1%)	225
Control	56(29%)	119(61.7%)	122(63.2%)	71(36.8%)	193
Overall	137	251	250	168	418

* 12 (5.3%) students from the experimental group and 18 (9.3%) students from the control group did not report their gender.

Four hundred and eighteen students participated in the study: 250 from 5th grade and 168 from the 7th grade. Students in the experimental group participated at least once a week in science and technology lessons that integrated the animation environment. The experiment was continued for two to three months, depending on the topic being taught. None of the students had participated in the past in this type of instruction. The students had full access to the animation environment after school hours as well. Eight science and technology teachers volunteered to participate in the study. To eliminate or reduce the teacher effect, in most cases the same teacher taught both the experimental and the control group. All teachers had at least seven years of seniority.

The Learning Context

The study focused on two topics from the science and technology curriculum for elementary and secondary schools in Israel:

- a. *The earth and the space (5th grade)* – 24 BrainPOP animations on such topics as the moon, the sun, galaxies, asteroids, the Big Bang, and life cycle of stars.
- b. *Materials and their properties (7th grade)* – 18 BrainPOP animations on such topics as the atom model, state of aggregation, compounds, isotopes, and acids.

The content of the animations is adapted to the curriculum, with strict emphasis on scientific accuracy and pedagogical suitability. Teaching and learning process is based on an interaction of Tim (a boy) and Moby (a robot) as main educational figures of the animations. An average duration of an animation is 3-5 minutes. Most videos are furnished with a lesson plan for the teacher, a quiz, and database of questions and answers for students. In addition, students can send questions to the system operators and to receive answers by e-mail.

Research Variables

Background variables:

- a. Gender
- b. Parents' occupation
- c. Participation in extra-curriculum scientific activities

Independent variable: Participation in classes integrating BrainPOP animations into the learning process at least once a week.

Dependent variables:

- a. **Transfer of knowledge.** The present study focused on transfer of knowledge to the new and unfamiliar situations (e.g. Salomon & Perkins, 1989; Bransford & Schwartz, 1999; Halpern, 1998). Transfer of knowledge is one of the key components of higher-order thinking skills. More general components of higher-order thinking skills include raising questions, making comparisons, resolving non-algorithmic and complex

problems, coping with disagreement, identification of hidden assumptions, and planning scientific experiments (e.g. Zohar & Dori, 2003, Zohar, 2004).

b. **Motivation to learn science and technology.** This variable has been defined as an internal state that arouses, directs and supports student behavior with regard to science and technology learning. Students tend to perceive the science and technology learning as a significant and profitable activity, and they aspire to derive maximal benefit from it (e.g. Glynn & Koballa, 2006).

Procedure and Research Tools

The study consisted of a multi-measure self-report questionnaire administrated using the pre-post method:

Pre-test: Before participation in classes integrating the BrainPOP animation environment.

Post-test: After the end of the learning period (2-3 months) of the relevant topics for each grade.

The questionnaire included the following components:

a. *Transfer of knowledge.* Six questions on topics related to earth and space or materials and their properties (according to grade), assessing the students' ability to transfer knowledge to a new and unfamiliar situation, such as¹:

¹ The questions were adopted by the researchers and a focus group of two teachers based on conceptualization of higher-order thinking skills with special emphasis on transfer, and questions from the science and technology curriculum for elementary and secondary schools in Israel.

- You are a member of a space crew! According to plan, the crew was supposed to meet the spaceship on the bright side of the moon. Because of a technical failure the spaceship landed at a distance of 220 km from the intended location. During landing most of the equipment was damaged. The survival of your crew depends on reaching the mothership. You must therefore choose the most essential items which will help your crew stay alive on the 200 km journey to the mothership. Attached is a list of 6 items (Matchbox, sky map, magnetic compass, space suit, 25 liters of water, transmitter activated by solar energy) that were not damaged. List them in order from the most important to the least important for your crew. Explain how each item can assist your crew and how it can be used.
- You must plan a basketball game on the moon. The size of the field on planet earth is determined by the players' ability to throw a ball from one side of the field to the other. The height of the basket is determined by the relative difficulty of reaching it by jumping. Will you recommend changing the length of the field and the height of the basket? Explain your answer (it is assumed that the mass of the ball has not changed).
- Imagine that you have tied two similar balloons together – one filled with helium, the other with carbon dioxide. What will happen to the balloons? Describe various possibilities.
- A fan is activated for a long time in a sealed room with no people inside. Will the temperature in the room go up or down? Explain your answer.

The answers were coded independently by two graduated students in education. Agreement in the answers was 83% for elementary and 88% for the secondary students.

b. Motivation for science and technology learning

The questionnaire included 10 items to assess the extent to which students were interested in science and technology learning. Participants reported the degree of their agreement with each item on a 5-point Likert scale (1=strongly disagree, 5=strongly agree), for example: I enjoy learning science and technology; scientific matters are related to my fields of interest; I want to continue learning science in the future; I want to be a scientist. The items were adopted from the SMQ-Science Motivation Questionnaire (Glynn, & Koballa, 2005). The reliability (internal consistency) of the questionnaire was .87. Additionally, participants were asked to make a drawing or write a text about a typical science and technology lesson. The qualitative data was intended to enrich the quantitative information collected with the motivation questionnaire. The drawings were analyzed using a quantitative method on drawing components. Following the establishment of the categories, student drawings were coded independently by three graduate students in education. Inter-coded agreement was 84% for both elementary and secondary students. Drawings were coded based on the following categories:

- Student at the center – Position of the student in the learning environment;
- Students enjoyment – Representing positive emotions, such as smiling or words like ‘happy’;
- Use of computer;
- Use of blackboard;
- Experiments by students

Students were also asked to indicate the background information, including gender, parents' occupation, and participation in extra-curriculum scientific activities. This information was collected because of potential interaction with study variables.

Results

Effect on transfer of knowledge

Students in the experimental and control groups were asked to complete the transfer of knowledge questionnaire before and after the experiment. The six questions were designed to indicate the students' ability to implement their knowledge to new situations in a science and technology context. Correct answers to the six questions summarized to produce grade of 100.

Table 2: Effects of BrainPOP animations on developing transfer of knowledge ability in elementary schools students

Group	Pre-test	Post-test	t(df)	ES
	Mean(SD)	Mean(SD)		
Experimental	44.31(21.95)	63.59(16.59)	11.50*** (122)	1.00
Control	43.65(21.68)	45.04(20.44)	3.58*(114)	.08

*** $p < .001$, ** $p < .01$, * $p < .05$.

Table 2 shows the results for elementary schools students. The findings showed that integrating BrainPOP animations into the learning process significantly increased the ability to transfer scientific and technological knowledge of elementary schools students

(ES=1.00, $t=11.50$, $p<.001$). During the same period, the findings showed only a low increase in the same ability of the control group.

Table 3: Effects of BrainPOP animations on developing transfer of knowledge ability in secondary schools students

Group	Pre-test	Post-test	t(df)	ES
	Mean(SD)	Mean(SD)		
Experimental	48.46(30.58)	72.53(20.95)	8.41*** (90)	.93
Control	50.63(26.14)	51.59(21.11)	.04*(62)	.04

*** $p < .001$, ** $p < .01$, * $p < .05$.

Table 3 shows the results of the secondary schools students. The findings showed that learning with animations significantly increased the ability to transfer scientific and technological knowledge also among the secondary schools students (ES=.93, $t=8.41$, $p<.001$). During the same period, only minimal increase in transfer of knowledge ability of the control group was found. In addition, the study showed that integrating BrainPOP animations into learning process increased classroom homogeneity among secondary schools students with regard to the ability of knowledge transfer (SD change of 9.63 in the experimental group and 5.03 in the control group).

No significant relations were found between integrating BrainPOP animations into the learning process and gender, parents' occupation and participation in extra-curriculum science activities of either elementary or secondary school students.

Effect on motivation to learn science and technology

Students in the experimental and control groups were asked to complete the motivation questionnaire before and after the experiment. Table 4 shows the results for elementary school students.

Table 4: Effects of integrating BrainPOP animations into learning process on the science and technology learning motivation of elementary schools students

Group	Pre-test	Post-test	t(df)	ES
	Mean(SD)	Mean(SD)		
Experimental	3.24(.77)	4.38(.58)	15.28*** (118)	1.70
Control	3.18(.87)	2.98(.78)	-4.57***(112)	-.24

*** $p < .001$, ** $p < .01$, * $p < .05$.

The findings showed that integrating BrainPOP animations into the learning process significantly increased science and technology learning motivation of elementary schools students (ES=1.70, $t=15.28$, $p<.001$). During the same period, the findings showed a decrease in motivation in the control group.

Table 5 shows the results for secondary schools students. The findings showed a similar pattern also among the secondary schools students. Learning with BrainPOP animations significantly increased the motivation of secondary schools students to learn science and technology (ES=.91, $t=9.90$, $p<.001$). During the same period, the findings showed a decrease in motivation in the control group.

Table 5: Effects of integrating BrainPOP animations into the learning process on science and technology learning motivation of secondary schools students

Group	Pre-test	Post-test	t(df)	ES
	Mean(SD)	Mean(SD)		
Experimental	3.00(.86)	3.67(.62)	9.90*** (90)	.91
Control	2.98(.82)	2.80(.68)	-3.80***(61)	-.42

*** $p < .001$, ** $p < .01$, * $p < .05$.

Effects on the perception of science learning – student drawings

Students in the experimental and control groups were asked to draw pictures of science and technology lesson before and after the experiment. The following categories were used to analyze the drawings (see the section on research tools): students in the center, scientific equipment, student enjoyment, learning with computers, and learning through experiments. Table 6 shows the results of the qualitative analysis of the elementary students' drawings before and after learning with BrainPOP animations.

Table 6: Effect of learning with BrainPOP animations on the perception of science and technology learning based on elementary schools' drawings

Category	Experimental group		Control group	
	Pre-test (%)	Post-test (%)	Pre-test (%)	Post-test (%)

Student at the center	20.7	58.1	21.4	19.6
Scientific equipment	22.6	56.6	24.2	30.6
Student enjoyment	32.4	64.5	30.7	28.3
Learning with computers	12.5	63.6	13.9	12.7
Learning through experiments	17.9	38.8	19.2	21.3

After integrating BrainPOP animations into the learning processes, the drawings of most of the elementary schools students showed the learner at the center of classroom interactions (58.1% compared with 20.7 before the experiment and with 19.6% in the control group during the same period). The drawings illustrated the use of ICT (63.6%) and showed greater emphasis on scientific equipment (38.8%). Most of the students' figures that appear in the drawings showed interest in learning (64.5% compared with 32.4% before the experiment and with 28.3% in the control group during the same time). Only small differences were found among in the control group between pre- and post-test drawings.

Table 7: Effect of learning with BrainPOP animations on perception of science and technology learning based on secondary students' drawings

Category	Experimental group		Control group	
	Pre-test (%)	Post-test (%)	Pre-test (%)	Post-test (%)
Student at the center	6.0	51.2	10.2	13.6
Scientific equipment	25.0	52.1	23.4	27.5
Student enjoyment	20.3	52.5	18.6	20.1

Learning with computers	14.6	45.8	12.1	10.3
Learning through experiments	24.0	42.9	26.4	28.8

Table 7 shows the results of the qualitative analysis of the secondary students' drawings before and after the integration of BrainPOP animations into the learning process. Similarly to elementary schools students, after the integration of BrainPOP animations into the learning experience, most of the secondary students' drawings placed the students in the center of the classroom interaction (51.2% compared with 6% before the experiment and with 13.6% in the control group during same period). The drawings illustrated ICT (45.8%) and emphasized scientific equipment (52.1%). Most of the students' figures in the drawings showed happiness and interest in learning (52.5%). Only small differences were found in the control group between pre- and post-test drawings. In sum, before integrating BrainPOP animations into the learning environment, the students' perception of science learning was characterized by use of the blackboard, minimal learning through experiments, and low use of ICT. Students saw themselves as peripheral in classroom interactions, with the teacher being perceived as the central figure. Most of the students' drawings included a component that was irrelevant to the lesson.

Discussion

The goal of this study was to examine the impact of BrainPOP animations integrated into the learning environment on transfer of knowledge and on science and

technology learning motivation. The findings showed that learning with BrainPOP animations increased significantly the students' ability to transfer scientific and technological knowledge to new and unfamiliar situations (elementary students: $ES=1.00$, $t=11.50$, $p<.001$; secondary students: $ES=.93$, $t=8.41$, $p<.001$). Results show that a technology-enriched learning environment that combines traditional components of teaching with ICT-assisted learning (animation videos and online quizzes), produces thoughtful learners with an ability to transfer knowledge, which is one of the most complex abilities (Haskell, 2001; Marini, & Genereux, 1995).

Transfer of knowledge is a process in which knowledge is used significantly in new context (target task) based on knowledge constructed in different situation (source task), including the reconstruction and adaptation of knowledge (Presseau, & Frenay, 2004). Educational goals that emphasize thinking in addition to knowledge construction can be achieved in a learning environment based on up-to-date psychological principles and educational goals (Rosen, & Salomon, 2007). The BrainPOP animations learning environment is partially based on these principles stressing multi-dimensional thinking and the demonstration of complex phenomena. Teachers and content experts are used as mediators in the learning process, erasing the borders between classrooms and home learning. The characteristics of the animations and especially of their heroes promotes perspective-taking among students. Children identify with the animation's heroes and view the content through their eyes. The psychological-educational dimensions of teaching and learning with animations lead to construction of knowledge transfer ability – one of the most important thinking skills (e.g. Salomon, & Perkins, 1989; Bransford, & Schwartz, 1999; Halpern, 1998). This finding is consistent with the results of previous

studies, showing the high potential of computer-based animations in learning about complex systems compared with a traditional learning environment that focuses on verbal explanations provided by the teachers (e.g. Park, 1994; Rieber, 1991; Tversky, Bauer-Morrison, & Betrancourt, 2002). The graphic interface of the BrainPOP learning environment provides a highly effective stimulus for the learner by means of sound and animation. The environment promotes visual thinking, which is very important in the information age (Eshet, 2004).

The study showed that learning with integrated animations significantly increased the motivation for science and technology learning (elementary students: $ES=1.70$, $t=15.28$, $p<.001$; secondary students: $ES=.91$, $t=9.90$, $p<.001$), while the motivation of the control group decreased during the year. The motivational components within the animations are consistent with the concept of *flow* (optimal experience), which includes feelings of concentration and enjoyment, excitement, internal motivation, and a tendency to repeat the activity (Csikszentmihalyi, 1988; Nakamura, & Csikszentmihalyi, 2002).

The study showed that students changed their perception of science learning as a result of learning with integrated animations. Students perceived themselves as playing a more central role in classroom interactions, felt greater interest in learning, and emphasized more the use of ICT and experiments during lessons. Thus, the change was not merely motivational but a conceptual change regarding the nature of learning. Whereas among learners the conceptual change was the result of learning in a new environment, the teachers reported on the need for an innovative conception among teachers as a necessary condition for teaching in a new environment. Teachers were

characterized by creativity, confidence, and a sense of commitment to their students in creating a new and improved learning space.

The study also found that among secondary school students learning with integrated animations there was an increased tendency toward class homogeneity with respect to transfer of knowledge (a change of 9.63 in SD). A possible explanation for this result is that learning in traditional settings is especially difficult for students with learning disabilities. Those students experienced feelings of optimal experience provided by the new animation-based environment. These feelings increased the learning motivation of students with learning disabilities and deepened their understanding of the topic. This result is consistent with those of previous studies that examined the effects of technology-enriched learning environments on students with learning disabilities (e.g. Ford, Poe, & Cox, 1993; Ota, & DuPaul, 2002).

Limitations and Recommendations for Further Research

1. The research examined differences in transfer of knowledge and motivation in a context of science and technology learning. An unanswered question is whether learning with animations makes a difference in other contexts as well, such as, social sciences and mathematics?
2. Participants in the study were elementary and secondary schools students. It remains to be determined whether results would have been different with high school or college students?

3. The present study focused on the ability of students to transfer knowledge into new situations. A remaining question is whether learning with animations affects additional aspects of knowledge, abilities, and skills?

4. Distinctions between near and far transfer, general and specific transfer have potentially great research and practical importance concerning the effect of a learning environment with integrated animations. Far transfer refers to transfer of knowledge and skills to situations significantly different from those in which the knowledge or skills were constructed. By contrast, near transfer refers to transfer to new, but partly similar learning situation (e.g. Misko, 1995, 1999). Transfer is considered to be general if the task is multi-disciplinary and specific if it takes place within the original field in which the knowledge and skills were constructed (e.g. Cormier, & Hagman, 1987; Perkins, & Salomon, 1989). It is recommended to examine the effect of animation-based learning on a variety of transfer types.

5. Based primarily on increased tendency toward class homogeneity with respect to transfer of knowledge, the findings showed that learning in an environment that integrates animations is especially beneficial for students with learning disabilities. It is important to design a study that examines specifically the effects of learning in an environment with integrated animations on students with learning disabilities.

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