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CONTENTS

Teaching Matters Again: Studying, developing, and implementing brain-based pedagogies.

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Recent dissemination of brain-based research on how students learn and how they learn science best has focused our research on how children construct their knowledge, think about their learning, and the context in which meaningful learning takes place. Two of the articles in this issue of EJSE utilize this research to better understand children's construction of meaning and learning in science. But, as science education researchers we have long known that the single most influential factor for students' learning in schools is the classroom teacher. Studying teaching practices that support children's learning as we understand it today is critical for teacher formation and development. As Sherwood and Hanson remind us in their analysis of recent NSF funding, more financial support is needed from the science community for these studies.

My own recent experience in working with many of the new NSF-sponsored science curricula at the elementary and middle grades level and their design addresses much of what we know about how children learn science. Yet, I begin to worry about the success of these new research-based curricula on student learning if we don't pay close attention to supporting our teachers in its implementation. Teachers who are new to pedagogical approaches that look at student conceptions, in-depth learning, true formative assessment, learning in context, and use of metacognitive tools may be quickly overwhelmed during teacher workshops and in subsequent teaching. In such instances they will do what they know best to do, potentially thwarting curriculum designers' intents. Yet, as practitioners, teachers also know effective ways to reach their children and implement curriculum in their school contexts. Curriculum designers may once again have taken the approach of 'one size fits all' when it comes to implementation and use. This harkens back to earlier NSF sponsored reforms of the 1960s and the 'teacher-proof' curricula that emerged. We learned from that era what we will likely learn again, that some teachers implement it well with high student learning gains, while other teachers struggle to see any gains over more traditional and well-known approaches. Further progress in meaningful student learning in science will once again come down to the teacher in the classroom.

So, in our renewed effort to study pedagogy that supports reform in science education through brain-based research on student learning, let's always be mindful that teachers of science are not all the same, and the skills, abilities, and attitudes to enact a reform-based curriculum will vary from teacher to teacher. With this in mind we need to ask ourselves in a constructivist manner, how can we build a bridge (or scaffolding) for teachers from where they are to where we want them to be? Even more radical than this, how can we build a bridge between our current knowledge of student learning and teachers as they are while still maintaining the integrity of best practice for meaningful science learning?

The Effects of Brain-Based Learning on Academic Achievement and Retention of Knowledge in Science Course*

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Abstract

The aim of this study is to investigate the effects of brain-based learning in a 5th grade Science course on academic achievement and retention of previously acquired knowledge. This experimental study, which was designed as pre- and post-test control group model, was conducted in 2004-2005 academic year at Kütahya Abdurrahman Paşa Primary School in Kütahya, Turkey. Two classes, namely 5-A and 5-B, were determined as experimental and control groups respectively. The participants of this study were 22 fifth graders from each group. The study lasted 11 days for a total of 18 class hours. During the research process, the experimental group was administered a brain-based learning approach, while the control group was administered a traditional teaching approach. Analysis of post-test and retention level tests revealed a significant difference between the groups favoring brain-based learning.

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Introduction

Today, new theories and approaches (e.g. constructivism, multiple intelligence, active learning, Inquiry-based learning) are put forward to eliminate the limitations of the traditional way of teaching and to improve the quality of instruction. Also, various theoretical (Taber, 2006; Wink, 2006; von Glasersfeld, 1995; Gardner, 1993) and practical (Akkus, Gunel & Hand, 2007; Barrington, 2004; Sivan, Leung, Woon & Kember, 2000; Watts, 1999; Cho, Yager, Park & Seo, 1997) studies are carried out to come up with different views for teaching. One of these views is brain-based learning.

Brain-based learning can be defined as an interdisciplinary answer to the question of "what is the most effective way of the brain's learning mechanism" (Jensen, 1998). Caine and Caine (2002) define brain-based learning as "recognition of the brain's codes for a meaningful learning and adjusting the teaching process in relation to those codes."

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* This paper is based on an MA study carried out under the supervision of Dr. Mehmet GULTEKIN at Anadolu University, Eskisehir

Studies (Hari & Lounasmaa 2000; Posner & Raichle, 1994) in the field of neurobiology have improved understanding of how the brain functions and how learning is formed. Educators who work in collaboration with neurobiologists integrate knowledge of the functions of the brain and adapt them to learning principles (Cross, 1999; Wortock, 2002). Brain-based learning aims to enhance the learning potential and, in contrast to the traditional approaches and models, provides a teaching and learning framework for educators (Materna, 2000).

The Principles of Brain-based Learning

The principles of brain-based learning provide a theoretical framework for the effective learning and teaching process, seeking the best conditions in which learning takes place in the brain. Based in neurobiology, these principles guide educators to select and prepare learning environments. Caine and Caine list these principles as follows (2002):

- Brain is a parallel processor,
- Learning engages the entire physiology,
- The search for meaning is innate,
- The search for meaning occurs through patterning,
- Emotions are critical to patterning,
- Every brain simultaneously perceives and creates parts and wholes,
- Learning involves both focused attention and peripheral attention,
- Learning always involves conscious and unconscious processes,
- We have at least two types of memory systems: spatial and rote learning
- The brain understands and remembers best when facts and skills are embedded in natural spatial memory
- Learning is enhanced by challenge and inhibited by threat,
- Every brain is unique.

The principles of brain-based learning propose that effective learning could occur only through practicing real life experiences. Learning becomes more expressive when the brain supports the processes in search of meaning and patterning. Accordingly, it enables the learners to internalize and individualize learning experiences. Therefore, it is essential that learners be encouraged to participate in the learning and teaching process actively and that teaching materials be chosen according to their learning preferences.

Various teaching strategies which enable learners to feel secure in the learning environment, to enrich learning and to assist the learning process should be utilized. Moreover, classroom activities should be encouraging and should eliminate the learners' redundant fears and anxiety. In short, brain-based learning puts forward some basic principles such as practicing real life experiences in the learning environment, establishing an effective communication with learners, and guiding learners through their learning processes. By putting these principles into practice, the quality of learning and the level of implementation of the objectives will be promoted.

Learning and Teaching Process in Brain-based Learning

Brain-based classrooms are called “brain friendly places.” These classrooms are the learning environments where the brain’s functions and their roles in learning are regarded in terms of teaching and learning process. These classes also have an emotionally enriched environment where learners are immersed into challenging experiences. Finally, in brain-based classrooms, it is believed that learners are unique and that former knowledge serves as a baseline for new learning (Fogarty, 2002).

Learners are encouraged to gain some skills during the brain-based learning process. They learn not only how to use thinking in learning process but also about the thinking process itself (Fogarty, 2002). The teaching and learning process is formed in three important phases; orchestrated immersion, relaxed alertness and active processing. Although these phases are not separated from each other with distinct lines, they invigorate components of each other in the teaching and learning process (Caine & Caine, 2002; Acikgoz, 2003).

The main focus of orchestrated immersion is to make the gist of the subject meaningful and vivid in learners’ minds. If learners grasp the gist through various sense organs, retention level of the new input will be increased. This phase helps learners establish patterns and associations in their brains while providing them with rich and complex experiences for them, making learning more permanent (Materna, 2000).

The relaxed alertness means challenging learners in a proper way but with a low level of threat (Caine & Caine, 1995). Learners need to feel secure so that they can take risks. If the objective is to change the thinking styles of learners through establishing associations between the old and new knowledge, then learners need to be secure and require a challenging relaxed alertness (Pool, 1997).

Orchestrated immersion and relaxed alertness play a significant role in the ongoing process of searching for meaning in the brain. However, the brain should work consciously in order to increase the patterning in its utmost level and perceive the experiences and additional possibilities. This process of brain-based learning is called active processing (Cram &Germinario, 2000).

Active processing is the theoretical organization and internalization of the meaningful information by learners (Caine & Caine, 2002), and should be regarded as a focus on meaningful learning rather than memorization. As Materna (2000) states, the brain struggles to form meaningful patterns from experiences as it processes information. Learners make associations in order to set up permanent learning prior to grasping the newly encountered information and storing it for the further use.

One of the components of active processing phase is evaluation (Caine & Caine, 1995). The context, the emotions, the physical environment, the process and the organization are the five components of a reliable evaluation in the brain-based learning. These areas of evaluation involve mental, physical and emotional processes as well as past, present and future (Jensen, 2000). Contrary to traditional evaluation procedures, such kind of evaluation does not involve the evaluation activities that exist at the end of each unit or the subject. The evaluation in this procedure is ongoing and cumulative. The aim of the evaluation activities is to figure out the interests and the weak and strong learning styles of the students. In order to achieve this goal in evaluation, the procedure should not be threatening, but should have motivating factors for learners (Stevens & Goldberg, 2001).

Brain-based Learning in Science Teaching

The subjects of science courses are inseparable units of various academic fields (e.g. physics, chemistry, biology, mathematics, social studies) and intermingled with real life experiences. Students come across various theories of physical science, definitions of chemical composites, and cell structures. They also come up with anxieties about the ecosystem, earthquakes and volcanic events. Extraterrestrial life, the movements of the planets and solar and lunar eclipses attract students' attention throughout their lives. It is only natural that they are affected by these events. In order to comprehend the continuous developments in the field of science, students should be aware of the basic science terms and they should gain the science skills throughout their schooling process (Fogarty, 2002).

The learning and teaching process in science courses should be based on exploration and inquiry. Since the brain inquires meaning and attempts to set associations in a natural way, exploration and inquiry based science teaching might function compatibly with the principles of brain-based learning approach (Mangan, 1998). Brain-based learning aids teachers in facilitating the learning and teaching process. One way of relieving the process is to give learners more responsibilities for their own learning and encourage them to establish associations with the formerly learned subjects and new knowledge in order to form the learning. In order to establish this easiness in the learning and the teaching process, metaphors, thematic teaching, integrated teaching and open ended questions should be used in the learning environment.

Teachers should provide learners with a secure classroom atmosphere which has a rich learning environment challenging learners to learn. To that end, the classrooms should have a bulletin board, an aquarium, various models, computer technology and simulations. Additionally, lesson plans should be flexible and serve learners' emotional needs (Mangan, 1998). Teachers should be able to link science courses with its sub-disciplines as well as other disciplines such as physics, chemistry and biology. This integration of courses makes them more meaningful and interesting for learners as well as facilitating them for the learners who have different learning strategies (Mangan, 1998). There are various ways for teachers to integrate science courses with other disciplines. For instance, while teaching refraction of light, teachers might integrate the subject with another discipline's subject, namely the subject of "the colors" in art, or a composition course's subject such as "writing a report."

In order to teach and learn science, the brain's thinking processes should be known. Teaching and learning science mostly depends on the use of social and emotional learning processes (Konecki & Schiller, 2003). Brain-based learning enriches input by operating various teaching approaches while establishing a secure classroom environment where learners are encouraged to take risks (Jacobs, 1997).

The process of science teaching, according to the brain-based learning approach, should employ thematic learning skills with a rich language which should be natural but complex at the same time. It should also include long-term structured projects and various evaluation techniques (Holloway, 2000). The use of abovementioned elements of brain-based learning yields three important effects on learners and learning process. First of all, learners grasp the gist of how learning takes place since they are involved in the learning process actively. Secondly, they discover that learning depends on their abilities to externalize their knowledge rather than focus on the marks they get in their exams. Finally, they understand that knowing how to think will support their studies.

The Aim of the Study

The aim of this study is to determine the effects of a teaching process based on the principles of brain-based learning on academic achievement and retention of formerly gained knowledge in a 5th grade science course.

Concerning the above-mentioned aim, the following hypotheses are proposed:

1. The experimental group using the principles of brain-based learning approach will perform significantly better than the control group using traditional instruction on the achievement test designed for this science course.

2. The experimental group using the principles of brain-based learning approach will perform significantly better than the control group using traditional instruction on the retention test designed for this science course.

Methodology

This section covers the definition of the research method, participants, data gathering and analysis procedures, and interpretation of the data.

Research Model

Designed as pre- and post-test control grouped model, this experimental study was conducted in order to determine the effects of the brain-based learning on academic success and retention of formerly gained knowledge in a 5th grade science course. The study was carried out with two intact classes selected randomly. One of the classes was defined as the experimental group and the other as the control group. Both classes were tested before and after the experiment.

Participants

The participants of this study were 5th graders, namely 5-A and 5-B, in 2004-2005 academic year at Abdurrahman Paşa Primary School. The groups were determined by drawing lots, then 5-A was defined as the control group and 5-B as the experimental group.

The reasons why the experiential study was conducted in Abdurrahman Paşa Primary School were that the school administration and the teachers had a supportive attitude towards scientific research and that the physical facilities of the school were suitable for the research. The fifth graders were chosen as the study group because they were assumed to possess the skills and abilities to study, examine and search scientific matters and had access to various resources to get information. Besides, they had a developed muscle and hand coordination and a strong and natural desire for learning.

Equalization

In order to equalize the participants of the study, a personal information survey was administered and they were paired accordingly. The participants who could not be paired concerning his/her personal information and those who did not take one of the pre-tests, post-test and retention test were excluded from the study. Twenty-two students out of forty-two in each class were paired and a total of forty-four students participated in the study. The characteristic features of the equalized participants are represented in Table 1.

As is depicted in Table 1, both groups have equal number of participants in terms of gender and of getting private science lessons or not. Furthermore, the personal information data depict that the participants display similarities in terms of the incomes of their families and educational backgrounds of their parents. Thus, it can be claimed that the participants in both groups have similar socioeconomic and educational backgrounds.

Table 1
Characteristic Features of the Participants

	Experimental Group		**Control Group**	
Characteristic Features	N	Percentages	N	Percentages
Gender				
Female	12	54.6	12	54.6
Male	10	45.4	10	45.4

Average income				
Less than 200 million Turkish Liras	1	4.6	-	-
Between 201-400 million Turkish Liras	2	9.0	2	9.0
Between 401-600 million Turkish Liras	3	13.7	3	13.7
Between 601-800 million Turkish Liras	5	22.8	6	27.2
Between 801 million and 1 milliard	2	9.0	3	13.7
Turkish Liras	9	41.0	8	36.3
1 milliard and over Turkish Liras				
Educational Background of Mother				
Illiterate	-	-	-	-
Literate	1	4.6	-	-
Graduate of Primary School	7	31.9	7	31.9
Graduate of Secondary School	2	9.0	2	9.0
Graduate of High School	4	18.1	10	45.4
Graduate of University	8	36.3	3	13.7
Educational Background of Father				
Illiterate	-	-	-	-
Literate	-	-	-	-
Graduate of Primary School	5	22.8	2	9.0
Graduate of Secondary School	3	13.7	4	18.1
Graduate of High School	7	31.9	7	31.9
Graduate of University	7	31.9	9	41.0
Getting Private Lessons or Not				
Students getting private lessons	5	22.8	5	22.8
Students not getting private lessons	17	77.2	17	77.2

In the equalization process, not only the information received from the personal information questionnaire, but also the students' pre-test scores were taken into consideration. After the application of the achievement test as the pre-test, a difference (0.16) favoring the experimental group was found between the means of the student scores in the two groups. To test the significance of this difference, a "t-test" was applied to the score means of the groups and 't value' was found to be 0.43. This value is under (2.021) with 42 Df and .05 point significance level. This result shows that the difference between the arithmetic means of both groups is not significant in statistical terms. In other words, before the experiment, there was not a significant difference between the experimental and control group students' achievement level in the Movement and Power Unit.

Background of the Instructors

Both of the teachers who designed teaching activities in experimental and control groups are male. Teaching activities of the experiment group were carried out by the researcher, whereas, the teaching activities of the control group were carried out by the teacher of the class. The researcher did not participate in the teaching-learning process of control group to provide neutrality for the research. However, in order to provide validity for the research, the researcher met the teacher one day per week and discussed the course plans, and they mutually shared their views about the teaching process of the control group. In terms of teaching experience, the classroom teacher is an experienced with 27 years in the field whereas the researcher has only one and half years teaching experience. The researcher works as a research assistant at a university and does not work as a teacher at any public school before. He has reviewed several articles on brain based methods of teaching prior to conducting his research. Moreover, he practiced a 6-hour-instruction on brain-based methods of teaching in a classroom environment at a public school and examined how the brain based learning process could possibly work. Additionally, he held some meetings with two experts in this field at the university in order to exchange views about how to practice brain-based learning in the teaching-learning process in classrooms. One of those experts is a research assistant, who has completed a master's thesis on the brain-based learning and the other one is the supervisor of the first author. When the present study was conducted the first author was an M.A student in the field of Primary Education and took several courses such as Methods of Social Science Research, Learning-Teaching Process in Primary Education, Child Development and Mature Psychology, Teaching and its Problems in Primary Education, Seminar, Curriculum Development In Education, Children Literature and Education. In addition to the field specific courses the researcher also took the courses related to science education such as Science Teaching and Laboratory Applications. The second author of the present study is also M.A thesis advisor of the first author. He is an experienced instructor with 20 years of experience in the field education. His areas of interest are program development, teacher education, primary education programs, teaching and learning process of new approaches.

Data Gathering Procedure

In order to establish a theoretical framework for the study, the suggestions made by several experts in the field were reviewed and discussed. The data gathering instruments used in the present study, on the other hand, were developed by the researchers. These instruments include "The Participants' Personal Information Survey," which was mainly used for equalization of the participant groups; "Achievement Test of the Unit Movement and Power," which was used in pre-tests, post-tests and retention tests; "Lesson Plans of the Unit Movement and Power," which were prepared in accordance with brain-based learning principles; and "Teaching Materials," which were used in those courses.

The Achievement Test of the Movement and Power Unit consisted of 40 multiple-choice questions. In order to determine the reliability of the test, "halving the test method" was used. Accordingly, the achievement test was administered to only a certain part of the students with all group characteristics rather than the whole sample group. Test results were examined in accordance with "halving the test method," which indicated the reliability of the half of the test. In order to determine the reliability of the whole test, on the other hand, Sperman-Brown formula was used and the reliability coefficient was found to be .82. Tekin (2000) states that the reliability coefficient ranges from (0.00) to (+1.00), and it is nearly impossible to develop tests with (+1.00) reliability. Therefore, .82 value was considered to be sufficient for the reliability of the test.

While developing the brain-based learning materials, a literature review was conducted and data regarding the application of brain-based learning approach were gathered. After determining the specific objectives of the Movement and Power Unit, the lesson plans and the brain-based learning materials to be used in the class were designed.

Experimental Process

Once the experimental and control groups were defined, the participants were informed about the research process and its scope. Both groups were administered an achievement pre-test on the subject of Movement and Power. The experiment process took 18 class hours, six class hours per week, between May 02 and May 23, 2004. Throughout the experiment process, the experimental group practiced the brain-based learning approach, whereas the control group practiced the traditional teaching approach. At the end of the experiment process, both groups were administered an achievement post-test on the subject of Movement and Power. Three weeks later, the same post-test was administered again with the purpose of assessing the retention level of the participants.

In the application of the brain-based learning, the science laboratory in the school was used. Students were asked to sit forming a “U”shape to let them see the board, television, and the slide show better. Also, this type of sitting arrangement promoted the interaction among the students. When group work was needed, the class was organized in a way allowing 4 or 6 students to work together at a time. When the pre, post, and retention tests were applied to the students, they were asked to sit alone, so four additional classrooms were also used in this process.

The Movement and Power Unit in the science course curriculum in Turkey aims at enabling students to comprehend the different movement types, speed, how the location changes in time, the effects of Power, and the basic Powers in the nature by means of observations, applications, experiments, and different activities. In this respect, the Movement and Power Unit is composed of two main titles: “Each Object is Moveable” and “Power Means Push and Pull.” The title “Each Object is Moveable” is composed of several sub-titles: Different Movement Types Around, Gauge Your Location and Find Your Way, How Location Changes in Time, and How to Find Speed. The sub-titles of “Power Means Push and Pull” are Power Has Various Effects, Push and Pull Exist Together in the Universe, and Gravity Determines the Weight.

The following section summarizes the brain-based learning process in the experiment:

The researchers designed the learning and teaching process based on the three basic fundamentals of brain-based learning, namely ‘orchestrated immersion’, ‘relaxed alertness’, and ‘active processing’. During the ‘orchestrated immersion’ phase, power-point presentations, cartoons and comic strips, documentary films and various pictures were used in order to help students grasp the subject matter in general. After each presentation, participants were guided either to individual work or to group work concerning the subject of the presentation.

In the phase of ‘relaxed alertness,’ heterogeneous groups were formed in order to make the participants collaborate with each other and become proficient in any subject. Hence, the knowledge that the participants get during the orchestrated immersion phase become internalized in the relaxed alertness phase. In this phase, in order to form schemata, the researchers prepare some work sheets and participants were asked to write short stories, poems and they were also asked to draw comic strips related to the subject matter. Additionally, the participants were given opportunities to design projects, and they were encouraged to discuss and share the findings of their projects within groups and the whole class. Furthermore, the participants were encouraged to ask questions to other groups regarding the groups’ fields of expertness.

During the ‘active processing’ phase, on the other hand, simulations, group discussions, role plays and dramatization techniques were used in order to ensure the retaining of the obtained knowledge and to ease the structuring of this knowledge as well as applying it into new situations. Also, during the phases of ‘relaxed alertness’ and ‘active processing,’ the participants were listening to classical music. During the brain-based learning process in the experimental group, the researcher walked around the groups in the class, acting as a member of a group when it was necessary. Thus, he actively participated in the learning and teaching process and also answered questions of the students. Hence, while he assisted the groups, he provided a classroom atmosphere where the groups worked in a planned manner.

In the traditional way of teaching, the teacher’s role is to acquire knowledge and skills and then, to transmit them to the students. For this reason, this process is called direct teaching. In other words, teachers teach and students learn. In fact, the students’ real task is to reinforce and internalize the target material by listening to the teacher, taking notes and doing the assigned tasks (Caine & Caine, 2001). In the control group, a teacher centered teaching approach was adopted. Therefore, the participants in the control group were asked to read relevant subjects and explain those subjects to the class. Furthermore, they were asked to listen to the explanations of their teacher, and make experiments in the way that their teacher made.

In both control and experiment groups, the focus of teaching was the unit of Movement and Power. The lesson plans that the teacher prepared for the control group were reviewed each week to see whether any activities other than traditional teaching activities were used or not. The traditional teaching activities, mentioned above are some teacher based activities such as note taking and correction type laboratory activities, which can be defined as any kind of activity that carried out to prove a theory or an experiment of which the results are already known. Subsequent to performing the activities in the courses, the researcher and the teacher held regular meetings and the researcher interviewed the teacher so as to clarify and identify the procedures that took place during the teaching-learning process.

As soon as the experiment period was over, both groups were administered an achievement post-test. Three weeks later, the same achievement test was administered again to evaluate the retention level of the participants.

The Analysis and Interpretation of the Data

After the experimentation process, the data obtained through achievement tests were analyzed in order to determine the effects of brain-based learning approach on the achievement and retention levels of the experimental group. The data obtained by the pre-test, post-test and retention test were scored. Since the achievement test included forty items, each correct item was graded as 2.5 points out of 100 in general.

The mean scores and standard deviations of the grades obtained via pre-test, post-test and retention test administered to both groups were calculated. Results from t-tests were used to compare the achievement and retention levels of the experimental and control groups. The SPSS 12.0 software program was used in the statistical data analysis procedure and "p" value was determined as .05 for the cutoff level of significance.

Findings

An achievement test was administered as a pre-test to the experimental and control groups in order to test the first hypothesis, which claims that the experimental group using principles of brain-based learning will perform significantly better than the control group using traditional instruction on the achievement test designed for this science course. Then, the mean scores and standard deviations of the scores received by the participants from the pre-test were statistically evaluated and the differences between the mean scores were examined by means of t-test. The pre-test scores of the experimental and control groups are summarized in Table 2.

Table 2
The pre-test scores of the experimental and the control groups

Participants	Number of Participants (N)	Mean $(\bar{X})$	Standard Deviation (Sd)	t value	Degree of freedom (Df)	Signifiance level (P)
Experimental Group	22	48.18	10.83	0.43	42	> .05
Control Group	22	48.06	06.16			

t table= 2.021

As is seen in Table 2, there is a slight difference (0.12) between the pre-test mean scores of experimental and control groups. In order to test the significance of this divergence, a t-test was conducted with the means of the group's scores and t=0.43 value was determined. It is observed that this t value is below the (2.021) within 42 Df and .05 p value. This fact shows that there was not a significant difference between experimental and control groups. In other words, before the experiment process there was not a significant difference among the participants in both groups in terms of their achievement scores on the subject of Movement and Power.

Additionally, in order to evaluate the effects of the experiment process, the divergence of the post-test scores of the participants in both groups were analyzed in terms of their statistical difference. The post-test scores of experimental and control groups are summarized in Table 3.

Table 3.
The post-test scores of experimental and control groups

Participants	Number of Participants (N)	Mean ($\bar{X}$)	Standard Deviation (Sd)	t Value	Degree of freedom (Df)	Signifiance level (P)
Experimental group	22	72.38	9.71	2.65	<.05	42
Control Group	22	64.31	10.44			

t table= 2.021

As Table 3 depicts, there is a difference (8.07) between the post-test mean scores of the experimental and control groups. In order to test the significance of this divergence, a t-test was made with the means of the groups' scores and t=2.65 value was defined. It is observed that the t value obtained is higher than the table value (2.021) within 42 Df and .05 p value. This finding shows that the teaching procedures between control and experimental groups have different effects on the participants' achievement level. This finding also suggests that the brain-based learning approach is more effective than the traditional teaching procedures in science courses. As a result, the first hypothesis is not rejected.

After a three-week postponement period, a retention test was administered to test the second hypothesis, which claims that the experimental group using the principles of brain-based learning approach will perform significantly better than the control group using traditional instruction on the retention test designed for this science course. The mean scores and standard deviations of the participants' scores on the retention test were calculated and the differences between the scores were reviewed through a t-test.

Table 4.
The retention test scores of the experimental and control groups

Participants	Number of Participants (N)	Mean ($\overline{X}$)	Standard Deviation (Sd)	t value	Degree of freedom (Df)	Signifiance level (P)
Experimental Group	22	71.93	10.32	3.25	42	<.05
Control Group	22	57.38	18.24			

t table= 2.021

As is summarized in Table 4, there is a significant difference (14.55) between the retention tests' mean scores of the experimental and control groups. In order to test the significance of this divergence, a t-test was made with the means of the groups' scores and t=3.25 value was defined. It is observed that this t value is above the table value (2.021) within 42 Df and .05 p value. This finding suggests that the teaching procedures between control and experimental groups have different effects on the participants' achievement and retention. As a result, the second hypothesis is not rejected.

However, this finding is obviously depicted that there is a greater loss in retention by the traditional method than the brain based teaching method. Regarding the reasons behind the loss in retention by the traditional method in the science courses it can be explicated that the traditional instruction does not focus on the learning process. On the other hand, the brain based method of teaching primarily based on process learning. As it is obviously known the process-based learning, which is a part of brain based method of teaching, the process of teaching and learning focuses on higher level learning, profound thinking and permanence as well as transfer of knowledge. The very first aim of such a teaching and learning process is to enable the learners to organize and internalize newly encountered information. However, this organization and internalization should be regarded as an emphasis on meaningful learning rather than memorizing. Moreover, learners in such a teaching method make associations in order to set up permanent learning prior to grasping the newly encountered information and storing it for the further use. Therefore it can be claimed that there is a greater loss in retention by the traditional method than the brain based teaching method.

Discussion and Implications

Regarding the findings of this study, the brain-based learning approach appears to be more effective than the traditional teaching procedures in science courses in terms of improving students' academic achievement. This finding, which suggests that the brain-based learning approach is more effective than the traditional teaching procedures, shows similarities with the studies of Cengelci (2005) and Wortock (2002). Cengelci (2005), for instance, found out that the brain-based learning approach improved student achievement in social science courses. Moreover, the results of the study by Wortock (2002) indicated that the web-based teaching procedures designed in accordance with the principles of the brain-based learning approach were very effective in enhancing the students' achievement.

The findings of this study also suggests that the brain-based learning approach appears to be more effective than the traditional teaching procedures in science courses in terms of enhancing the retainment of the gained knowledge as well. This suggestion is similar to those of other studies in literature, particularly the studies of Getz (2003) and Cengelci (2005).

In light of the findings of the present study, the implications and suggestions are as follows:

The teachers of science courses in primary schools can take advantage of implementing the brain-based learning approach in their teaching procedures on account of enriching their students academic success and retainment of the previously learned subjects. The materials, which were developed within the framework of the present study for the purposes of in-class practice procedures of the brain-based learning approach, can be adapted or modified by the teachers of science courses in primary schools.

An in-service training program on the implementation of the brain-based learning approach in the science courses in primary schools can be offered to teachers. In collaboration with the teachers, some additional materials which are based on the brain-based learning principles, can be modified for the science courses in the 6^{th} and 7^{th} grades of primary schools. The syllabus of science teaching courses in primary school teacher training programs of educational faculties can be reshaped based on the principles of the brain-based learning approach.

The following topics can be suggested for further research: the effects of the brain-based learning approach on student attitudes towards science courses, the effects of the brain-based learning approach on the students' thinking skills and comprehension, the effects of the brain-based learning approach on the improvement of students' attitudes towards cooperative and group work, the effects of the brain-based learning approach on the students' achievement and retention in other courses, and the effects of the brain-based learning approach on the students' critical thinking and problem solving abilities.

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A Review and Analysis of the NSF Portfolio in Regard to Research on Science Teacher Education

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Some of this analysis was undertaken while the first author was a Program Director at the National Science Foundation. However, any opinions, findings, conclusions or recommendations expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation

Abstract

Several recent policy papers have called for science education to be based on substantive research activities that provide guidance for the field both in teacher preparation and student learning. For example, *America's Pressing Challenge – Building a Strong Foundation* (2006) calls for the country to "Invest in research on teaching and learning that will better inform development of science and mathematics curricula and pedagogical approaches." (p.5). In an attempt to understand what the National Science Foundation has supported in terms of research within science education teacher education a review was undertaken based upon the publicly available NSF Awards Database in regard to projects funded. The database for selected programs at NSF contained over 3000 awards for the time period January 1, 1996 to January 1, 2006 however the percentage of awards that were deemed to represent research studies in regard to science teacher education were a very small fraction of these awards (approximately 2.5%). The awards that were identified were categorized by research method, grade level and project focus. Selected awards were also reviewed to see if the results of the studies could be found in the science education literature. Implications for policy and the research community are discussed.

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Introduction

In the recently completed *Studying Teacher Education: The Report of the AERA Panel on Research and Teacher Education* (Cochran-Smith & Zeichner, 2005), the authors note that, "Again it is worth repeating that this dearth of larger and longer studies is the case, at least in part, because teacher education has rarely been a research priority for funding agencies or a focus of well-supported programmatic research." (p. 5). This report and discussions within NSF undertaken by the senior author raised the question of whether research in science teacher education had been a significant part of the programs that NSF had supported in the late 1990's and early 2000's. Such programs as Teacher Preparation (NSF 99-96), Teacher Enhancement (NSF 99-92), Teacher Professional Continuum (NSF 05-580) and the Research on Learning in Education (NSF 02-023) program had been active during this time period. As will be shown in this paper, these programs had been funded with multiple millions of dollars. Had NSF funding gone to projects that had a research on science teacher education emphasis?

In considering the funding history of teacher education from NSF, a distinction needs to be made between funding for research on teacher education and funding for teacher education activities. As noted by Vanderputten (2004) NSF has had a long history of funding projects that have supported the teacher education in the science, technology, engineering, and mathematics (STEM) disciplines. As early as 1956, NSF was providing support for secondary school teachers to develop new knowledge and skills related to their teaching. These activities include presently funded projects with such programs as the current Mathematics Science Partnership program (MSP). Generally, these types of projects have been implementation projects that have funded individuals or groups of teachers in upgrading their skills within STEM content areas or developing their pedagogical knowledge. While recent projects (within the last ten years) have had requirements for evaluation studies attached to the projects, the evaluations have been limited to particular aspects of the project and have not, in general, produced a significant amount of new knowledge for the general STEM teacher education literature. It was determined that a review of the types of projects funded within the last ten years might be especially useful in developing an overall picture of the funding levels and general direction of funding.

Data Sources and Selection of Awards

Using the publicly available NSF Awards Database (http://www.nsf.gov/awardsearch) a search was made for all awards that had award start dates of January 1, 1996 until January 1, 2006 from the division of Research, Evaluation, and Communication (REC). A second search for all awards from the division of Elementary, Secondary, and Information Education (ESIE) was made for the same period. The third division that funds some STEM teacher education research is the Division of Undergraduate Education (DUE) and it was also searched. All of these divisions are part of the Education and Human Resources Directorate (EHR) of NSF. NSF divisions outside of the Education and Human Resources directorate do at times fund or co-fund projects that have some relationship to teacher education. If the project was co-funded by one of the divisions in EHR it appeared in the database. However, some limited independent funding does occur. For example, the Engineering Directorate has made a substantive commitment to Research Experiences for Teachers (RET) supplements to engineering research projects that have been previously been funded. In general, however, these projects have been of the "summer workshop" type activity which will conduct only a limited evaluation study of the particular funded activity.

These searches produced 774 awards for REC, 2283 awards for ESIE and 307 for DUE. The DUE search was restricted to programs where a possible relationship to teacher education would have been found including the Teacher Preparation program, Teacher Professional Continuum program, and Teacher Enhancement program. All of these divisions fund projects of a variety of natures and therefore a first review was made to determine which of the programs within the divisions would be appropriate to examine more closely for projects that had a direct bearing on STEM teacher education research.

For the REC dataset (774 awards, $599 million total funding), a search on the word "teacher" was conducted of both the title of the project and the abstract. This resulted in a reduced dataset of 273 awards. The abstract of each of these awards was reviewed, if present, to determine if the award could be considered a research study that involved teachers as the main subject of the study. This resulted in a subset of 107 awards meeting this initial criterion (13.8 % of the original data set). These 107 awards were reviewed to determine which of the awards were related to science teacher education versus other STEM areas or were focused on science and another STEM area. Awards, for the REC awards and the other divisions outlined below, were also checked to see if the PI transferred an award to a new institution, which generates a new award number but not a new project. This reduced the dataset further to 42 awards with total funding of $35.5 million (5.4 % of the original data set by number of awards and 5.9% by funds).

For ESIE the categorization of awards was somewhat more complicated due to the large number of awards. To facilitate review, the larger database was split into two five year periods, 1996 to 2001 and 2001 to 2006. The raw database for the 96-01 awards contained 1531 awards and represented $1.078 billion dollars and the 01-06 database represented 752 awards and $919 million dollars of awards. For the 96-01 database only those awards that were made in the Teacher Enhancement and Instructional Materials Development programs were considered for categorization. Searching first on the word "teacher", then "science" and then reviewing the resulting abstracts produced only three awards representing $1.94 million dollars that could be considered science teacher education research awards.

For the 01-06 awards period, more programs had been started therefore, and a wider search was conducted. Removed from consideration were the following programs; Instructional Technology Experiences for Students and Teachers (ITEST), and Informal Science Education (ISE). These programs do not fund projects with a research focus. This resulted in a reduced dataset of 399 awards representing $598 million in funding. The key words of teacher and science were then searched for in the abstract and title in this reduced dataset and resulted in 179 awards being found that met these criteria. The abstracts of these awards were then individually read to see if the award had a teacher education research focus. As previously noted, a large number of the awards in the ESIE reduced subset were for projects that were designed to enhance the professional development of teachers and, even with evaluation components; they were not considered to be studies of STEM teacher education. This resulted in 36 awards representing $33.28 million dollars

The DUE dataset of 307 awards, with a dollar amount of $154 million, was searched for projects related to science, which reduced the dataset to 154 awards. These abstracts were then read to determine if the project was a teacher education research related project. Only five awards met this criterion with awards totaling $4.44 million.

Given the relatively small number of awards found from the ESIE and DUE datasets, they were combined into a single set of 41 awards (1.6% of the total awards) and $37.72 million dollars (1.7% of the total dollars).

Proposal submitted to NSF are, by regulation, not public documents and are considered the property of the submitting organization and cannot be released. General information (Title, Organization, Dates, Principle Investigators, Funding Level and Abstract) on proposals funded must be made public but the actual proposals are not released by NSF. Abstracts are of a modest length (approximately one page) and generally provide the major objectives of the project and expected outcomes. Therefore, this study was restricted to only information that was publicly available from the NSF database.

Characterization of Reduced Datasets

ESIE and DUE Reduced Datasets

The awards found in the combination of ESIE and DUE reduced datasets (41 awards) could be characterized in a number of ways but a limited set of these was used for this analysis. First, the NSF program that funded the study was determined. All but ten of the studies were funded by the relatively new (2003) Teacher Professional Continuum (TPC) program, with five being funded by the Instructional Materials Development (IMD) program, four by the Teacher Enhancement (TE) program, and one by the Science, Engineering, Technology, and Mathematics Teacher program.

Project abstracts where reviewed for the research method and the grade level of the teachers involved in the study. Tables one and two show a summary of these characteristics.

Table 1
Categories of Method

Method	Number of Awards
Descriptive	19
Experimental	2
Quasi-experimental	12
Case Studies	4
Multiple Methods	4

Table 2

Grade Level of Teachers in Study

Grade Level	Number of Awards
Elementary	7
Middle	5
Secondary	12
Elementary & Middle	3
Middle & Secondary	5
Multiple Grades	8
Undetermined Grades	1

Two types of designs are the most prevalent in the studies. About half of the studies are descriptive in nature, examining an intervention of some type and reporting on the results of the intervention usually using a change in teacher ability as an outcome measure although some also used measures of student outcomes. Fourteen studies have quasi- or experimental designs where some type of comparison group is used. Smaller numbers of studies use case studies or were using multiple methods. The most common grade level of the teachers was secondary with other grades and combinations thereof somewhat evenly distributed below that level.

Perhaps of more interest is what the project was actually studying. Given that the TPC solicitation had as a category of study "Research on Models of Professional Development" it was not surprising that several studies had this as the focus. Table three shows the number of studies in various categories.

Table 3
Focus of Project in ESIE/DUE Reduced Dataset

Focus of Project	Number of Awards
Testing of a Professional Development Model (PDM)	16
Induction Programs	3
Professional Content Knowledge (PCK)	5
Teacher Portfolios	2
Use or Modification of Curriculum Materials by Teachers	4
Impacts of Technology on Professional Development or Teaching	3
Assessment Practices of Professional Programs	2
Development of Adaptive Expertise in Teachers	1
Amount of Teacher Turnover	2
How Teachers Sustain Reform in a Local System Change Project	1
The Nature of Science and Inquiry Orientation of New Teachers	1
Effect of Reformed Science Courses on Pre-service Teachers	1

The assignment of studies to these categories was difficult and the variation in what was being studied in the projects that were lumped under the "Testing of a Professional Development Model" includes projects that are working in a variety of settings. They include pre-service programs, in-service programs and studies at both levels. The professional development models vary greatly in their depth of the model, activities and outcome measures.

REC Reduced Dataset

The awards from the REC reduced dataset were classified in the ways that were described above for the ESIE/DUE dataset. In terms of NSF program, the great majority of studies were funded by the Research on Learning in Education (ROLE) program, 19. Eight awards were funded by the Program Evaluation program, three by the Educational Research program, one each for the Advance program and the Professional Opportunities for Women in Research program. Nine awards did not have data in that cell in the database.

Tables four and five provide summary of the method of the study and the grade level of the teachers.

Table 4
Categories of Method

Method	Number of Awards
Descriptive	20
Experimental	1
Quasi-Experimental	4
Case Studies	5
Survey	4
Instrument Development	3
Existing Databases	3
Multiple Methods	4

[1] Total does not add to total number of awards (42) due to some studies being in more than one category

Table 5
Grade Level of Teachers in Study

Grade Level	Number of Awards
Elementary	5

Middle	3
Secondary	4
Elementary & Middle	3
Middle & Secondary	2
Multiple Grade	23
Undetermined Grades	2

From the abstracts provided, most of the studies were of a descriptive nature that involved multiple grade levels although classification was somewhat more difficult than with the ESIE/DUE studies due to the more general nature of abstracts.

As with the ESIE/DUE reduced dataset the abstracts of the REC dataset were reviewed to determine the focus of the study. More categories were needed for this dataset and the results of this analysis are shown in Table 6.

Table 6
Focus of Project in REC Reduced Dataset

Focus of Project Awards	Number of
Study of a professional development model	6
Long term impact of systemic initiative	5
Studies of middle and secondary school teachers practice of teaching science	4
The design or study of teacher induction programs	3
Teachers’ use of web-based instructional/knowledge environments	3
The use of video cases to assist in teacher professional development	3
The use of modeling by teachers as an approach to instruction	2
Analysis of teachers who are successful in both science and reading	2
Teachers understanding and use of inquiry-based science	2
Long term studies of how elementary teachers learn to teach science	2
The study of new models of teacher preparation	2
Evaluation of alternative routes to teacher certification	2
Studies of policies that effect hiring of teachers or their participation in professional development	2
National surveys of STEM teachers	2
Collection and analysis of the stories of Native American	1

teachers-in-training	
How to adapt and then study the process of Japanese lesson study	1

While the two datasets yielded somewhat different results in terms of the focus of the studies, there were some similarities. Both had a significant number of the studies related to the study of professional development models, which is consistent with the major thrust in that area in terms of NSF funding on professional development of STEM teachers. Prior to the start of the Teacher Professional Continuum program these awards, usually from the Math Science Partnership and or Teacher Enhancement programs, provided for the actual professional development activities and some evaluation. In depth study of the activities, however, were usually not part of the awards and principle investigators, evaluators, or faculty who were interested in their study had to apply through REC for research awards. In the REC dataset, as opposed to the ESIE/DUE dataset, there were a significant number of studies related to the systemic initiatives awards that had been funded during the late 1990's and early 2000's. As with the teacher professional development activities, these studies appear to be attempts to study in more depth the activities of particular projects with the objective of finding principles that could generalize to other school systems. In addition, the study of teacher induction programs appears in both lists as well indicating the interest in the field in these programs that have generally been introduced within the last ten years.

Impact of Awards on the Field

While fully connecting awards to papers that appear in the literature is a task that will take additional study for a full review, some examples do appear from the analysis. More examples are available from the REC dataset than the ESIE/DUE dataset owing to the fact that almost all of the research studies that have been awarded under ESIE/DUE are still underway. However, an on-going study from the first cohort of the TPC program has prepared a manuscript based upon first year results. Okhee Lee (NSF Award ESI - 0353331) and colleagues at the University of Miami (Lee, et al., in review a & b) have reported on the teachers' perspectives on teaching science to ELL students in the current testing environment in the State of Florida, as well as, student achievement results. While tentative, the first year results do show positive teacher response to the science activities of the project, as well as, increased student achievement.

In terms of the REC dataset seven examples from projects that have been completed can be connected to work funded, in part, by NSF.

Sasha Barab and colleague's work on web-based professional development communities (Barab, Makinster, & Scheckler, 2003) is one example of such a connection between a funded award (NSF Award ESI-9980081) and a published paper in the literature (Barab, MaKinster, & Scheckler, 2003). In their work with 5-12 grade mathematics and science teachers, they have provided some design principles for such environments as well has outlining some of the opportunities and challenges that such environments afford for teachers. Of particular note is one finding from the paper, "Our research suggests that designing for virtual communities involves balancing and leveraging complex dualities from the "inside" rather than applying some set of design principles from the "outside." (p. 237). This provides an interesting commentary on the design process and the need to understand the community of users well if the system is going to be used effectively.

Tom Smith and collaborators (NSF Award ESI - 0231884) have studied multiple policy issues related to the professional development of science and mathematics teachers. Their work (Desimone, Smith & Rowley, in press), using a national sample from the Schools and Staffing Survey (SASS), provides insights into the relationship of policy factors such as; authority (teacher leadership and control over school and classroom policy), power (frequency of evaluation of teachers and professional development, and ease of dismissal of teachers), consistency (extent to which a policy is aligned with other policies in the same school, district, and state), stability (the extent to which policies and people remain a stable part of the policy landscape) and the types of professional development teachers choose to participate in. They conclude, "This analysis suggests that authority and stability may play more of a role than power or consistency in fostering teacher's participation in professional development that is focused on content, and has opportunities for interaction." (p. 11).

Gaining insight into teaching science within urban settings was researched by both Barry Fishman and colleagues (Marx, Blumenfeld, Krajcik, Fishman, Soloway, Geier and Tal, 2004) and Kenneth Tobin and Rowhea Elmesky (Elmesky & Tobin, 2005) under the auspices of NSF funding. Both research groups investigated effective strategies to promote science learning to these typically low achieving students in rather poor and unpredictable conditions. Fishman reported gains in student science understanding from their work with the Detroit Public Schools (REC-9876150) in urban systemic reform. In this three-year study, the research team concluded that low achieving students in an urban setting could succeed by implementing a carefully designed curriculum supported with teacher professional development. Middle-school (6-7-8th grades) students demonstrated yearly statistically significant gains using inquiry and technology-based units that related to the students' daily lives and embedded activities to build skills and background content knowledge (How Can I Build Big Things?, What Is the Quality of Air in My Community?, What Is the Water Like in My River?, and Why Do I Need to Wear a Helmet When I Ride My Bike?). All units were collaboratively designed initially by university facility then later incorporated suggestions and feedback by the teachers. This research demonstrates that through collaboration and through a specified multi-faceted program, even low achieving students can experience success in science.

Using a critical ethnographic lens, Elmesky and Tobin (2005) described insight gained while teaching science in an urban setting. The research team used students as researchers to provide insight into Tobin's teaching and to their culture. This methodology was successful as the students provided a deeper level understanding than was previously possible. The researchers discovered the value of respect (symbolic capital) in the student-teacher relationship and recognized how valuable incorporating elements of their culture, giving the students a voice, were to that relationship. They also saw how the students' identities outside the classroom may influence their science learning. Many students felt alienated by the cultural differences and the idea that their cultural capital, knowledge and perspectives are not valued. Successful science teaching in this setting "recognizes, understands, and draws upon the resources of low-income and minority students" (p. 825) Based on their five-year research, Elmesky and Tobin recommend conscious efforts be made to connect practices from their culture into their science lessons.

In her work in the learning sciences, Sharon Derry and colleagues (Derry, 2006; Derry, Hmelo-Silver, Feltovich, Nagarajan, Chernobilsky, & Halfpap, 2005; Derry, Hmelo-Silver, Feltovich, Chernobilsky & Beitzel, in press) (REC #0107032) developed a unique online resource to assist teacher candidates in transferring conceptual content presented in teacher preparation courses to actual classroom practices. Their program, STELLAR, combined text-based instruction with video case studies, instructional activities, and online tools to allow the preservice teachers opportunities to engage in interactive problem based learning. This program was integrated into two teacher education courses at the University of Wisconsin and Rutgers with promising results. By analyzing authentic video cases, it appears that preservice teachers using the STELLAR program developed a deeper level of student understanding over comparable sections using traditional methods. Although the model is still being refined, this grant-based program represents a "pioneering step" in developing effective collaborative problem-based learning that may be capable of influencing future classroom practices.

Senta Raizen and Edward Britton used National Science Foundation funding to research various induction systems over a three-year period. Raizen and Britton, along with colleagues (Raizen, Paine, Pimm & Britton, 2003), shared their findings on comprehensive and successful teacher induction programs. Using many international models, they provided insight that into programs that support beginning science and math teachers in numerous modes of support. In this book, the authors provide a guide for beginning teacher induction programs with information ranging from whom it should serve, what should be included in such programs and the policies needed for it to become a reality.

The work of Betsy Davis (NSF Award ESI - 0092610) in collaboration with Joe Krajcik is a final example. Their article titled "Designing Educative Curriculum Materials to Promote Teacher Learning" (2005) notes that with careful design, and a full consideration of some of the principles of teacher development, curriculum materials that are designed for K-12 students can also provide teachers ways to improve their knowledge base. This combination of perspectives that involves a faculty member whose primary work involves teachers (Davis) and one whose work is primarily with K-12 students (Krajcik) has implications for educational research. The education of K-12 students has multiple aspects, curriculum, teachers, assessments, schools, policy, etc. If work can be undertaken that allows groups of researchers to cover multiple aspects of this arena, the impact of the work may be greatly enhanced. NSF has made some commitment to this direction through the "Learning Progressions" (Smith, et al., 2006) solicitation that is part of the IMD 2005 solicitation (NSF 05-612) and DR-K12 (NSF 06-593).

Limitations and Conclusions

The analysis undertaken does have some significant limitations. The use of key word searches may have left out some studies that would have been appropriate to consider but did not happen to use the key words. One person did the categorization and the work was undertaken using only project abstracts, which are sometimes limited in their content. Also, the review did not take into consideration some types of awards such as the Centers for Teaching and Learning (CLT) projects, many of which have multiple research projects some of which may be teacher education research related, and the Math Science Partnership's Research, Evaluation and Technical Assistance (RETA) projects. Finally, documents funded by NSF such as NRC reports, e.g., *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium* (NRC, 2001) do not appear in an awards analysis such as this.

The question of whether publication is the only indication of impact is also a concern within this study. Projects that have demonstrated a strong local or regional impact on teacher knowledge, skills, attitudes, etc. via an evaluation study must be considered to have been important for those teachers. While publication in referred journals is not the only measure of success of a project it generally results in wider knowledge disbursement than local evaluations. As Burkhardt and Schoenfield (2003) point out in their article on improving educational research;

> "Although good insight-focused research identifies problems and suggestions possibilities for progress, it does not itself generate reliable solutions that can be directly implemented on a large scale. To achieve that, research-based development and robust well-tested models of large-scale change are both essential." (p. 5)

Neither one of these two outcomes can be readily measured unless the information about the project reaches the field through publication.

Even considering these limitations, this analysis would indicate that the amount of support that NSF has put toward research in STEM teacher education has been relatively small compared to the amount of funding for STEM professional development projects and research on student learning. In the ten-year period of this analysis, only 83 awards out of a total of 3364 (2.5%) and $73.24 **million** out of $2.751 **billion** dollars (2.7%) met the criterion of having a project focus on science teacher education research. Based on some of the intermediate datasets, all of STEM teacher education research would probably only double the number of awards and dollars. This is not especially surprising given, as noted in the introduction, the relatively low support at the policy level for studying teacher education. Similar to the issues surrounding the general funding of educational research, policy makers have found it difficult to see major impacts from research activities as compared to services directly to teachers or the support of the new curricula/materials for students. Part of the responsibility of research supporters such as NSF, as well as the educational research community, is to be able to answer policy makers concerns in this area and show the impact of funding decisions.

However, even with these very limited funds, several projects have been able to show results that have made their way into the peer reviewed literature. While a fuller analysis of the datasets is needed to confirm these examples, it does show some promise that impact can be shown and progress made in understanding the K-12 educational system.

In addition, recent STEM policy documents; *Rising Above the Gathering Storm: Energizing and Employing American for a Brighter Economic Future* (NRC, 2006), *American Competitiveness Initiative* (OSTP, 2006) and *America's Pressing Challenge - Building A Strong Foundation* (NSB, 2006) all call for increased and improved STEM teacher education, including some indication of the importance of research on learning as a priority. For example in the *American Competitiveness Initiative,* a "bullet" notes that the initiative is designed to; "Strengthen K-12 math and science education by enhancing our understanding of how students learn and applying that knowledge to train highly qualified teachers, develop effective curricular materials, and improve student learning." (p. 3). *America's Pressing Challenge* calls for the country to "Invest in research on teaching and learning that will better inform development of science and mathematics curricula and pedagogical approaches." (p. 5) Making these initiatives reality will take more than rhetoric. Significant long-term funding for research in STEM learning, including teacher education, is needed.

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Appendix A

ESIE and DUE Awards

Award Number	Award Title	Principal Investigator
ESIE Dataset		
0455819	Investigating the Meaningfulness of Preservice Programs Across the Continuum of Teaching (IMPPACT) in Science Education	Tillotson, John
0455637	Entering the Guild: The Effects of Teacher Professional Community and Professional Development on New Teachers and Their Students	Shore, Linda

0098406	Exploring Potential Research Uses of Connecticut's Beginning Teacher Portfolios in Mathematics and Science -- A Small Grant for Exploratory Research	Britton, Edward
9553548	Investigating the Implementation of a Classroom-based Assessment System: The Case of SEPUP	Wilson, Mark
0455811	Professional Development Threading Content, Pedagogy and Curriculum: A Study of Classroom Impact	Singer, Jonathan
0083276	SGER: Exploring the Portfolios of National Board of Professional Teaching Standards (NBPTS) Candidates in Middle School Mathematics and Science	Baxter, Gail
0353451	Project MAESTRo: Measuring Adaptive Expertise in Science Teachers' Reasoning	Crawford, Valerie
0353440	Mentoring and Induction Support for Urban Secondary Science and Mathematics Teachers	Radford, David
0455711	What Influences Teachers' Modifications of Curriculum?	Hammer, David
0455679	Policy Research Initiatives in Science Education (PRISE) to Improve Teaching and Learning in High School Science	Stuessy, Carol
0455744	The Organizational Sources of Mathematics and Science Teacher Turnover	Ingersoll, Richard
0003857	Research-based Science Curricula: Developing Methods to Determine How They are Used in High School Classrooms -- A Small Grant for Exploratory Research	Miller, Jacqueline
0545445	Effects of Content-focused and Practice-based Professional Development Models on Teacher Knowledge, Classroom Practice and Student Learning in Science	Shinohara, Mayumi
0455685	Change Associated with Readiness, Education and Efficacy in Reform Science (CAREERS)	Young, Betty
0455582	The Impact of Online Professional Development: An Experimental Study of Professional Development Modalities Linked to Curriculum	Fishman, Barry
0455735	Research on the Effectiveness of the Observing for Evidence of Learning Professional Development Model for Improving Grades 6-8 Science Instruction	Hood, Leroy
0353377	The Professional Learning Community Model for Alternative Pathways in Teaching Science and Mathematics (PLC-MAP)	Herbert, Bruce
0455846	Project BEST: Better Education for Science Teachers	Powell, Janet Carlson

0353406	Problem-based Learning Designed for Science and Mathematics Professional Development	Eberhardt, Jan
0003895	Sustainable Reform In Science Education -- A Small Grant for Exploratory Research	Kozaitis, Kathryn
0455359	Project TEACH - CWU: Targeted Science Instruction for Future Teachers	Filson, Robert
0455573	Developing Inquiry-based Instruction Skills	Adams, April
0455786	Temple University Science Math Assessment Research for Teachers: TU-SMART	Jansen Varnum, Susan
0550847	Exploring the Development of Beginning Secondary Science Teachers in Various Induction Programs	Luft, Julie
0455877	Mentored and Online Development of Educational Leaders for Science (MODELS)	Linn, Marcia
0538974	Effects of a Coach-focused Professional Learning Model on Lesson Development, Lesson Delivery and Student Learning, Achievement and Performance	Stowell, Scott
0455752	Project NEXUS: The Maryland Upper Elementary/Middle School Science Teacher Professional Continuum Model	McGinnis, James
0455781	Development of K-8 Teachers' Knowledge and the Transition from University Student to Professional	Allen, Deborah
0456124	Teacher Learning of Technology-enhanced Formative Assessment	Leonard, William
9731282	Primary Science Documentation: Strategies and Materials	Jones, Jacqueline
0455866	Strategic Integration of Mathematics and Science	Baxter, Juliet
0455795	Researching the Wireless High School: Effects on Science Teaching and Implications for Professional Development	Drayton, Brian
0455749	Low Science and Math Teacher Retention: Causes, Consequences, and How Some Urban Middle and High Schools Are Making Progress	Levy, Abigail Jurist
0455710	Lesson Study for Successful Science Teaching: Creating Science-specific Accommodations for Students with Learning Disabilities?	Mutch-Jones, Karen
0353331	Promoting Science Among English Language Learners (P-SELL) within a High-stakes Testing Policy Context	Lee, Okhee
0435727	Applied Research on Implementing Diagnostic Instructional Tools	Minstrell, James
Total Funding for ESIE Awards		$33,275,982

DUE Dataset		
9727648	A Model for Physics Education in Physics Departments: Improving the Teaching of Physics from Elementary through Graduate School	McDermott, Lillian
0088840	Development of Research-Based Curriculum to Improve Student Learning in Physics	McDermott, Lillian
0302119	Induction and Mentoring in a Middle Grades Science and Mathematics Accelerated Teacher Preparation Program	Mitchener, Carole
0119078	A Follow-up Summative Evaluation of the New York City Collaborative for Excellence in Teacher Preparation	Flugman, Bert
0427570	Use of Research to Improve the Quality of Science Education in Urban High Schools	Tobin, Kenneth
Total Funding for DUE Awards		$4,442,713
Total Funding for ESIE and DUE Awards		$37,718,695

Appendix B

REC Awards

Award Number	Award Title	Principal Investigator
9973004	Modeling Nature: A Route to Understanding Central Themes in Elementary and Middle School Science	Abbeduto, Leonard
0128062	Supporting Teachers and Encouraging Lifelong Learning: A Web-Based Integrated Science Environment (WISE)	Linn, Marcia
0237922	CAREER: Teaching Elementary School Science as Argument (TESSA)	Zembal-Saul, Carla
0089222	Looking Inside the Black Box: Classroom Practice that Supports High Achievement in Both Science and Reading: A Planning Grant	Century, Jeanne Rose
0238129	CAREER: Comprehension Strategy Support in Inquiry-based Science	Bannan-Ritland, Brenda
0092610	PECASE: Making a Case for New Elementary Science Teachers	Davis, Elizabeth
9903328	Pathways to Teaching Science for Understanding in Diverse Schools: Merging Inquiry-Based Science and Sociocultural Constructivism with Multicultural Education	Brown, Susan
9876150	CAREER: Teacher Knowledge, Beliefs, & Technology: Constructing Models of Change in Systemic Reform	Fishman, Barry

0087560	Beginning Science Teachers in Action: Investigating Mis/Connections Between Preservice Content and Classroom Instruction	Bianchini, Julie
0107022	ROEL: Teaching and Learning of Science in Urban High Schools	Tobin, Kenneth
9733700	Science Teaching and Learning in Economically Disadvantaged Urban Areas.	Barton, Angela
9970830	Teacher Leadership for Systemic Reform	Miller, Barbara
9815931	A Longitudinal Study of a Teacher Enhancement Project	Hynes, Michael
9804929	The Inquiry-based Classroom in Context: Bridging the Gap Between Teachers' Practice and Policy Mandates	Drayton, Brian
0000976	SGER--Identifying and Understanding the Effects of SMET Education Undergraduate Reform on K-16 Teachers	Feldman, Allan
9909475	Learning from Lesson Study, A Japanese Approach to Developing Teaching Skills and Innovations	Fernandez, Clea
9980081	KDI: The Internet Learning Forum: Fostering and Sustaining Knowledge Networking to Support A Community of Science and Mathematics Teachers	Barab, Sasha
0089247	Professional Development Support Systems for Mathematics and Science Teaching	Gitomer, Drew
0133900	CAREER: Understanding the Role of Video in Teacher Learning	Sherin, Miriam
0231808	Understanding and Fostering Model Based Learning In Science	Clement, John
0087562	Experimental Design to Measure Effects of Assisting Teachers in Using Data on Enacted Curriculum to Improve Effectiveness of Instruction in Mathematics and Science Education	Blank, Rolf
0438359	Improving Evaluation of Professional Development with Mathematics and Science Teachers through Developing Research-based Measures of Quality with States and School Districts	Blank, Rolf
0115716	IERI/REC: Planning an Infrastructure to Support Ambitious Science for Urban School Children	Gomez, Louis
0228158	Phase-I Study of the Effects of Professional Development and Long-term Support on Curriculum Implementation and Scaling Up	Brandon, Paul
0335523	Alternate Routes to Teacher Certification in Missouri:	Scribner, Jay
9714189	Evaluating the Long Term Effects of Teacher Enhancement	Lawrenz, Frances

9804925	Systemic Reform, Mathematics and Science Education, and Equity In New Jersey	Firestone, William
9602137	Bridging the Gap: Equity in Systemic Reform	Meece, Judith
0310721	Making Visible the Science in Science Teaching: Using TIMSS-R Conceptual and Video Tools to Support Teachers' Inquiries of Science Teaching, Content, and Student Learning	Roth, Kathleen
0238385	PECASE: Bridging the Gap Between Theory and Practice in Teacher Education: Guided Interactive Virtual Environments (GIVEs) for Case-Based Learning	Moreno, Roxana
0107032	ROLE: Video Cases Online: Cognitive Studies of Preservice Teacher Learning	Derry, Sharon
0089271	Promoting Active Reading Strategies to Improve Students' Understanding of Science	McNamara, Danielle
0118355	Evaluating Quality of Teachers and Teaching in Science and Mathematics Education: Use of Surveys and Data Systems to Evaluate Quality of Preparation, Development & Practices	Blank, Rolf
9980458	Going to Scale with High Quality Instructional Practice: Exploring Strategies in New Jersey's SSI	Firestone, William
9814246	1999 National Survey of Science and Mathematics Education	Weiss, Iris
0337061	Examining Teacher Preparation: Does the Pathway Make a Difference?	Wyckoff, James
0137730	ADVANCE Fellows Award: Implementing Inquiry Pedagogy in Elementary and Middle School Science Classrooms	Cartier, Jennifer
0207623	Research-Based Design Framework for Mathematics and Science Teacher Induction	Britton, Edward
0075011	POWRE: A Narrative: Science Stories by Native American Teachers-In-Training	Ollerenshaw, Jo Anne
9814803	Middle Grades Mathematics and Science Teacher Induction in Selected Countries	Raizen, Senta
0107014	ROLE: Empirical Research on Critical Issues in Recruiting and Retaining the Mathematics and Science Teaching Workforce	Burke, Daniel
0231884	Teacher Professional Development in Mathematics and Science: Do the Policies Add Up?	Smith, Thomas
Total Funding for REC Awards		$35,517,772

Students' Comprehension of Science Concepts Depicted in Textbook Illustrations

Michelle Cook, PhD
Clemson University

Abstract

Visual representations are commonly used in science instruction to enhance learning. In this study, 86 high school biology students were asked to study an illustration of meiosis to determine their ability to recognize, understand, and interpret textbook images. Data collected from interview and written responses to questions revealed that while the task helped them learn about the topic of meiosis in terms of labeling structures and describing the phases, students were unable to communicate an understanding of the overall purpose of meiosis. The findings of this study have implications for the design and scaffolding of visual representations.

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Introduction

Historically, educational research has emphasized verbal learning while interest in visual learning has lagged behind. As the amount of information acquired through visual mediums multiplies, visual literacy, or the ability to understand, evaluate, and produce visual messages, has become increasingly important in education (Stanley, 1996). Specifically, considerable attention has been devoted to the effect of visual learning on the acquisition of knowledge and the understanding of relationships and processes in science courses (Mandl & Levin, 1989). Illustrations are the basis of visual learning in the science classroom and include representations found in typical science textbooks such as photographs, diagrams, charts, graphs, drawings, and tables. In a survey of six science textbooks, Mayer (1993) found that 55% of the printed space was accounted for by illustrations. Since illustrations are a large part of science textbooks, more attention must be focused on understanding the impact visual images have on students and their learning.

Visual presentations play a very important role in the communication of science concepts (Ametller & Pinto, 2002). Visual learning can foster the obtainment of knowledge that students may not get from verbal text alone (Mayer et al., 1996), and improve the retention of ideas presented (Newton, 1984). According to Lemke (1998, p. 110), "our visual discrimination is far better than our linguistic system at dealing with complex ratios and continuous variations in space, line, shape, and color." In science especially, visual images are preferred for displaying multiple relationships and processes that are difficult to describe. Thompson (1994) called thoughtfully designed illustrations "instructional obstacles," or devices that create a cognitive "hurdle" in the mind of the learner. These hurdles are necessary for learning and result from the construction of cognitive schemas where information is organized and linked together for storage in long-term memory. As the learner studies the details of the picture, s/he begins to overcome the cognitive hurdle. As a result, a fuller understanding of the concept is acquired. These hurdles do not hinder learning unless the visual is poorly designed; in that case, the illustration may easily overwhelm the learner's cognitive resources.

Unfortunately, not all illustrations will cause the same degree of improvement in comprehension and retention. Therefore, research on the impact of illustrations sometimes leads to contradictory results in which the value of illustrations is called into question (Thomas, 1978). Concepts can be represented pictorially in numerous ways and not all will be equally understood (Newton, 1984). As with verbal communication, illustrations have to be "read." In order to bring about more consistent improvement in knowledge acquisition, researchers have explored what factors enhance the readability of illustrations.

Textbooks make use of many types of visual displays to help teach difficult science concepts. Unfortunately, most textbooks also include decorative color photographs that are present more for selling purposes. Elaborate visuals, such as tables, diagrams, and flow charts that provide the bare essentials of a science concept, serve more to educate the student (Holliday, 1990). These summarizing visuals accent important relationships and reorganize information presented in printed text. They add clarity, and can segregate and group important information about difficult ideas.

Other research studies also indicate that the type of illustration could determine how powerful the illustration will be as a learning aid (Duchastel, 1978; Mayer, 1993). Mayer (1993) summarized four types of illustrations, modified from Levin's system of classifying illustrations. Mayer concluded that explanative illustrations, those illustrations with a verbal explanation that describe how scientific systems or processes work, elicit the highest level of cognitive processing. Other types of illustrations, like decorative color pictures, may not even affect cognitive processing. Most studies emphasize that a combination of both visual and verbal methods is ideal (Levie & Lentz, 1982). In one such study, visual-verbal learning had an additive memory effect over visual learning alone (Vasu & Howe, 1989). Visual-verbal learning allows students to reconcile the two modes and compare carefully the information available in the picture with the explanation in the text (Reid et al., 1983).

Other factors can affect what students comprehend from visual images. For example, different features of images affect the comprehension of the message transmitted by the image (Ametller & Pinto, 2002). The use of color, the use of arrows to display the flow of events, mixing of real and symbolic entities, highlighting of certain words or images, wording of verbal explanations, and integrating several images into one all have been shown to affect students' understanding of images (Stylianidou & Ormerod, 2002). Dwyer (1972) documented more difficulties in learning from realistic drawings and photographs than from simplified diagrams. He concluded that simple diagrams of the relevant structure were more beneficial because the important parts could be more easily viewed and identified while other details could be de-emphasized. Some students attach too much importance to artificial color in photographs and become confused when they see the real thing (Holliday, 1980). Mayer et al. (1996) found that the length of verbal explanation accompanying the illustration is also important. Short captions with simple illustrations are more effective than illustrations with lengthy verbal explanations. Contradictory results have been found about the ability of the learner and their understanding of visual images. Reid and Beveridge (1986) found that pictures with text were more distracting to some lower level students while other research indicates that lower ability students, who often struggle with verbal communication, benefit the most from visual learning.

More research on the factors that contribute to the readability of images is warranted, especially since studies have indicated that learners do not make full use of visuals in textbooks (Eshach & Schwartz, 2002). Many researchers have addressed whether students make the same sense of illustrations as experts do. Many expert readers, when tackling an academic article, "read" the visuals before the rest of the article. Novices may not understand how a system or process works from an illustration, while experts comprehend it easily and recognize the wider context (Goldsmith, 1984; Kozma & Russell, 1997; Kozma et al., 2000).

Although visual learning has received attention in the literature, much of the current research has focused on the visual representation of chemical phenomena (Kozma et al., 2000; Kozma & Russell, 1997; Wu et al., 2001). Very few studies concentrate on student learning from images typically found in biology textbooks. While computer-based multimedia instructional materials have become more prevalent, students' main exposure to visual representation is through textbooks. In this study, a visual representing the process of meiosis was utilized to determine students' recognition, identification, and learning from illustrations. Specifically, students were asked to study an illustration of meiosis and were then assessed on their ability to label the structures involved in meiosis, summarize the phases in meiosis, and give an overall summary of the purpose of meiosis.

The implications of the role of visual images in student learning are important. Visual images are a language and visual literacy can be learned, just as reading and writing are learned. Understanding the impact of visual images on viewers can be helpful with the design of illustrations in textbooks. In addition, educators in all disciplines at all levels can aid students in processing visual images more efficiently and in thinking critically about those images.

Method

This study was conducted to determine what students comprehend from a typical meiosis illustration. Data were collected from 86 biology students attending a suburban high school in the southeastern region of the US. A convenience sample of 47 students enrolled in freshman Honors Biology (two classes) and 39 students enrolled in senior Advanced Placement (AP) Biology (two classes) participated in this study. The same teacher taught all four classes using the same instructional methods. Although Honors Biology is the first science course these students take, they have had previous success in middle school science courses and on a placement test to be considered for this course.

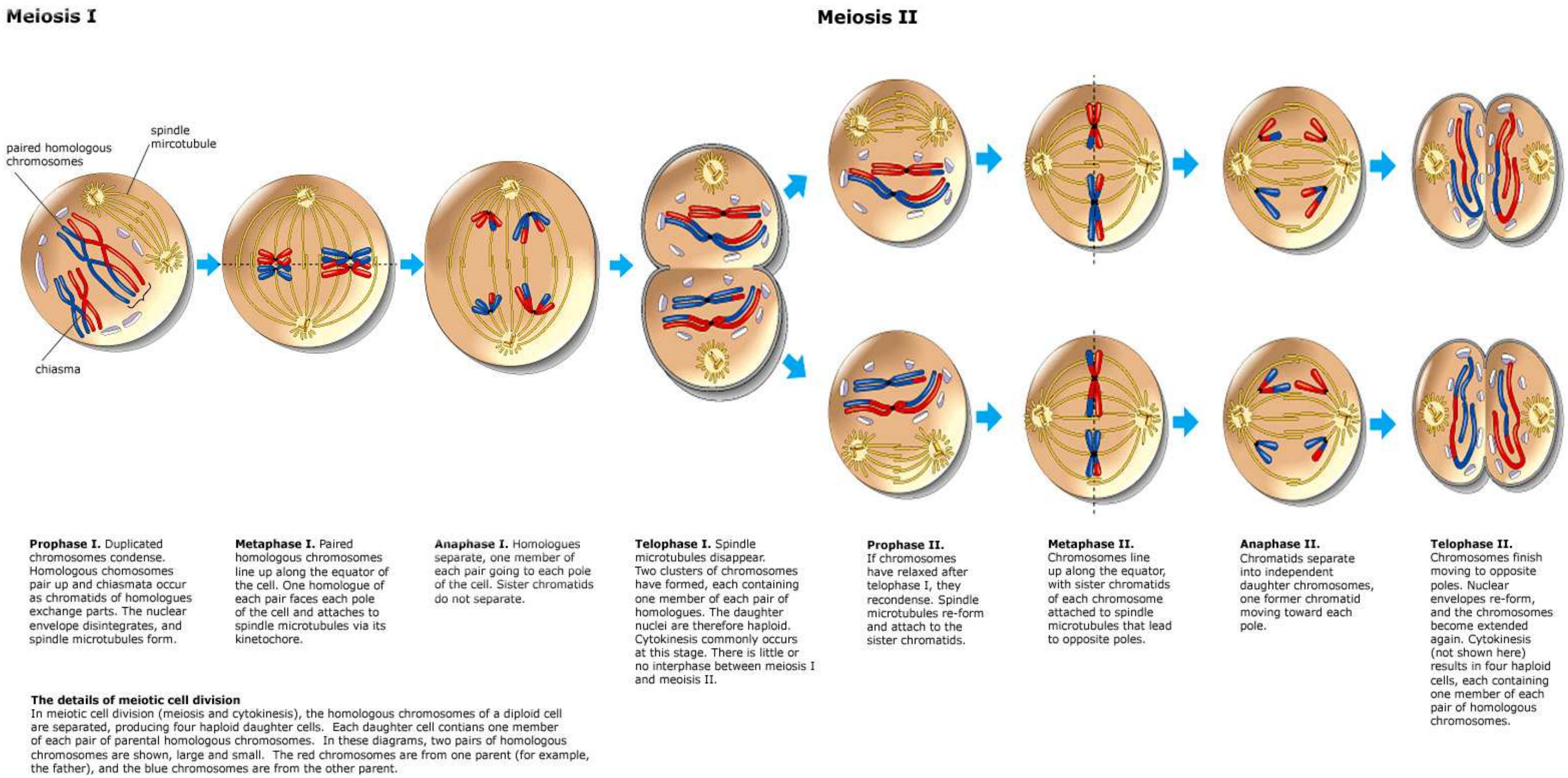

Figure 1. Meiosis illustration with accompanying verbal explanation (Campbell & Reece, 2002). (*Biology*, Cambell& Reece, ©2002. Reprinted by permission of Pearson Education, Inc.)

Students in AP Biology earned at least a B in previous biology and chemistry classes. Many of these students have previously taken or are concurrently enrolled in AP Chemistry or physics.

To familiarize the students with the concepts needed to understand the process of meiosis, they were taught the process of mitosis predominately through direct instruction. The teacher explained mitosis using visuals, and the students viewed the stages of mitosis through the microscope and participated in a group activity where mitosis was simulated using yarn. Following instruction on mitosis, students were presented a typical meiosis illustration (Figure 1) and asked to study the picture and the accompanying explanation. Students were asked to study the illustration for at least 10 minutes, but no longer than 20 minutes, in order to be able to answer questions about meiosis.

When students had completed their study of the graphic, they were given a handout with the same illustration of meiosis without verbal explanations (Figure 2). Students were asked to complete the following tasks:

1. Label the structures in the illustration.
2. Label the phases of meiosis and summarize what is occurring in each of the phases.
3. Give an overall summary of meiosis

Once the handout was completed, students were taught meiosis over the next three days. Similar to the direct instruction methods used while teaching mitosis, the teacher instructed the students by visuals and simulations with yarn.

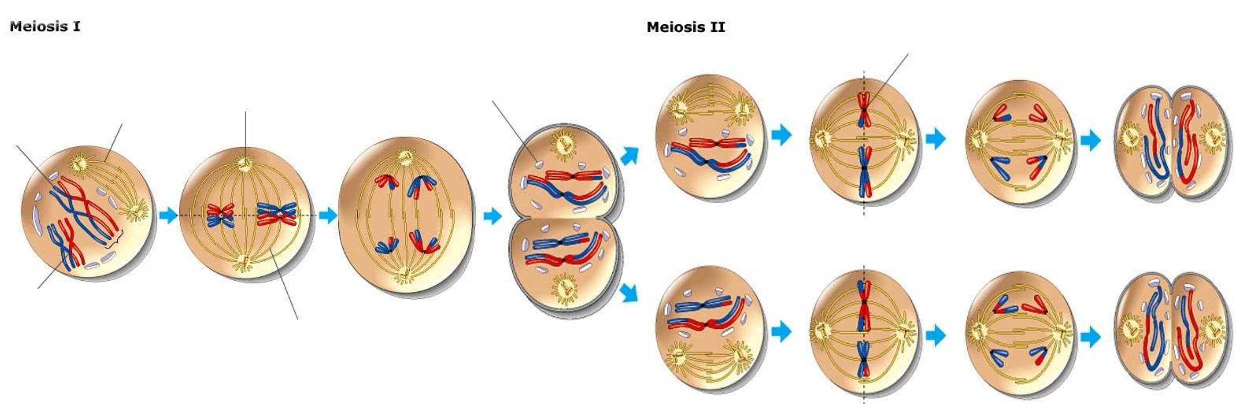

Figure 2. Meiosis illustration without accompanying verbal explanation (Campbell & Reece, 2002).

Following instruction on meiosis, 22 volunteers (10 AP Biology and 12 Honors Biology students) were interviewed. The following questions were asked during the interviews:

1. Are you aware of any errors you made on your handout or misconceptions you may have had before meiosis was covered in class?

2. When you were studying this illustration, did you look at the picture first or did you read the explanation first?

3. Were the structures depicted easily identifiable? Why or why not? How could this be improved to increase your understanding?

4. Were the various colors used in this illustration helpful in allowing you to better understand the process of meiosis? Why or why not? How could the color be improved to increase your understanding?

5. How helpful was the accompanying explanation to your understanding of meiosis? Did it give too much or too little detail? How could the explanation be improved to increase your understanding?

6. Overall, did the illustration aid in your comprehension of meiosis? Why or why not? Are there any other ways it could be improved to increase your comprehension?

Students' written responses on the handout were analyzed with a scoring rubric that identified students as having limited, marginal, or proficient understanding of the structures involved in meiosis, the phases of meiosis, and the purpose of meiosis. Students' ability to label the structures in the meiosis graphic was assessed, as well as which structures seemed to be the most difficult to identify. In addition, the detail in which students could recall the steps of meiosis was examined to determine if a particular concept was difficult to understand or completely overlooked. The ability of students to indicate the basic function of meiosis, as well as state ideas that were not directly described by the illustration or text, was also evaluated.

The responses from the interviews were analyzed using the constant comparative method (Strauss & Corbin, 1998). Initially, the data from each question were coded to develop categories; however, a key strategy was to constantly compare these categories. Categories that emerged were compared from one participant to the next, to allow for categories to be interrelated and refined, so that the patterns in how AP and Honors Biology students interpreted the illustration could be discovered (Hatch, 2002).

Findings

Labeling Structures

Relatively few errors were made in the labeling section of this task. As Table 1 indicates, 48.8 % of the students demonstrated a proficient understanding by identifying at least six of the seven structures correctly, while only 7.0% demonstrated a limited understanding by labeling five or more of the structures incorrectly. Most students were familiar with the terminology of meiosis from their prior experiences with mitosis. They had previously looked at pictures of mitosis and were able to identify the structures in mitosis illustrations. In their interviews, 12 students indicated that the colors of the structures helped in distinguishing between maternally and paternally inherited chromosomes. The structures most difficult for students to label were those involved exclusively in meiosis. Students struggled with labeling the chaisma and homologous chromosomes. Some tried to spell the unfamiliar word “chiasma,” and it became apparent that they remembered what letter it started with and nothing else. Others could not remember the terminology of “paired homologous chromosomes” but instead used other descriptions like “exchanged DNA” or “reassembled chromosomes.” In their interviews, many of these students stated that they understood what was happening in the process of crossing-over, but could not remember the terminology of the illustration. However, some students never even acknowledged the process of crossing-over, and instead labeled the structures with terminology from their prior background with mitosis. Instead of labeling the structure as chaisma, they labeled a portion of the structure a non-sister chromatid.

Table 1
Number (and percent) of AP and Honors Biology students who exhibit proficient, marginal, and limited understanding of the structures involved in meiosis

	Proficient Understanding	Marginal Understanding	Limited Understanding
AP	23 (59.0)	14 (35.9)	2 (5.1)
Honors	19 (40.4)	24 (51.1)	4 (8.5)
AP + Honors	42 (48.8)	38 (44.2)	6 (7.0)

Meiosis I Versus Meiosis II

Many students were able to accurately describe the steps of meiosis I and meiosis II, as shown in Table 2. These students with proficient understanding were able to describe the phases included in meiosis I and meiosis II in complete detail. Because they were familiar with prophase, metaphase, anaphase, and telophase from their study of mitosis, they were able to recall all of the pertinent information when writing out the process. They described chromosomes condensing, the formation of spindle microtubules, and attachment of the chromatids to kinetochores. However, not all students were able to incorporate the steps that were unique to meiosis or had difficulty describing all of the steps involved in a particular phase; these students were classified as having a marginal understanding of the phases of meiosis (see Table 2). For example, it appears as if some students never understood that homologous pairs of chromosomes segregate in meiosis I, whereas sister chromatids segregate in meiosis II. Therefore, if students had any misconceptions, it was almost always in meiosis I. Some students were vague about what was separated in anaphase I and wrote very generally that “chromosomes” segregated, and some recalled what they learned from mitosis and mistakenly wrote that sister chromatids separated. Regardless of mistakes made when labeling chiasma and paired homologous chromosomes, all but 17 students were able to indicate that chromosomes “exchanged sections” in prophase I. Only one instance existed where the student correctly labeled the chiasma in the labeling section, but then did not talk about its occurrence during prophase I.

Table 2
Number (and percent) of AP and Honors Biology students who exhibit proficient, marginal, and limited understanding of the phases of meiosis

	Proficient Understanding	Marginal Understanding	Limited Understanding
AP			
Prophase I	14 (35.9)	23 (59.0)	2 (5.1)
Metaphase I	12 (30.8)	26 (66.7)	1 (2.6)
Anaphase I	11 (28.2)	27 (69.2)	1 (2.6)
Telophase I	12 (30.8)	25 (64.1)	2 (5.1)
Prophase II	20 (51.3)	19 (48.7)	0 (0)
Metaphase II	24 (61.5)	15 (38.5)	0 (0)
Anaphase II	21 (53.8)	18 (46.2)	0 (0)
Telophase II	18 (46.2)	21 (53.8)	0 (0)
Honors			
Prophase I	12 (25.5)	31 (66.0)	4 (8.5)
Metaphase I	9 (19.1)	36 (76.6)	2 (4.3)
Anaphase I	8 (17.0)	36 (76.6)	3 (6.4)
Telophase I	10 (21.3)	34 (72.3)	3 (6.4)
Prophase II	14 (29.8)	29 (61.7)	4 (8.5)
Metaphase II	18 (38.3)	27 (57.4)	2 (4.3)
Anaphase II	21 (44.7)	24 (51.1)	2 (4.3)
Telophase II	16 (34.0)	28 (59.6)	3 (6.4)
AP + Honors			
Prophase I	26 (30.2)	54 (62.8)	6 (7.0)
Metaphase I	21 (24.4)	62 (72.1)	3 (3.5)
Anaphase I	19 (22.1)	63 (73.3)	4 (4.7)
Telophase I	22 (25.6)	59 (68.6)	5 (5.8)
Prophase II	34 (39.5)	48 (55.8)	4 (4.7)
Metaphase II	42 (48.8)	42 (48.8)	2 (2.3)
Anaphase II	42 (48.8)	42 (48.8)	2 (2.3)
Telophase II	34 (39.5)	49 (57.0)	3 (3.5)

Overall Purpose of Meiosis

All but 12.8 % of the students were able to indicate the basic function of meiosis (see Table 3). Those that wrote that meiosis produced four haploid cells from a parent cell were characterized to have at least a marginal understanding of meiosis. In addition to the production of haploid cells, if students understood that meiosis produces reproductive cells with genetic variation, they were considered to be proficient. Of those students with a proficient understanding, only five students stated that the reason why the four cells only contained half of the genetic information was because there is only one DNA replication in meiosis. Eighteen students stated that the purpose of meiosis was to make reproductive cells, but only seven students indicated that this process was restricted to the gonad region. Students with a limited understanding of the purpose of meiosis either stated that the resulting cells were identical or diploid.

Table 3
Number (and percent) of AP and Honors Biology students who exhibit proficient, marginal, and limited understanding of the purpose of meiosis

	Proficient Understanding	Marginal Understanding	Limited Understanding
AP	11 (28.2)	25 (64.1)	3 (7.7)
Honors	7 (14.9)	32 (68.1)	8 (17.0)
AP + Honors	18 (20.9)	57 (66.3)	11 (12.8)

Approach: Picture or Text First?

In the interview portion, 16 of the 22 students indicated that they viewed the picture of each step before they read the corresponding text. They visually accounted for the movement of the chromosomes and spindle microtubules, and then reconfirmed their visual analysis by reading the text. Only two students viewed all of the pictures first before they read the corresponding text underneath each picture. Four students tackled the illustration by reading the text underneath each picture first, and then ensured each picture showed what the text indicated.

Differences between freshman and AP Biology Students

The freshman biology students spent more time studying the meiosis figure. They utilized between 10 to 20 minutes studying the details of the visual whereas many of the AP Biology students were finished after 10 minutes. Since they were instructed to spend at least 10 minutes studying the figure, many of the AP students took out other work while waiting to receive the second part of the activity. In addition, the freshman biology students needed more time to identify the structures and describe the process of meiosis. Many of them required the remainder of the 45-minute period, while a majority of the AP Biology students were finished with 10 to 20 minutes left in the period.

The differences in the amount of time the different groups of students took to complete the task did not have an impact on their conceptual understanding of meiosis. The AP Biology students more accurately labeled the structures in the picture partly because their textbook explanation of mitosis was more detailed; 59.0% of AP students labeled at least 6 structures correctly compared with 40.4% of the Honors Biology students (see Table 1). The AP students were able to label the kinetochore and nonkinetochore spindle fibers even though they were not labeled on the illustration, while many of the freshman students were not able to make that distinction. In addition, the AP students more accurately wrote out the steps of meiosis. They were more likely to include all the events unique to meiosis; a higher percentage of AP students demonstrated a proficient understanding than Honors Biology students for each of the phases of meiosis (see Table 2). Finally, the AP students had a more complete description of the overall function of meiosis with 28.2% having a proficient understanding compared with

14.9% of Honors students (see Table 3). More AP students stated that this process made reproductive cells and was restricted to the gonads.

The AP Biology students asked questions after they were finished with the activity. These students wanted to ensure they accurately knew the details of meiosis and were more concerned than the freshman biology students to know if the answers on their papers were "right." Many of them asked the researcher to check the labeling of structures they may have had difficulty identifying. Some were concerned that their overall understanding of the process of meiosis was not complete enough. Others asked about specific steps of meiosis that were unfamiliar to them, such as crossing over in prophase I.

In the interviews, the AP students were less confident about their overall understanding of meiosis. Even though they labeled, portrayed the steps of meiosis, and gave the overall function of meiosis more accurately, they were less likely to believe they would have performed well on a test on meiosis. More freshmen students felt they would have performed adequately on an assessment than AP students.

Discussion

Overall Effectiveness of Illustration

Illustrations that depict biological processes have been shown to aid in the acquisition of knowledge and the understanding of biological concepts such as meiosis. Because the illustration used in this study was an explanative illustration, one with a verbal explanation of how a process works, it elicited a higher level of cognitive processing than a decorative color photograph would have. Every student interviewed indicated that the amount of verbal explanation supplied was important in his or her understanding of meiosis. Some students indicated that the color used in this illustration was helpful in identifying structures involved. As other researchers have found, attributes such as color and length of verbal explanation are important in fostering learning from illustrations. Finally, students in this study reconciled two modes of learning, visual and verbal, by studying the illustration and the accompanying text.

Most students interviewed felt like this activity helped them learn meiosis to an extent. Almost all of the students had a strong background in mitosis and knew much of the terminology. Almost all students verbally indicated in the interview portion that they would not have been able to label structures or list out the steps of meiosis unless they had that prior knowledge, since it seemed to them that the illustrations assumed prior knowledge. Five AP students missed the mitosis section due to an out-of-town field trip and one stated in his interview that he was not as confident about the labeling section. After viewing their answers, more mistakes were made in the labeling section, but many of them accurately detailed the steps of meiosis.

The results indicate that the students did not have too many misconceptions from studying the illustration, but they did not have a good foundation. They were fairly successful at labeling structures involved, listing the steps of meiosis, and indicating the overall purpose of meiosis. However, in their interviews, many students felt that even if they could recall the steps of meiosis, they did not feel as if they completely understood the whole process. They would have been able to detail what happens in each of the phases, party due to their prior knowledge, but they would not have been able fully incorporate all the unique aspects of meiosis. For example, several students knew crossing-over was occurring in the picture, however, they did not know why it was happening. Most students still wanted a verbal explanation from the teacher about how the chromosomes move and how genetic variation is introduced. Once they learned the process of meiosis through classroom explanations and activities, they were able to recognize their misconceptions in labeling and writing out the steps of meiosis, and understood more about the overall process of meiosis.

Most students recognized that this process was helpful. Even if they did not feel completely confident in their understanding, they realized that this activity served as a good introduction for learning meiosis in more detail. Some students indicated that when the process was covered in class, they related the new material learned back to what they wrote in this activity, and made connections. Even the student that continually claimed he was an auditory learner saw benefit to doing this activity. Many suggested that this process would be a good culminating activity for the unit.

The researcher expected to find that AP level students were more proficient at interpreting and learning from illustrations. In addition to having more prior instruction on the mitosis and meiosis, the AP Biology textbook covers these topics in more depth than the Honors Biology textbook. This prediction was confirmed by the results of the study; the AP students performed better on labeling structures, recalling the process of meiosis, and understanding the overall function of meiosis. However, the researcher did not expect the AP students to have more questions and need more reassurance about their level of understanding after the activity. From the researcher's classroom observations, the Advanced Placement students seem to be more independent than the Honors Biology students. Usually, they did not rely on the teacher as much for verification of the "right" answer and had developed a more "relaxed" attitude about learning. The researcher suspects that because there is not enough time to cover all topics and details in class, they are accustomed to learning independently. However, in this case, many of them did not feel comfortable about their specific understanding of the process of meiosis and were concerned that they were not going to receive any more clarification in class.

Limitations

The subjects of this research were high achieving, academically motivated students. They were Honors and AP Biology students who have been successful in their previous schoolwork. The results may have been different had a wide variety of students been sampled. Also, this study does not give any indication as to how helpful visual images are when learning a completely unfamiliar topic. Students had a basic understanding of chromosomes and mitosis before they were asked to study the illustration on meiosis. The study may have been more meaningful if it targeted how helpful illustrations are to students as they are covering the material in class. Instead, in this study, students were asked to look at an unfamiliar picture and label structures and steps in meiosis without any coverage of the material in class.

Implications

Visual representations play a critical role in the sciences, and the literature indicates that students may have more difficulty understanding them than initially assumed (Wu et al., 2001; Benson, 1997). It is important to study whether and to what degree students recognize the objects depicted in the illustrations (Constable et al., 1988). Teachers often assume students understand the visual images present in science textbooks. Student misconceptions in interpreting illustrations have been documented (Billings & Klanderman, 2000) and many stem from the lack of prior experience with the subject in their daily lives (Wu et al., 2001). Teachers must help students develop the basic skills of visual communication, specifically by teaching them to critically evaluate the form and content of visual communication. Students need to be taught how to read illustrations in order to avoid potential causes of confusion (Constable et al., 1988; Stylianidou & Ormerod, 2002) and teachers need to be aware of students' difficulties when reading images (Ametller & Pinto, 2002).

Many illustrations in textbooks depicting biological processes assume prior knowledge on the part of the student. Illustrators need to be aware that students may not have the background concepts they need in order to completely understand figures and tables commonly found in textbooks. They must present enough information in the illustrations to ensure student understanding. However, students also have difficulty identifying and understanding the concepts that unique to a particular process. Therefore, illustrators must be mindful of both what information they include to illicit students prior knowledge, and what information they include to foster comprehension of new concepts. Finally, they must pay careful attention to the colors used in illustrations, since many students interpret different colors to represent different structures.

Science teachers must organize the content in such a way that a student's previous knowledge can be used to acquire new knowledge. The sequence in which topics are covered should be planned with the intention to build upon the student's preexisting framework of concepts. Teachers must also emphasize the unique concepts related to a process and help students understand the relationship between this new process and what they have already learned. From this study, it is apparent that students cannot merely memorize structures and steps in a process and feel confident about their understanding of the process. Many students stated they needed a more complete understanding of "why" the steps were occurring. Therefore, illustrations can be used as a tool to aid in the comprehension of a process, but other tools should also be used for complete understanding.

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Bad wolf kills lovable rabbits: children's attitudes toward predator and prey

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Abstract

This cross-age study explores children's attitude toward a model predator (wolf) and prey (rabbit). We administered a Likert-type attitude questionnaire with 30 items (15 per predator and 15 per prey) to a total of 462 children aged 10 – 15 year in Slovakia. The mean score from three dimensions derived by a factor analysis (scientific, ecologistic and myths about parental care) was then subjected for pair wise comparisons. We found that younger children aged 10-11 year showed significantly more positive attitude toward a rabbit (prey) relative to wolf (predator). However, as children's age increased, the difference in means score disappear and positive attitudes toward predator and prey generally decrease. We hypothesize that these patterns could reflect either greater children's 'ecological thinking' or, more simply, decreasing interest toward animals in older children. The difference in attitudes toward predator and prey suggest that children's affective domain should not be neglected in future environmental programs, because attitudes influence pro-environmental behavior of future citizens.

Key words: attitudes, animals, predator, prey, ecology

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Introduction

It is generally appreciated that teaching positive environmental attitudes and values is more important in bringing about change in environmental behaviour than the teaching of environmental knowledge (Ballantyne and Packer, 1996). Newhouse (1990) proposes that environmental attitudes can be changed by enduring positive or negative feeling about some object or person which means through affective domain. However, many of the research studies have been focused on children's *understanding* rather than *feeling* environmental problems although an emphasis on an affective domain should be considered in this field (Iozzi, 1989; Alsop and Watts, 2003).

It is based on the constructivist notion that all learning is a process of personal construction of children's existing knowledge (Fraser and Tobin, 1998). This construction of knowledge takes place within a context of social interaction and agreement. In the process of construction, children develop relatively stable patterns of belief. They construct knowledge in ways that to them are coherent and useful. Children's explanation of natural phenomena, however, often differs from those of scientists (Fischer, 1985). These differing frameworks have been described as alternative conceptions. There are numerous works that showed that alternative conceptions are resistant to conventional teaching approaches and that they are found frequently among children, students or even teachers (Wandersee, Mintzes, & Novak, 1994). However, few works examined whether negative views or prejudice of animals influence attitudes toward them. Currently, for example, Prokop and Tunnicliffe (2008) examined children's attitudes toward spiders and bats, well known, 'disgusting' animals. They found significant correlation between untrue myths and attitudes, whereas more beliefs in myths resulted in more negative attitudes toward spiders and bats.

Relationships between predators and prey are fundamental parts of understanding food webs. To date, number of studies examined children's understanding of food webs (e.g. Griffiths and Grant, 1985; Leach *et al*., 1995, 1996a,b). It was found that children see simple linear causality when describing relationships in nature where only one population directly affects another (Adeniyi, 1985; Goldring and Osborne, 1994; Grotzer and Basca, 2003; Helldén, 2003). Leach *et al*. (1996b, p. 140) note that "pupils are more likely to infer changes to food webs up through trophic levels than down: lack of food causing starvation is a stronger cause – effect link than an absence of predators causing increased changes of survival". Palmer (1998) also has shown that high school students believe that a change in one population will only affect the other population if the two are related in a predatory–prey relationship and it will not affect several different pathways of a food web.

The teaching a role of predators in ecosystems has another dimension than only scientific understanding the importance of predators. Large carnivore predators have been viewed as human competitors through our evolutionary history (Breitenmoser, 1998) and, unfortunately, many hunters still show a negative attitude toward them (Ericsson and Heberlein, 2003; Naughton-Treves *et al.*, 2003). Some animals still agitate fear and initiate defensive responses (Öhman, 1986), because they might be have been dangerous to humans in prehistoric times (Morris and Morris, 1965, Shepard, 1997). Therefore, it is important to understand children's attitude toward particular animal, because children's knowledge and attitudes toward animals are closely related (Kellert, 1993; Thompson and Mintzes, 2002; Dimopoulos and Pantis, 2003) and anxiety from an animal correlate negatively with achievement (Randler *et al.*, 2005). Emotional appeals also may be more effective in changing attitudes formed on the basis of affect (emotion) than cognition-based arguments (Edwards, 1990).

Attitudes toward animals

An attitude can be generally defined as the tendency to think, feel, or act positively or negatively toward objects in our environment (Eagly and Chaiken, 1993; Petty, 1995). Social psychologists have long viewed attitudes as having three components: the cognitive, the affective, and the behavioural (see Reid, 2006 for a review). The cognitive component is a set of beliefs about the attributes of the attitudes' object and its assessment is performed using paper-and-pencil tests (questionnaires). The affective component includes feelings about object and its assessment is performed using psychological or physiological indices (heart rate). Finally, the behavioural component pertains to the way people act toward the object and its assessment is performed with directly observed behaviours (Eagly and Chaiken, 1993). Attitudes to animals are, however, traditionally measured using paper/pencil tests (e.g. Herzog, Betchart and Pittman, 1991). We therefore used standard psychometric procedures to measure children's attitudes using paper/pencil tests following Weinburgh and Steele (2000).

A specific way to investigate attitudes toward animals and factors influencing these attitudes has been proposed by Stephen Kellert (Kellert, 1976, 1985, 1993; Kellert and Westervelt, 1983). Kellert developed a descriptive analysis of nine fundamental attitudinal 'types' (Kellert, 1976). He also identified important changes in the development of children's perceptions of animals and found three transitions (Kellert, 1985). The first transition, (6 – 9 years of age) involves changes in affective and behavioural variables. The second transition from 10 to 13 years of age is typical by a major increase of cognitive abilities. The third transition (13 – 16 years of age) embraces an ethical concern and ecological awareness of the role of animals in their natural habitats. A brief description of Kellert's attitudinal types is provided below:

- *naturalistic:* interest in direct experience with animals and exploration of nature.
- *ecologistic:* concern for the environment as a system; for inter-relationships between wildlife species and natural habitats.
- *humanistic:* interest and strong affection for animals, with strong emotional attachment and 'love' for them.
- *moralistic:* concern for the right and wrong treatment of animals, with strong opposition to exploitation or cruelty toward animals.
- *scientific:* interest in the physical attributes and biological functioning of animals.
- *aesthetic:* interest in the artistic and symbolic characteristics of animals.
- *utilitarian:* concern for the practical and material value of animals; their body parts and/or habitats.
- *dominionistic:* interest in the mastery and control of animals, as in sporting or other competitive contexts.
- *negativistic:* orientation toward an active avoidance of animals as a result of indifference, dislike or fear.

Purpose

Attitudes toward wolf itself have been investigated in several countries (for a review, see Williams et al., 2002). However, no study investigated how attitudes toward predator and prey differ and change over the children's life. This is however an intriguing question, because predators are essential elements for understanding ecological relationships. Peoples' beliefs about the object determine their attitudes toward it (Pooley, 2000). Thus, it is important what children know about predator - prey relationship, but feeling or the affective domain may significantly influence their future attitudes and behaviour (Kraus, 1995). From the environmental education perspective, it is essential to investigate what children feel about predators, not just what they know, because there is much stronger correlation between environmental attitude and behaviour rather than between environmental knowledge and behaviour (Kraus, 1995). In this study, we used a wolf as example of well known predator, and a rabbit, as an example of well known prey to examine differences of children's perception of predators and prey.

We have chosen to focus this study on wolves because they can benefit substantially from effective conservation education programmes. Wolves are rare predators with decreasing population at lest in Slovakia and surrounding countries. Unfortunately, wolves suffer from a negative 'public image' (Bjerke et al., 1998) (unlike domestic dogs), which works to reduce wolf populations rather than to conserve them.

Research Questions

The present study focuses on answering following questions:

1. Are there any differences in children's attitudes toward predator and prey?
2. How much do children's attitudes toward predator and prey change from fifth (age 10/11) to ninth (age 14/15) grade?
3. Are there any differences in children's attitudes toward predator and prey differ with respect to gender?

Method

Construction of the Questionnaire

We measured children's attitudes toward wolf and rabbit by Likert-type items developed similarly to Kellert's (1985) attitude scale toward animals. The questionnaire consists from 30 items (15 item for rabbit and 15 for wolf) that were scored by participants from 1 (strongly disagree) to 5 (strongly agree). Items were either formulated as positive (e.g. "I like natural history films about wolves") and negative (e.g. "Wolves have negative impact on other animals in ecosystem") following suggestions by Likert (1932), Hausbeck et al. (1992) and Oppenheim (1993).

Negative items were scored in the reverse order. Two professors of zoology from two different universities and two biology teachers independently and separately checked items in order to maintain validity of research instrument. Their suggestions and improvements were accepted and final version of the questionnaire was altered accordingly. We tried to use similar items for both wolf and rabbit which would allow us to compare them with paired statistics. Many of items were identical, but in some cases items differ. We notice these differences in text. The differences were especially in food habits of both two animals which greatly differ. Because children tend to have some difficulties with double negative items, classroom teacher who administered questionnaires instructed children about meaning of some of these items.

Score from the questionnaire was analyzed by factor analysis with Varimax rotation for both wolf and rabbit separately. Five factors loaded for rabbit and five for wolf. We deleted all items below factor loadings 0.38 and all other items that loaded with more than one factor were also deleted (Palaigeorgiou et al., 2005). In total, four items per a rabbit and four items per a wolf were omitted. Only factors that were represented at least by three items were accepted for further consideration.

Three dimensions, scientific, ecologistic and myths about parental care, for each wolf and rabbit were loaded and used for pair wise comparisons (Table I and II). The Cronbach's alpha of whole items for wolves (0.74) and for rabbit (0.70) showed appropriate reliability (Nunnaly, 1978). Reliabilities for each dimension are shown in Table 1 and 2. The Cronbach's alpha for the ecologistic dimension is relatively lower, and some caution must be made when interpreting these data.

Table 1
Factor structure of children's attitudes toward wolves

Items	Scientific α = 0.76	Ecologistic α = 0.48	Myths about parental care α = 0.5
I would like to rear a wolf	0.51		
I would like to know more about wolves	0.72		
Wolves are attractive animals	0.73		
I like natural history films about wolves	0.77		
I would like to participate on an expedition for investigating wolves	0.76		
Wolves have negative impact on other animals in ecosystem		0.73	
Wolf is important for stability of ecological relationships in nature		0.55	
Wolf kills only bigger animals such as deer, pigs, etc.		0.86	
Female wolf often kills her offspring, it is therefore said 'wolf's mother'			0.45
Wolf female does not feed her offspring and they therefore kill each other and only the best wolf survives			0.4
Wolf female very much caries of her offspring			0.8
Eigenvalue	4.28	1.7	1.3

Table 2
Factor structure of children's attitudes toward rabbits

Items	Scientific	Ecologistic	Myths about

	α = 0.79	α = 0.43	parental care α = 0.49
I would like to rear a rabbit	0.66		
I would like to know more about rabbits	0.76		
Rabbits are attractive animals	0.40		
I like natural history films about rabbits	0.79		
I would like to observe life history of rabbits in the field	0.81		
Rabbits are important for stability of ecological relationships in nature		0.47	
Rabbits are important for regulation of other organisms in ecosystems		0.63	
Rabbits eat away the bark of trees		0.72	
Rabbits are important part of nature			0.78
Rabbit female very much caries of her offspring			0.55
Rabbit female protects her offspring even she risks her life			0.39
Eigenvalue	4.99	1.56	1.15

Sample

The study was conducted between March and May 2006. A total of 462 children (225 boys and 237 girls) from five different age classes (grade 5 – 9, age 10 – 15) participated in the study. Children were selected randomly from 6 typical Slovak schools from various regions in Slovakia as whole classes to avoid potential bias of children more or less interested in biology. The number of participants with respect to grade level was similar (5 – 9 grade, N = 81, 85, 101, 85, 110, respectively). After teachers agreed with participation in our research, one of us visited the school and administered a questionnaire about attitudes toward predator and prey. The children were also asked for basic information about their age/grade and gender. To avoid social desirability in answering questions the questionnaire was anonymous (Streiner and Norman, 1989).

Children were not time limited during completing a questionnaire. Because between-schools data did not show significant differences, data from all schools were pooled.

Results

Scientific attitudes toward wolf and rabbit

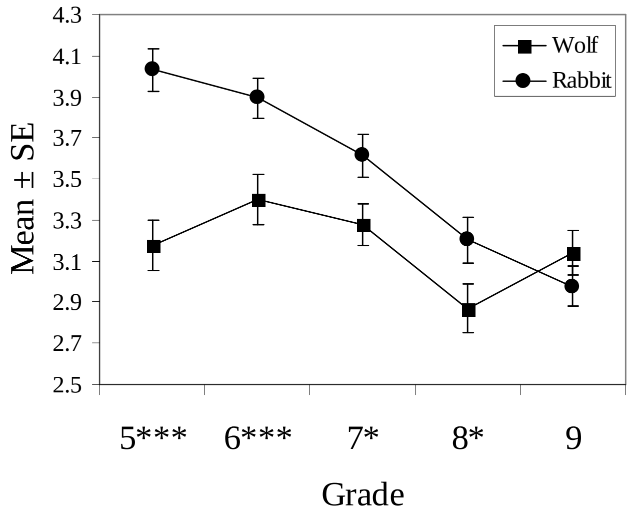
A two-way ANOVA with gender and grade as factors and score from wolf and rabbit's scientific attitude showed significant effect of both gender ($F(2,451) = 7.44$, $p < 0.001$) and grade ($F(8,902) = 10.57$, $p < 0.0001$). An interaction between gender × grade was not significant ($F(8,902) = 1.39$, $p = 0.2$). Boys showed more positive attitudes toward wolf than did girls (mean score = 3.35 ± 0.07 vs. 3.00 ± 0.07, Tukey post-hoc test, $p = 0.003$). Effect sizes calculation showed that this difference was of small - medium size (Cohen's $d = 0.27$). This means that about 60 % of boys exceed the score of the average girl (Cohen, 1988). On the contrary, girls' scientific attitudes toward rabbit tended to be higher that that of boys' (mean score = 3.6 ± 0.07 vs. 3.48 ± 0.07, Tukey post-hoc test, $p = 0.07$), but the effect size was very small ($d = -0.15$). Differences between grades, as indicated by Tukey post-hoc test, were clearly significant only for the rabbit; in case of wolf only 6th graders showed significantly more positive attitudes than 8th graders ($p = 0.01$), but other differences were not statistically significant. Attitudes toward rabbit conspicuously decreased as age of children increased (Fig. 1).

Mean attitude score suggest that scientific attitudes toward rabbit were more positive that that of wolf except for the 9th grade. As shown in Figure 1, attitudes toward predator and prey in 9th grade were very similar showing no statistical difference. The highest differences were found among 5th and 6th graders (age 10 – 12), who showed very positive attitudes toward a rabbit, but rather neutral attitudes toward a wolf.

Children consider rabbits generally more attractive than wolves (76 vs. 50% of all children) and want to breed rabbit more likely than wolf (52 vs. 33%). In contrast, direct observations of rabbits and wolves in nature attracted similar number of children (54 vs. 50 %) and little more children like natural history films about wolves relative to rabbits (50 vs. 46%).

Figure 1
Children's scientific attitudes toward wolf and rabbit

Asterisks denote significant difference between mean wolf and rabbit's score based on paired t-test. * $p < 0.05$, *** $p < 0.001$.



Ecologistic attitudes toward wolf and rabbit

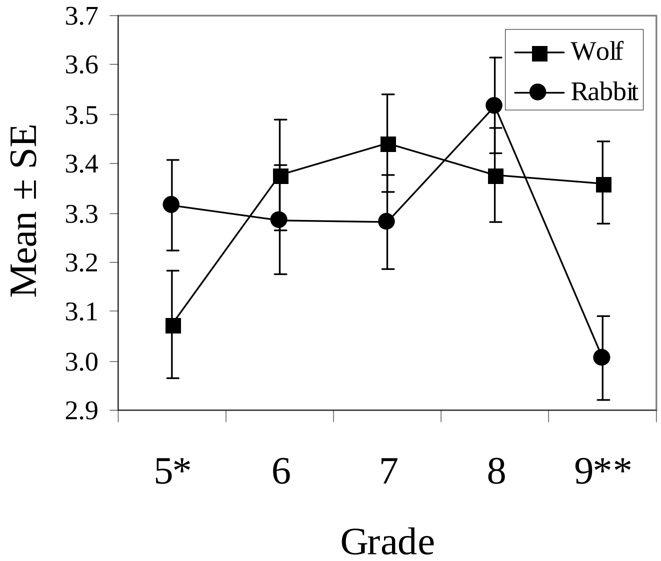
A two-way ANOVA with gender and grade as factors and score from wolf and rabbit's scientific attitude showed significant effect of both gender ($F (2,451) = 7.14$, $p < 0.001$) and grade ($F (8,902) = 2.81$, $p < 0.01$). An interaction between gender × grade was not significant ($F (8,902) = 0.59$, $p = 0.78$). Boys and girls showed a similar attitude toward wolves (3.37 ± 0.06 vs. 3.27 ± 0.06, Tukey post-hoc test, $p = 0.25$, $d = 0.11$), but boys showed more positive attitudes toward rabbit than did girls (3.44 ± 0.06 vs. 3.12 ± 0.06, Tukey post-hoc test, $p < 0.001$). The effect size was also of medium size ($d = 0.37$) which means that more than 60 % of boys exceed the score of the average girl. Age related differences showed very weak variance; Tukey post-hoc test failed to show any difference for wolf, and only one difference (between grade 8 and 9) was shown for a rabbit (Fig. 2).

Mean attitude score suggests that ecologistic attitudes toward wolf and rabbit are similar. Only 5th graders showed less positive attitudes toward wolf relative to rabbit and the reverse was found for 9th graders.

Relative more children favoured the importance of rabbits in ecological relationships in nature (64 vs. 43% of all children), but a similar number of children (about 50%) reported the importance of wolf and rabbit in the regulation of other organisms in the ecosystem. Food habits seem to be less understood, because only 30 % of all children knew that rabbit eat away the bark of trees and about 50 % thought that wolf forage only on higher mammals such as deer, etc.

Figure 2
Children's ecologistic attitudes toward wolf and rabbit

Asterisks denote significant difference between mean wolf and rabbit's score based on paired t-test. * $p < 0.05$, ** $p < 0.01$.



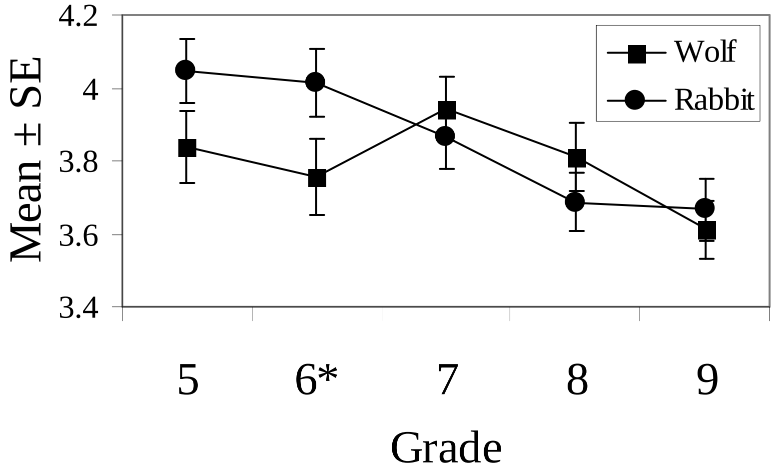
Myths about parental care in wolves and rabbits

A two-way ANOVA with gender and grade as factors and score from wolf and rabbit's myths about parental care showed significant effect of grade (age) ($F(8,902) = 3.1$, $p \leq 0.001$), but not effect of gender differences ($F(2,451) = 0.48$, $p = 0.62$). Both boys and girls showed positive mean scores toward wolf (3.76 ± 0.06 vs. 3.83 ± 0.06) and rabbit (3.83 ± 0.06 vs. 3.87 ± 0.05). Interaction between gender × grade ($F(8,902) = 1.22$, $p = 0.28$) did not show significant effect. A Tukey post-hoc test showed no differences between children's attitude toward wolf with respect to different grades. However, several statistically significant differences were found for rabbits whereas most positive attitudes were found for 5 and 6 grade children. Older children had less positive attitudes relative to younger ones. Mean score for rabbits and for wolves generally did not significantly differ except for grade 6, and non-significant tendency was found in grade 5. These data should be interpreted cautiously, because not all items in this dimension were identical.

While 60 % of children agreed that female wolf take great care of her offspring, relative more children (72 %) showed the same belief for female rabbit. Paired t-test for these two identical items showed significantly higher score of rabbits ($t = -4.21$, $df = 463$, $p < 0.0001$). Surprisingly, 64 % of children believe that female wolf often kills her own offspring, it is therefore said 'wolf's mother'. The same number of children thought that female wolf does not feed her offspring to encourage them to kill each other and therefore only the 'best' wolf survives. In contrast, the same proportion of children see female rabbit nearly self-sacrificing when protect her own offspring.

Figure 3
Children's myths about parental care in wolves and rabbits

Asterisks denote significant difference between mean wolf and rabbit's score based on paired t-test. * $p < 0.05$



Relationships between attitude dimensions

We performed a series of Pearson correlation coefficients to examine inter-relationships between attitude dimensions of wolf and rabbit. Correlations between wolf's and rabbit's scientific ($r = 0.21$), ecologistic ($r = 0.23$) and myths ($r = 0.2$) attitudes showed statistically significant correlations (all $p < 0.001$).

Discussion

Analysis of children's attitudes toward a model predator and prey showed that rabbit (prey) was relatively more positively perceived than wolf (predator), especially by the younger children aged 10 – 11. Generally, Slovakian children expressed rather positive or neutral attitudes toward both predator and prey, while children's age also seems to play an important role in attitude change. This information might be useful for curriculum developers and environmental educators who are concerned in preservation of predators or other animals that are endangered by negative public attitudes.

The relative higher preference for rabbit reflects human preference for small animals (Bjerke and Østdahl, 2004) although dog is also one of the most preferred animal species (Bjerke and Østdahl, 2004) and most frequently keeping pet in Slovakia (Prokop et al., 2008). Despite wolves are silent, bashful and intelligent predators, they sometimes cause serious injuries or deaths to humans (e.g. McNay, 2002) and/or domestic animals (e.g. Treves et al., 2002). Direct interference and competition with humans can explain wolves' negative image in myths and folklore. Research on attitudes toward wolves also show that humans living in closer proximity with wolves, and especially hunters and those who are keeping livestock, show more negative attitudes than others (Ericsson and Heberlein, 2003; Røskaft et al., 2003). In contrast, rabbit is a small, physically harmless and one of the ten most preferred pets among Slovakian children (Prokop et al., 2008).

These strong differences result in less positive attitudes toward wolves, especially for girls in scientific dimension. Moreover, children generally prefer domestic rather than wild animals (Paraskevopoulos et al., 1998). Boys, but not girls, like less-preferred animals such as snails, bats or rats (Bjerke and Østdahl, 2004) and this is probably the case, why boys scored better toward wolf in scientific dimension. Adult females also express greater fear toward wolves in comparison with males (Røskaft et al., 2003), but we did not find any support for this prediction in a sample of Slovakian children. Girls just scored better in interest toward a rabbit (the scientific dimension) which corroborate previous finding that girls exhibit greater interest on rearing pets than boys (Lindemann-Matthies, 2005; Prokop et al., 2008). In contrast, boys scored better in ecological attitudes toward rabbit which can be partly explained by greater interest of boys toward native, wild animals (Lindemann-Matthies, 2005).

Our data confirm Kellert’s (1985) description of age – related differences in children’s attitudes toward animals. The great difference in perception of predator and prey disappeared when children’s age increased which may reflect a switch from affective to cognitive abilities. This finding also correlate with children’s ‘ecological thinking’ that develop around age of 9 – 12 (Leach et al., 1996a). This is also supported by the greater differences in mean score for ecological dimension in grade 5 (age 10) and the absence of such difference in grade 6, 7 and 8. In addition, there was a statistically significant correlation for each dimension between both wolves and rabbit’s score which suggest that greater ecological thinking equally influenced attitudes toward predator and prey. Thus, fewer differences in mean score between wolf and rabbit would reflect better understanding of the role of predator and prey in ecosystems. However, children’s interest toward animals (both wolves and rabbits) measured by the scientific and myths dimension decreased with increasing age. This would reflect generally lower participation of older children in animal - related activities (Bjerke et al., 2001). Older children should have greater understanding of ecology, but, considering the fact that it is unclear whether attitudes lead to increased knowledge or vice versa (Zimmermann, 1996), we cannot reject or support ‘ecological thinking’ nor ‘decreasing interest’ hypothesis. Further research in this area is therefore needed.

Correlations between attitude dimensions imply that more scientific interest in a wolf result in greater appreciation of wolves in nature. Science educators should encourage children’s interest in wolves for example through their observations in zoological gardens through project learning. Gathering information supported by direct observations and their presentation to other children in the classroom would result in better understanding of the role of wolves in ecosystems. Morgan and Gramman (1989) for example found that participation on an environmental program focused on the ecology of snakes significantly improved children’s attitudes toward them.

Additionally, it is unclear whether children understand phylogenetical relationship between domestic dogs and their predecessor, a wolf. Dogs are most frequently owned pets in Slovakia (Prokop et al., 2008) which would be meaningfully utilized in formal science education lessons to explain evolution of relationships between humans and wolves.

Conclusion

Both predators and prey play a fundamental role in ecosystems and, consequently, in ecological education. All animals, regardless of their familiarity with human, play important role in food webs and contribute to biodiversity and ecological stability of the nature. Children's attitudes to animals may later influence public behaviour (Thompson and Mintzes, 2002), building of positive attitudes is therefore necessary for increasing pro-environmental behaviour of future citizens. Our results suggest that attitudes toward a model predator are less positive than attitudes toward 'lovable' animals like a rabbit. This means that the feeling toward animals requires more attention of science teachers, environmental educators and researchers, because environmental strategies of each state depend on changing of peoples' behaviour and attitudes. Predators, unlike phytophagous animals, are often food deprived in the field (e.g. Wise, 1993). Children are however not enough sensitive for these facts and think that predators are 'bad' because they kill other animals. We suggest that participation in non-formal biology settings perhaps in zoological gardens or environmental programs for endangered mammals would have positive effect on children's attitudes and possibly on public behaviour toward large carnivore predators. Further research on the role of movies or environmental interventions in building children's attitudes to predators is necessary.

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