# Misconceptions in Science Education

*Help Me Understand*

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By

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Cambridge
Scholars
Publishing

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This book first published 2017

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library



ISBN (10): 1-4438-9389-7
ISBN (13): 978-1-4438-9389-3

*To my ever-present parents and inspiring family, that keep on showing me the power of empathy, tolerance, and acceptance.*

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# ACKNOWLEDGMENTS

This book brings together conclusions and insights regarding a study on misconceptions and the source of incorrect responses in science and mathematics, and focuses primarily on the intuitive rule "same A - same B" and its incorrect application in conservation tasks. The intuitive rule "same A - same B" is one of three intuitive rules that have been extensively studied and formulated by Prof. Ruth Stavy and Prof. Dina Tirosh, Tel Aviv University, Israel.

I wish to express my most sincere gratitude and appreciation to Prof. Stavy and Prof. Tirosh, who introduced me to the wondrous concept of intuitive rules and its implications for science and mathematics education, which became the basis for the studies presented in this book. This concept, like many ingenious ideas, appears at first blush self-evident, but in fact, is a complex notion that calls into question existing approaches and demands reexamination and a measure of skepticism, both of which are vital to learning and teaching.

At the center of the book lies the intuitive rule “same A – same B.” The decision to focus on this rule is based on its unique role as expressed in conservation tasks - an increase in incorrect “same A - same B” responses with the development of the conservation scheme. This surprising phenomenon reinforces the notion that the source of the incorrect responses is related neither to knowledge (about the subject of conservation) nor to cognitive ability (such as the ability to acquire an understanding of conservation), but rather to perceptual-given, intuitive or sensory factors. The application of this intuitive rule as a pedagogical tool will make it possible to deal with incorrect responses given by learners from varied age groups (from kindergarten to pre-service teachers), and thus contribute to the work of the pre-service teachers that understand the importance of discussing the limitations of its application.

I would like to thank my students (pre-service teachers) who helped with their ideas and discussions, every year for five years, in the context of the seminar course on “Misconceptions in the teaching of science.” The students’ hesitation at the start of the process was quickly transformed into increasing enthusiasm for the work and the learning, as they delved into the study that uncovered incorrect responses

in their field of experience. The students became partners to the research, presenting up-to-date, research-oriented points of view. We shared knowledge, thoughts, concerns, dilemmas, evidence from the field, all of which became authentic and objective components that contributed to a better understanding of the findings. I thank them for their willingness to participate in the study, for rising to the challenge posed by an action research seminar and for their application of the insights produced by the research in the field of education.

I would like to express my appreciation and thanks to the teachers for their honest and courageous sharing of dilemmas that engaged them in their teaching, and for their questions: Should I have been teaching differently? What could I have done to make the subject clearer?

My gratitude goes to Prof. Shlomo Beck for reading the various parts of the book and for his very important and helpful comments.

It is my hope that the message that this book proposes will find representation in the teacher-training process both in terms of content and affect. I further hope that the advantages presented by the use of the intuitive rule “same A – same B” as a pedagogical tool in teacher training will contribute to

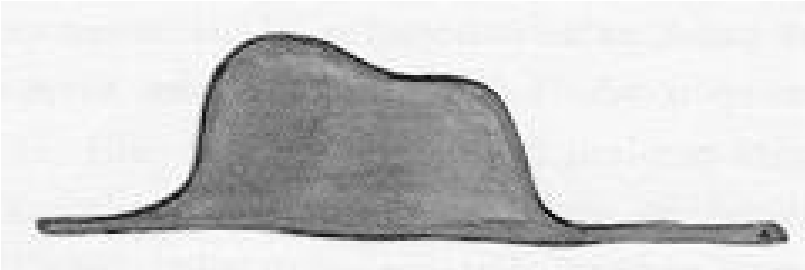
improving the quality of the relationship of those involved in it thanks to empathic effort and support, alongside recognition of and respect for the feelings of learners as part of the practical-reflective teaching-learning process.

# EPIGRAPH

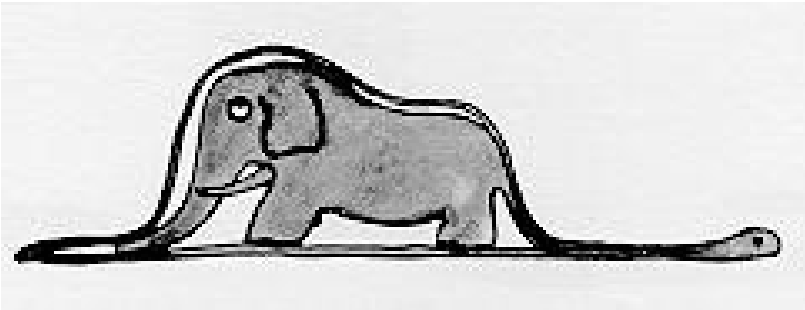
Once when I was six years old I saw a magnificent picture in a book, called True Stories from Nature, about the primeval forest. It was a picture of a Boa constrictor in the act of swallowing an animal. Here is a copy of the drawing.

In the book it said: "Boa constrictors swallow their prey whole, without chewing it. After that they are not able to move, and they sleep through the six months that they need for digestion." I pondered deeply, then, over the adventures of the jungle. And after some work with a colored pencil I

succeeded in making my first drawing. My Drawing Number One. It looked something like this:



I showed my masterpiece to the grown-ups, and asked them whether the drawing frightened them. But they answered: "Frighten? Why should anyone be frightened by a hat?" My drawing was not a picture of a hat. It was a picture of a Boa constrictor digesting an elephant. But since the grown-ups were not able to understand it, I made another drawing: I drew the inside of a Boa constrictor, so that the grown-ups could see it clearly. They always need to have things explained. My Drawing Number Two looked like this:



The grown-ups' response, this time, was to advise me to lay aside my drawings of Boa constrictors, whether from the inside or the outside, and devote myself instead to geography, history, arithmetic, and grammar. That is why, at the age of six, I gave up what might have been a magnificent career as a painter. I had been disheartened by the failure of my Drawing Number One and my Drawing Number Two. Grown-ups never understand anything by themselves, and it is tiresome for children to be always and forever explaining things to them. So then I chose another profession, and learned to pilot airplanes.… I have lived a great deal among grown-ups. I have seen them intimately, close at hand. And that hasn't much improved my opinion of them. Whenever I met one of them who seemed to me at all clear-sighted, I tried the experiment of showing him my Drawing Number One, which I have always kept. I would try to find out, so, if this was a person of true understanding. But, whoever it was, he, or she, would always say: "That is a hat." Then I would never talk to that person about Boa constrictors, or primeval forests, or stars. I would bring myself down to his level. I would talk to him about bridge, and golf, and politics, and neckties. And the grown-up would be greatly pleased to have met such a sensible man.

*The Little Prince,*

Written and illustrated by

*Antoine de Saint Exupéry*

Retrieved April, 17, 2017, from,

http://www.angelfire.com/hi/littleprince/frames.html

# LIST OF ILLUSTRATIONS, FIGURES AND TABLES

# INTRODUCTION

# MISCONCEPTIONS IN SCIENCE EDUCATION: HELP ME UNDERSTAND

## Or: How do we make sense of our world?

In discussions held with pre-service teachers as part of a seminar course about “misconceptions in science education,” the question of how the students' worldview is shaped in regard to science-related phenomena, often comes up. During the discussion, two main ideas emerge, one of which relates to the development of technology, which facilitates the students’ accessibility to information, making it much more available to them. On the other hand, however, it does not offer a solution to students’ misconceptions that are inconsistent with the accepted scientific theories. Moreover, it is also suggested that because students have become accustomed to receiving immediate answers to any question or subject - by clicking a button on the keyboard - this impacts the immediate, intuitive way students answer questions - sometimes leading to incorrect answers.

The second idea is derived from the first, and focuses on changing the status of the teacher as an exclusive source of knowledge, as well as on the implications of this change on the pre-service teachers' sense of self-confidence as teachers, on just how much a teacher is needed in teaching, and hence, on the changing role of the teacher in the teaching-learning process. The pre-service teachers sometimes stand helpless and devoid of any tools to deal with the situation. Indeed, in light of studies that point to the complexity of the learning process (e.g., Berkovich & Eyal, 2015; Blackmore, 2010; Muijs & Harris, 2003); the change in the teacher's role in the era of knowledge and technological availability (e.g., Murphy, 2005; Spillane, 2012); and the importance of training pre-service teachers to deal with misconceptions (e.g., Gomez-Zwiep, 2008; Halim & Meerah, 2002; Meyer, 2004), there seems to be a real basis for this feeling, and it points to the importance of relating to this essential issue within the framework of teacher training.

The need to cope with this challenge led to the search for a different perspective on misconceptions in a way that might also affect the role of the teacher in the complicated teaching-learning process. This combination pointed to the use of the intuitive rule "same A - same B" as a pedagogic tool. The

researchers Stavy and Tirosh (2000), who undertook an in-depth study of incorrect responses in science and mathematics, described in the literature as misconceptions, maintain that a considerable proportion of the incorrect responses described in the literature as misconceptions result from the use of a limited number of intuitive rules (“more A - more B,” “same A - same B,” and “everything can be divided”), leading to an erroneous intuitive response.

The current study is based on these ideas and suggests that incorrect responses of this kind should be treated as an opportunity for learning rather than as a barrier or obstacle, and suggests making use of the potential contribution that lies in using the intuitive rule “same A - same B” as a pedagogical tool in teacher training.

This contribution, which goes beyond predictability for incorrect responses (Stavy & Tirosh, 2000), can also be expressed in possible ways of dealing with incorrect responses, and in exposing teachers to a learning experience that inspires a sense of empathy for their learners. Activity of this kind as part of the educational work of teachers can help to reduce teachers' sense of helplessness when faced with their students’ misconceptions, and on the other hand, inspires teachers to constantly examine their ability to operate

effectively in situations of ambiguity and uncertainty in different learning contexts when they are exposed to misconceptions.

The current study cautiously suggests that misconceptions should be treated as a challenging opportunity to better understand learners' incorrect responses; to address incorrect responses by using the intuitive rule "same A - same B" during learning; and to gain a better understanding of the role of feelings and empathy awareness during learning interactions. Doing this may turn misconceptions into a means to understand and improve learning.

Thus, two central ideas underlie the book: The first - befriend misconceptions - is related to approaching misconceptions as an opportunity for learning rather than as an obstacle to make them part of the teaching-learning process. The second - comprehending emotion - is related to the changing role of the teacher and suggests a more vigorous application of affective aspects in response to the challenges of teaching-learning in the information age.

## Befriend Misconceptions

The idea of treating misconceptions as an opportunity for learning rather than as an obstacle combines the findings of

studies that point to teachers' meager knowledge regarding their students' misconceptions (Gomez-Zwiep, 2008), and as a result, their tendency to ignore incorrect responses during the learning process and to consider them a specific difficulty of learners, one that causes teachers to feel helpless:

> "I don't know what else to do; after all, I've taught it and the students seemed to understand. How is it that they are giving incorrect responses?"

Indeed, ignorance of the source of the misconception is a barrier to learning, but focusing on them is a challenge that can lead to the advancement of learning.

In this study, an effort was made to understand the phenomenon of misconceptions by placing the spotlight on the learners - kindergarten to junior high school students and pre-service teachers who major in mathematics and science - with an eye to investigating not only the perspective of the learners, both the younger ones and the pre-service teachers, but also to try to understand the perspective of the pre-service teachers as teachers. The book proposes a change in the attitude toward misconceptions, that is to see them as an educational event that can advance learning rather than as one that limits it, thus helping teachers and students "make friends" with incorrect responses as part of the teaching-

learning process. This can be done by training an ability to delay the natural need to obtain a single 'correct' answer (Land & Hannafin, 1996), to encourage discussion on different points of view, and to foster tolerance for ambiguous and uncertain situations when questions remain open to discussion, despite the sense of unease that accompanies these situations. To advance this process, the teacher should try to understand the possible source of incorrect responses.

Indeed, since misconceptions appear to be a barrier to learning, understanding what lies behind them might reinforce the process of knowledge building. Some of the ideas proposed in this book are consistent with studies that point to the importance of exposing teachers already at the early stage of learning - in elementary school - to incorrect perceptions and to look for ways that contribute to dealing positively with them (e.g., Gomez-Zwiep, 2008). However, students often avoid seeing them, while teachers treat them as gaps in knowledge that will be filled during learning, although research findings contradict this current assumption (e.g., Allen & Coole, 2012; Gomez-Zwiep, 2008).

Despite the attempt to understand the possible source of the misconceptions, most of the studies relate to a specific content area (for example, electric circuit, force, energy, evolution),

and thus lack a comprehensive, overall and broad view to the problem (Fensham, 2001). A more overall and broad point of view is offered by Stavy and Tirosh (2000), who address misconceptions from another perspective, based on a theoretical framework that can interpret important misconceptions in science and mathematics as evolving from some general intuitive rules. They maintain that in many cases, students give answers that are not based on a single correct or incorrect perception, but rather that their answers vary, based on visual information related to a specific aspect of the task, from which they often erroneously infer for another aspect (Stavy & Tirosh, 1996, 2000). For example, young children (aged 4 - 5) claim that two glasses of sugar water of different size are equally sweet because both glasses have the same amount of sugar (one teaspoon of sugar was placed in different amounts of water - one cup filled with water and the other only half filled with water). The visual information regarding the equal amounts of sugar led to an incorrect answer regarding the degree of the water's sweetness. Similarly, children often claim that a taller child must be older (when comparing two children of the same age who differ in height; a similar answer is given even if the older child is shorter than the younger one). The visual

information regarding the children's height leads to an incorrect answer regarding their age.

According to the researchers, in the first case, the children's answer was consistent with the intuitive rule "same A - same B" (same amounts of sugar - same water's sweetness); in the second case, the children's answer was consistent with the intuitive rule "more A - more B" (the taller - the older). The studies presented in this book are based on the intuitive rule "same A - same B" (Stavy & Tirosh, 2000) that serves as a pedagogical tool whose application contributes to understanding the possible source of students' incorrect responses to conservation tasks; to examining the limits of the application of this intuitive rule in conservation tasks; and to find ways to deal with the incorrect responses.

According to this approach, the proposal is to examine different learners' perspectives, to try to investigate the source of the incorrect answer and to accordingly plan and implement the instruction. Alongside the cognitive pursuit of the content aspect of the incorrect responses, the present study also emphasizes the importance of the affective-emotional aspect, the quality of the relationship with the learners and teacher - learner interactions, as a factor that contributes to learning.