Third Misconceptions Seminar Proceedings (1993)

Paper Title: Learning in Science as Affected by Perceptions of the Nature and Functions of Models
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Abstract:

Keywords: concept formation,teacher education,educational methods,scientific concepts,misconceptions,teacher background,teacher education programs, change strategies,scientific methodology
General School Subject: physics
Specific School Subject: physics
Students:

Macintosh File Name: Finegold - Models
Release Date: 10-16-93 A, 11-5-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

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LEARNING IN SCIENCE AS AFFECTED BY PERCEPTIONS OF THE NATURE AND FUNCTIONS OF MODELS

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PRESENTATION TO THE
THIRD INTERNATIONAL SEMINAR
ON MISCONCEPTIONS AND EDUCATIONAL STRATEGIES
IN SCIENCE AND MATHEMATICS

CORNELL UNIVERSITY

AUGUST 1st. to 4th. 1993

BACKGROUND

This paper is based on a simple premise concerning science teaching and learning. It is that teachers affect student understanding of science, present and future, not only by means of the substantive knowledge which they impart, but also, and perhaps primarily, by the picture they present of the nature of science as an enterprise. In our experience, courses of study which are limited to preparation for school leaving or university entrance examinations, or which are organized along the lines of standard examination syllabi, are not very likely to provide their students with such a picture. Our consideration of how the picture of science is presented deals with just one aspect of science education which we have found to be largely neglected both in the education of future science teachers and in our high schools. It is that of the nature and functions of models as they appear throughout the history of science and as they affect understanding of the enterprise as a whole.

A COMPARATIVE STUDY

This is a report of a study carried out in South Africa and in Israel with the aim of investigating how science teachers in training and high school students understand the nature and functions of models as they have changed and as they are used in the development of knowledge in science. We believe that this is an important issue in science education and therefore believe that science teachers must have a sound knowledge of the origin and nature of the explanatory models which have been created, developed and changed together with the development of science as a discipline.

The first part of the study was carried out in South Africa. 196 students in 16 university teacher training departments in South Africa and Namibia responded to a questionnaire on models in general and on models in optics in particular. The questionnaire was developed on the basis of a series of individual interviews.

The second part of the study was carried out in Israel and used the original questionnaire translated into Hebrew. There are two main differences between the target populations in the two studies. In Israel the questionnaire was administered to student teachers and to grade eleven high school students, whereas the responders in South Africa and Namibia were all teachers in training. Furthermore, the South African and Namibian teacher trainees were all B.Sc. graduates studying for a diploma in teaching physical science, while the responding teaching students in Israel were all undergraduates pursuing their pedagogical studies in parallel with their B.Sc. programs. The grade eleven high school responders in Israel were taking an advanced program in physics but had not yet studied optics.

The first part of the study suggests that South African and Namibian students preparing themselves for science teaching careers do not have the necessary understanding of the nature of models in science and would probably not be able to incorporate properly them in their teaching. Furthermore, general misconceptions about models were identified and it was assumed that these misconceptions could have a far reaching effect on the structure of knowledge in science to which the future students of these student teachers would be exposed.

More specifically it was found that science teachers in training seem to see the importance of models in tuition rather than in research and development. They tend not to distinguish between models in science and models as used by engineers in the planning of structures such as bridges, and they depict models as pictures or likenesses of the entity modeled. The lack of differentiation between anatomical or topological models on the one hand and models of the atom or of the kinetic theory of heat on the other hand lead to considerable confusion, with student impressions often dominated by the models used in a particular course or discipline. For example it was found that students of biology who were accustomed to the use of anatomical models in class were more likely than were students of physics to confuse technical models with scientific models. Connections between theories and models also appear confused, with models often seen as pictorial illustrations of theories and therefore as visual by nature. In short, these future teachers were found to be far from prepared to develop in their students an understanding of the nature and function of models in science and will presumably present their future students with a distorted view of the nature of science as an enterprise.

The second part of the study, relating to student teachers in Israel, was slightly more encouraging though here too understanding of the nature and functions of models in science leaves much to be desired.

The study of grade 11 high school students, all taking physics at an advanced level, suggests that while they are successful in dealing with the substantive physics called for in their school syllabus, the broad view they have of physics as a research enterprise is limited to factual knowledge.

THE QUESTIONNAIRE

The questionnaire presents a number of statements about models. Responders are asked if they agree with, disagree with, or are unsure about the statements and are asked to explain their answers. The first fifteen statements relate to models in general and the next eight statements relate to optics and optical phenomena. In addition, each responds is asked to define a model using his or her own words, to name three models used in physics, and to explain how a model can be used in physics. The first fifteen statements follow. For the sake of brevity they are not in the original format which provided space for responses and explanations.

FIFTEEN STATEMENTS ON MODELS IN GENERAL

1. All models are creations of the human intellect.
2. All models are representations. (Some are purely visual, some can be seen and felt).
3. Any representation that one makes of an object, of a structure, or of a process is called a model.
4. Models exist in nature.
5. All models are mental images (existing only in the human mind).

6. Models are aids that are used to obtain knowledge of nature.
7. A model always provides a complete description of the object, structure or process in nature that it models.
8. A model is formulated using facts obtained by experiment and/or observation.
9. The terms model and theory are synonymous.
10. The only function of models in science is in teaching.
11. Models are of a temporary nature. With the increase of knowledge a model may become obsolete or useless and either adapted or replaced by another model.
12. A scientist always has more knowledge of an object, process or structure than is represented by the model itself.
13. An important function of any model is to describe something (an object, a structure, or a process) in nature.
14. Models play an important role in the explanation of phenomena.
15. Models can be used to predict phenomena, structures or processes that have not previously been observed.

<u>Ideas about models</u>

Here we present some of the major ideas about models as they are indicated by the explanations of responses to the fifteen questions on models. Authors' comments are inset.

1. A model helps one understand "things" in nature.

    Here "things" probably relates to:

    Natural phenomena as observed, such as a blue sky, or a red sun at sunset.

Outcomes of experiments showing for example the transfer of heat between bodies at different temperatures, or differential absorbtion of radiated heat by differently colored surfaces; or

Practical experience such as the screeching of tires as a car makes a fast turn.

2.A model is an identical or nearly identical representation of something real with a one to correspondence between the model and the real thing it represents.

This seems to represent an assumption that all models are of the "toy car" variety in which the success of the model depends upon the degree to which a miniature copy of each part of the original can be found in the model.

3. A model depicts or describes a theory, being based upon or deduced from a theory.

One of the examples given was the particle model of a gas which describes or explains the kinetic theory of gases.

4. A model represents something found or observed in nature.

Here a model is not seen as part of reality but as something which represents reality. Some of the responses suggested that in this sense the model is seen as a theoretical entity, as something existing only in the mind.

5. Models can be real, that is, concrete or material.

This notion relates not so much to what a model is, but rather to the limits placed upon it. It has something in common with the notion of the model as copy or replica but the words "can be" suggest that it does not rule out the possibility of a model existing only in the mind.

6. Models have a role to play in research.

It was not clear from the responses what this role might be and it is possible that this was merely a vague belief, something heard and tucked away in memory, with no real understanding of how a model could be part of an investigation.

7. Models help to explain complex or abstract "things".

Responses gave the impression that models were seen as devices designed to explain otherwise impenetrable observations, again, with no suggestion of how they may be used. Although students used the word 'explain' they were apparently not thinking in terms of models as an instructional or educational tool.

8. Models are visual representations of the abstract and the unseen.

Here it seems that a model is conceived as a means of making it possible to look at something which cannot actually be seen, of seeing it "in the mind's eye". This may relate to things which are too small to see, like an atom, or too far away to see, like a galaxy, or too abstract to see, like energy.

9. Models are used in teaching since they make it easier to remember complicated ideas.

These responses suggest that models, insofar as they appear in high school education, do so as techniques of instruction rather than as an intrinsic part of the enterprise of science.

10. There is no difference between technical or construction models and scientific models.

Basically no differentiation is made between scale models such as are used by engineers and explanatory models such as are used by scientists. A model of a bridge, for example, is seen to have the same standing as a model of an atom, the only significant difference being that one is scaled down while the other is scaled up.

At this point it is of interest to examine responses to the fifteen questions on models as made by the three groups ˇtudied. The graphs following show by percentage, responses which are in agreement with the statements, as made by student teachers in South Africa and Namibia, student teachers in Israel, and grade 11 high school students in Israel, respectively. The statements have been grouped according to topic rather than to their order in the questionnaire.

<u>Student teachers' perceptions of models</u>

The statements that models are creations of the human intellect and that they are mental images, are similar. Similar responses were therefore expected to (1) and (5) but in fact the histogram indicates some confusion. It was also expected that negative responses to (4) which states that models exist in nature, would be reflected in positive responses to (5). This expectation was met only partially. For example a 30% agreement to (5) might have been expected to lead to a 70% agreement to (4) but this was not the case.

Statements (2) and (3) both describe models as representations, a view largely accepted by student teachers in South Africa but largely rejected by student teachers in Israel. In contrast, a large majority of all three groups agree with statements (13), (14) and (15) which describe the descriptive, explanatory and predictive functions of models.

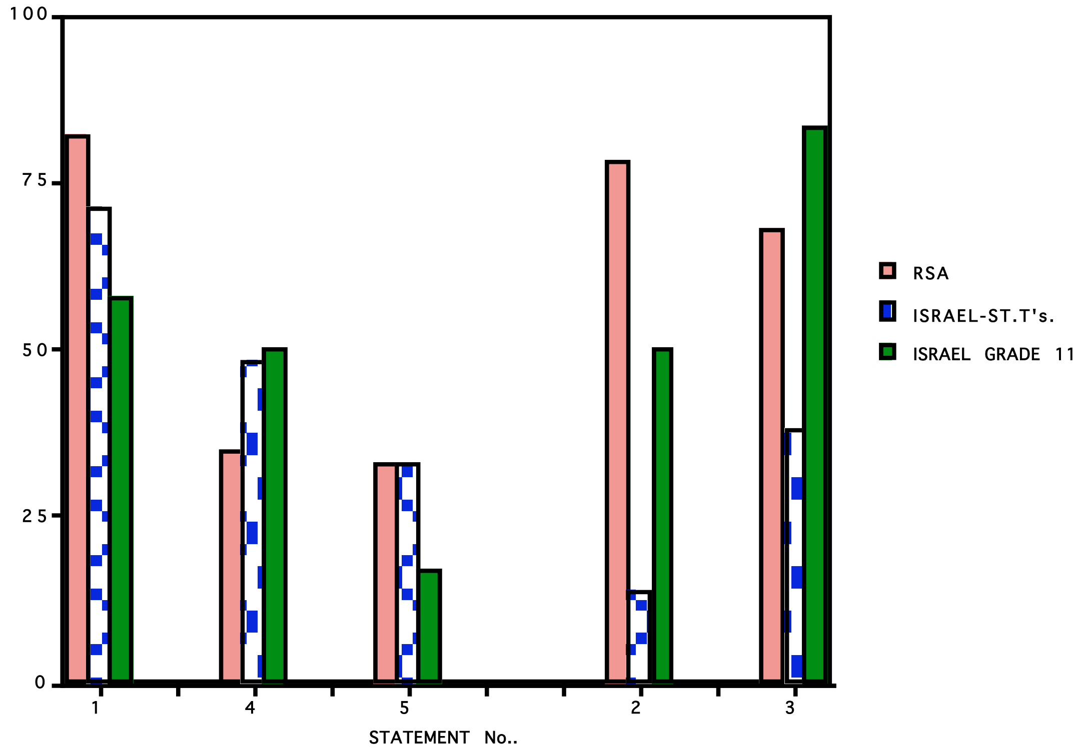
Statement (6) relates to the function of models as aids in obtaining knowledge but (10) suggests that their only function is in teaching. Responses by both groups of student teachers indicate understanding of the research function of models and of the fact that their main function is not in teaching. However this interpretation of the function of models is not shared by all.

Statement (11), dealing with the transient nature of models, presents a very important view of models in science. Responses indicate that only about 70% and 50% respectively of the two groups of student teachers are aware that in science models are not fixed and permanent.

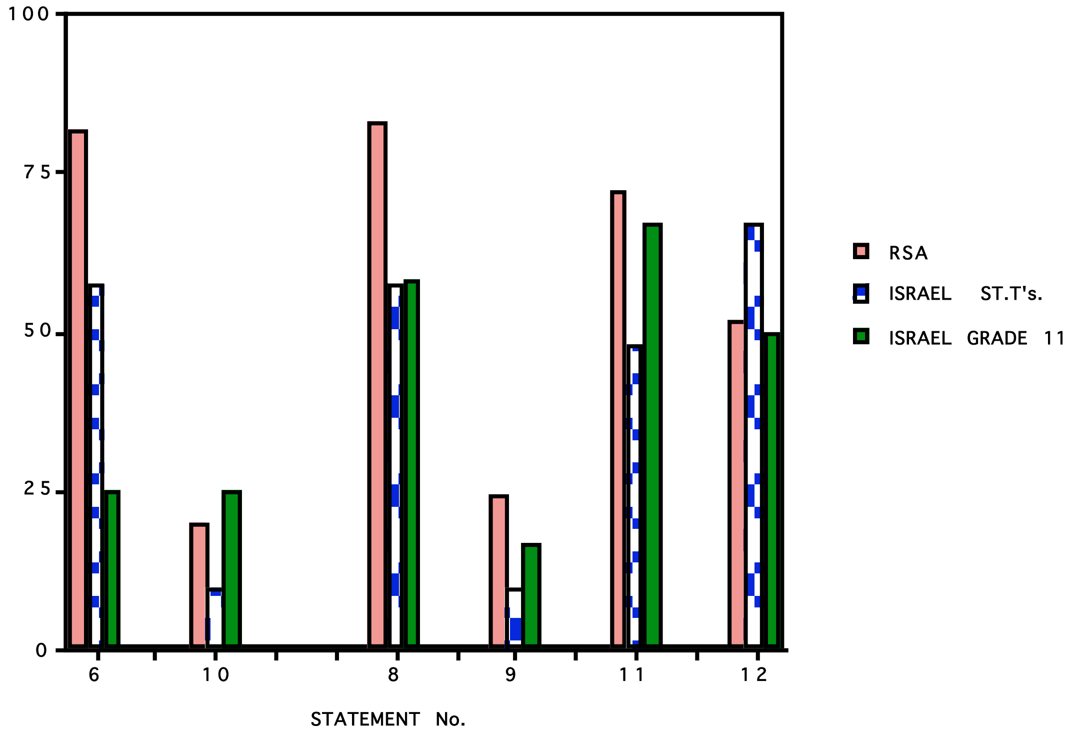
High school students' perceptions of models

The major differences between responses by student teachers in Israel and by high school students in Israel relate to statements 2, 3, 6 and 7. Half of the high schoolers, as compared with only 10% of the student teachers, agree that all models are representations, and 80% of the high schoolers, as compared with 40% of the student teachers, believe that any representation may be called a model. It appears that here the high schoolers are the more sophisticated. With respect to the practical functions of models, high schoolers are less convinced that models are aids in obtaining knowledge from nature, and are more likely to claim that the main function of models in science is in teaching. Whereas almost no student teachers saw models as providing complete descriptions, some 30% of the high schoolers did.. Here they were somewhat less sophisticated.

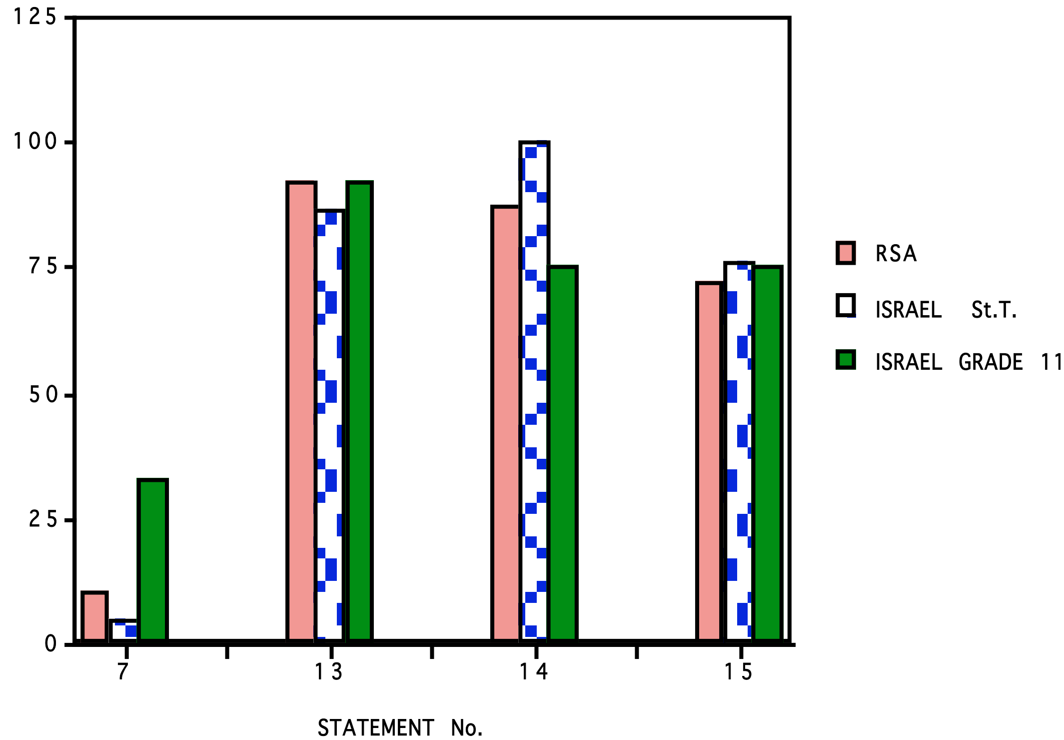
COMPARISON OF RESPONSES TO STATEMENTS ON MODELS
(STATEMENTS 1, 4 & 5; 2 & 3)



COMPARISON OF RESPONSES TO STATEMENTS ON MODELS
(STATEMENTS 6 & 10; 8, 9, 11 & 12)



COMPARISON OF RESPONSES TO STATEMENTS ON MODELS
(STATEMENTS 7, 13, 14, & 15.)



The next part of the questionnaire was designed to provide insight into conceptions of models in the field of optics.

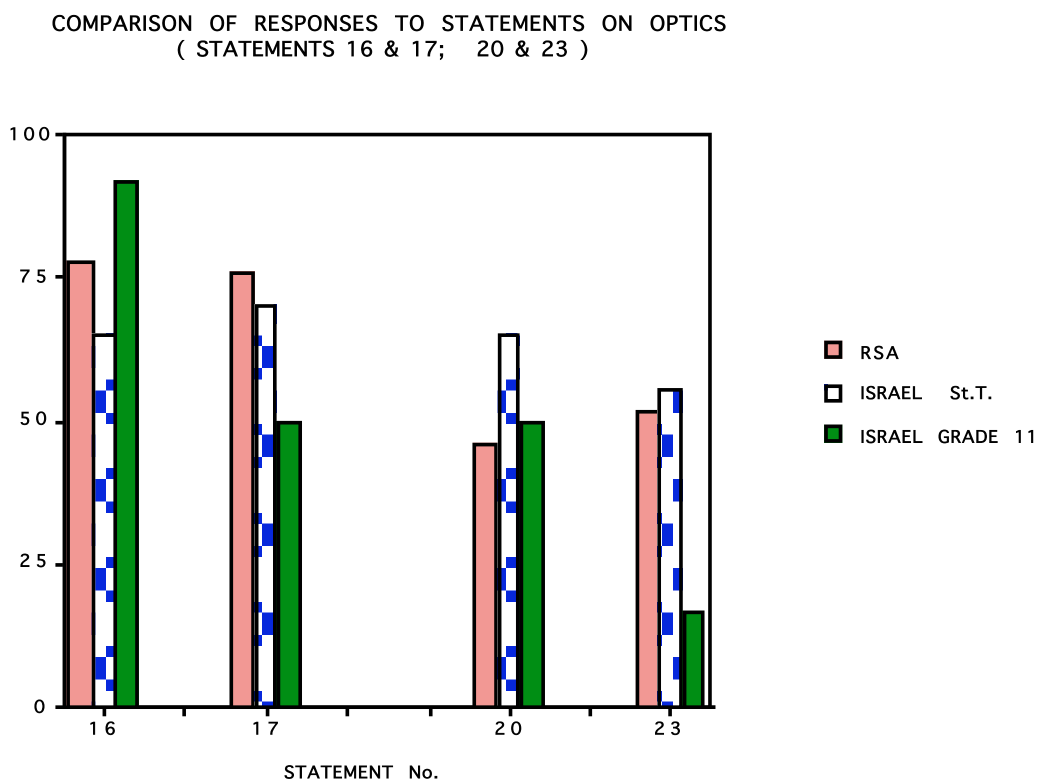
SIX STATEMENTS RELATING TO OPTICS AND OPTICAL PHENOMENA.

16. Light rays occur in nature
17. Light beams occur in nature.
18. Light is electromagnetic waves.
19. Light is the propagation of particles.
20. Light is either a wave phenomenon or a particle phenomenon.
21. Light possesses certain properties of transverse waves.

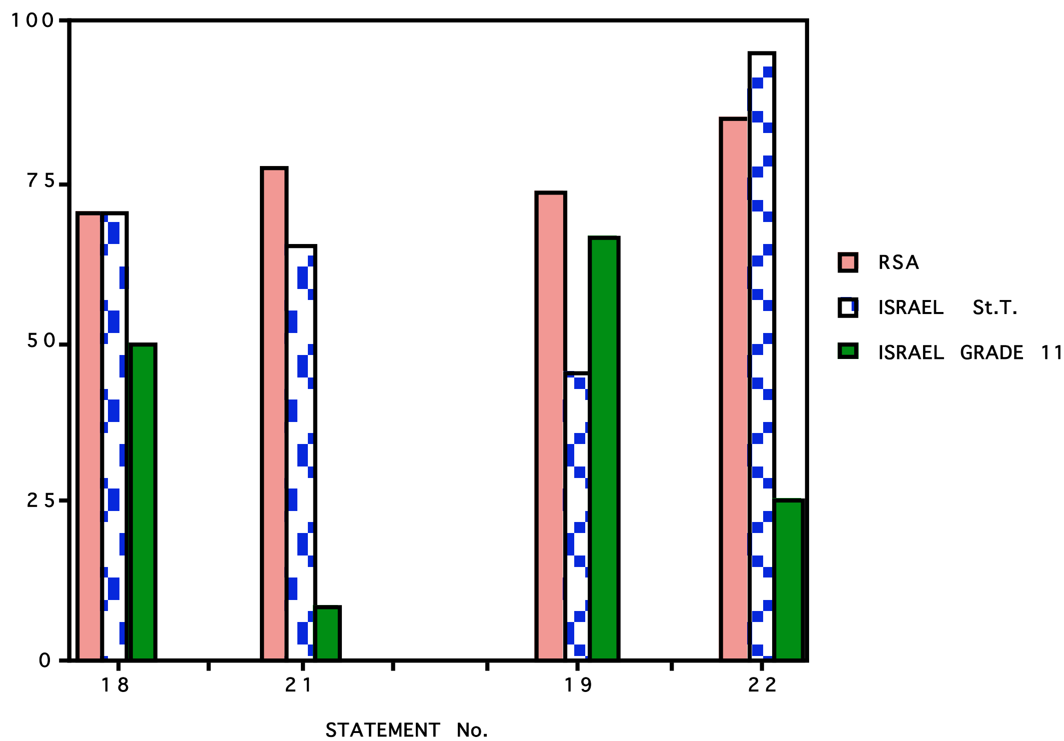
22. Light possesses certain properties of moving particles.

23. The wave and particle models are not applied simultaneously to explain a particular optical phenomenon.

We now examine responses to the eight questions on optics as made by the three groups studied. The graphs following show responses by student teachers in South Africa and Namibia, student teachers in Israel, and grade 11 high school students in Israel, respectively. The statements have been grouped according to topic rather than to their order in the questionnaire.



COMPARISON OF RESPONSES TO STATEMENTS ON OPTICS
(STATEMENTS 18 & 21; 19 & 22)



Responses to (16) and (17) suggest that little difference is seen between light rays and light beams, both being regarded as occurring in nature.

Responses to statements that light "is" electromagnetic waves, (18), or "is" the propagation of particles, (19), or "is" one or the other, (20), suggest that light "actually is" the model chosen to represent it, whichever that model is.

It is therefore interesting to compare statements 18, and 19 with 21 and 22. Responses by student teachers to 18 and 21 are almost identical, suggesting the view that light has wave properties simply because light is a wave. Responses by South African student teachers to 19 and 22 are quite consistent. However, responses by Israeli student teachers differ considerably, with less than half claiming that light is particle propagation and almost all saying that light has certain properties of moving particles. In fact the most popular view of all is that light possesses certain properties of moving particles.

No comments are made on perceptions of optical phenomena held by the high school students since it became clear that they had not yet studied optics. However the relevant histogram is presented.

HOW CAN UNDERSTANDING OF MODELS BE ENHANCED?

It is clear that within the groups studied here, understanding of the nature and functions of models, both by student teachers preparing to become teachers of science and by high school students, is unsatisfactory. It is also clear, from familiarity with the text books commonly used in schools, that very little attention is paid to this aspect of science, of research in science, and of teaching in science. It is not the case, however, that the significance of models has been totally neglected.

Perhaps the most attractive scheme for the development of student understanding of models was that adopted by the PSSC program.. Unfortunately, although the PSSC program has had a great deal of influence on curriculum developers all over the world, its treatment of models has been largely forgotten. The topic was treated in a number of ways, any or all of which provide a useful model for teaching and learning about models.

One method was the use of Swift's "Gulliver's travels" to show the physical meaning of scaling. The Brobdignagian, differing from Gulliver only in that his linear dimensions were scaled up by twelve, must have felt just as Gulliver would have felt had he to carry eleven friends on his back. The Lilliputian, differing from Gulliver only in that his linear dimensions were scaled down to one twelfth, would have been enormously strong as compared with Gulliver but would have had to spend a far greater proportion of his time eating than would his visitor from overseas. The value of the analogy is that when carefully explained it demonstrates the limitations of scaling in a very attractive manner, and provides scope for further examination of the implications of scaling. Most importantly it shows why the "toy automobile" type of model is not a model in the scientific sense, and that a simple copy does not constitute a scientific model.

Another aspect of modeling dealt with, in this case in one of the PSSC films, was the significance of time and time scaling. Two of the models presented are of particular interest in the context of this paper. One was that of a model bridge exploded dramatically for the film "For whom the bells toll", the other was a model of a ship being tested in a wave tank. The former showed the effects of time scaling as pieces of the bridge flew upward and then fell to earth, the latter showed the need for time scaling if the model was to behave as the ship would. In the first case, scaling up of the model (say by 100) to look like a real bridge, meant scaling up of the height to which the pieces of the bridge rose (by 100), and this meant scaling up the time of projection, not by 100 but by 10. In the second case, scaling down the linear dimensions of the ship by 100 for example, meant that in any test of the model's behavior in a simulation of a rough sea, its period of oscillation would increase only by a factor of ten. This would have to be taken into account in using the model's behavior as a basis for conclusions concerning the ship's behavior.

It is not suggested that the PSSC approach to teaching about models is the best or only avenue of approach to the improvement of understanding. After all, it has not been adopted by teachers as perhaps it might have been were it evaluated only with respect to its scientific integrity. We regard the present study not as an attempt to show how to teach about models in science, but as a. warning. Perhaps the PSSC materials do show a way out of the difficulty.. Whether they do or not, we had best attend to the matter.

A NOTE ON MODELS

It is appropriate at this point to add a note concerning views held by the science community on the nature and functions of models in physics. Israel Scheffler writes, in "The anatomy of inquiry", - "A new theoretical scheme seems, in general, to be preferred, in point of intelligibility, to the degree that a familiar model can be provided for it". Much of learning in science presents to the student new theoretical schemes, and in this sense the student does need familiar models to make these schemes intelligible.

A literature survey (D'Espagnat 1983; Harre 1960, 1970; Hesse 1954, 1966; and Leatherdale 1974;) showed the following general views:

Models are constructions of the human mind and are temporary by nature.

Models used in science are analogues of things and processes.

The two main uses of models in science are, (1) Heuristic - to simplify a phenomenon or make it easier to deal with; and (2) Explanatory - to explain the unknown mechanism which is responsible for the phenomenon.

The models utilized in physics are not pictures of the underlying reality but are viewed as representations of real entities.

An important role is played by models in the acquisition of knowledge about nature.

A clear distinction is made between a model and a theory.

Ideally a theory should contain the description of a plausible model, modeled on some thing, material, or process which is already well understood.

Models help the physicist to predict, describe and explain natural phenomena, particles and structures. The descriptions are never complete and different models can be used to describe the same entity.

REFERENCES

D'Espagnat, B. (1983). In search of reality. New York, Springer-Verlag. ; ; Van Oers 1988

Harre, R. (1960). An introduction to the logic of sciences. London, Macmillan.

Harre, R. (1970). The principles of scientific thinking. Chicago, University of Chicago press.

Hesse, M.B. (1954). Science and the human imagination. London, SCM press Ltd.

Hesse, M.B. (1966). Models and analogies in science. Notre Dame, Indiana. University of Notre Dame press.

Leatherdale, W.H. (1974). The role of analogy, model and metaphor in science. Amsterdam, North Holland Publishing Co.

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