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ABSTRACT

As a paper presented at the 1972 Convention of the National Association for Research in Science Teaching, discussions are included concerning research activities and misperceptions about scientific endeavors in the science education community. The purpose is to suggest some acts necessary for science teachers and educators to implement science education. Research reports are exemplified to illustrate the prevalent ways for reporting research conclusions as truth, findings, and trivia. Misperceptions of scientific endeavors are described as an explanation for researchers' selection of the reporting styles. Diverse views about truth, objectivity, ambiguous nature, and research scope in science are considered as the primary characteristics of misperceptions, and the inability or unwillingness to separate findings from explanations is taken as their major source. Reflections of the misperceptions to science teaching are discussed, especially for the non-generalizability of research findings to the teaching situation. The author suggests the science teacher and educator make distinctions between findings and explanations, ask questions about the source of truth, and encourage students to present rival ideas and prize the doubt in order to be morally honest to the knowledge of the scientific endeavor. (CC)

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SCIENCE EDUCATION INFORMATION
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OCCASIONAL PAPER SERIES
SCIENCE PAPER
THE EMPEROR'S CLOTHES PHENOMENON
IN SCIENCE EDUCATION

by

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THE EMPEROR'S CLOTHES PHENOMENON IN SCIENCE EDUCATION*

by

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It is with great trepidation that I have come this morning to address scientists about science - especially with the rather condescending title I elected to use in a weak moment. My being here can only be justified on the basis that, analogously speaking, fish are the last to discover water. (How we have the audacity to suggest that fish haven't discovered water is really the crux of my talk.)

Styles of Research Reporting**

I would like to begin this morning by sharing with you several styles of research reporting I have observed in the distinguished *Journal of Research in Science Teaching*. None of my comments about style should reflect upon either the quality of the research nor upon the competencies of the authors whose articles I have chosen to use as illustrations. This is true simply because in the balance - style vs substance - style is perhaps an insignificant aspect of research reporting. Also, authors may not have had a free hand in the writing of their research reports either due to space limitations or an editor's fine but heavy hand.

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*Paper presented at the 1972 Convention of the National Association for Research on Science Teaching, 4 April 1972; Chicago, Illinois.

**The first section of this paper is based on an earlier article. See reference 22.

<u>Conclusions as Truth</u>. Some researchers report their conclusions in such a manner that the reader might assume that the research hypotheses identified for test in the first sections of the report have been determined to be "true". A rather common practice which demonstrates this "style" is that of merely re-stating research hypotheses under the heading "<u>Conclusions</u>". Let me give some examples of this style.

I. Based on the findings of his study, Leon Hoch advances the following conclusions:

> (1) Factual knowledge is increased as a result of sex education.
>
> (2) Students do not become more permissive in their attitudes involving sexual behavior as a result of sex education. (13)

To be fair here, it must be noted that Hoch did not state research hypotheses in his paper.

II. R. F. Shuck writes his conclusions in the following style: "On this basis, (referring to cautions to generalization), the findings listed in this study would appear to warrant the following general conclusions:

> (1) Pupils taught by teachers trained in the deliberate use of set-induction techniques will achieve significantly higher than those exposed to teachers not trained in this instructional skill." (24)

Other similarly worded conclusions are included in this article. Shuck's paper did present hypotheses for test: they were stated in the null form in his manuscript.

III. John J. Koran, Jr. states that three hypotheses were tested by his research, the third of which was as follows: Both the written model and the film-mediated model are expected to produce significant changes in behavior from Trial 1 to Trial 3. After presenting a summary of his data, Koran writes, "....; hence Hypothesis 3 may be accepted". (16)

In terms of my training and with reference to my readings in science methodology, all of the conclusions presented in this section are not sufficiently qualified. It may be that I am speaking only of matters of style or tradition in reporting research in science journals. Perhaps the obviously needed qualifications are expected to be supplied by the reader. Of course there may be other explanations for why researchers choose to use this style of research reporting.

As I understand it, an obvious limitation of the inductive process is that inductive procedures do not ever prove a generalization. They may only permit scientists to say that the data collected in a research context either support, fail to support, or in some cases falsify a generalization. For example, suppose a researcher hypothesizes that Method A is more effective than Method B. He randomly assigns students to either of the two methods and finds at the conclusion of his experiment that students assigned to Method A did indeed score significantly higher on relevant measures than did students assigned to Method B. Does his finding prove that Method A is more effective than Method B? In my judgment, the answer is NO. This researcher may conclude that the data support the hypothesis that Method A is more effective than Method B.

This is not to suggest that the words "proof" or "prove" are never to be used. They have very specific meanings in logic and in mathematics and they can be useful in communicating ideas in very free and loose conversations. But so often, in doctoral committee meetings I hear them used as follows: "Was your design adequate to prove your hypotheses?" Again, those of my colleagues who use "prove" in this way may be merely using a word they fully understand in a "shorthand" sort of a manner.

Conclusions as Findings. A second style for reporting conclusions in a research study is that of really not reporting conclusions at all - but of merely reporting findings. Thus, while a research hypothesis is either stated or implied in the first sections of the research report, under the heading "Conclusions," the findings are merely summarized, leaving the inferring of conclusions to the reader. Let me cite some examples of this style from the Journal of Research in Science Teaching.

I. L. R. Allen states that the purpose of his "study was to investigate whether participation in the SCIS elementary science program at the Grade I level results in a performance superior to that of Grade I nonparticipants in the program when certain SCIS objectives are considered." Under a heading of "Conclusions," he has two numbered paragraphs. The second paragraph illustrates the point I am trying to make here.

> "2. In four out of the five test items in which objects were presented for examination and manipulation (Items #1, 2, 3, 4), chi-square calculations show that SCIS children exhibited significantly more exploratory behavior than did non-SCIS children." (1)

II. It was hypothesized in a study reported by R. Amos that the opinions of teachers on the objectives of biology teaching might be related to sex of teacher and length of teaching experience. Under a heading called "Conclusions and Implications" Amos states: "Analysis of variance reveals that the most important variable to be considered is the effect of teacher experience, and only in rare cases does the effect of sex show any significance." (2)

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III. To show complete objectivity, let me cite a report written by a woman. H. H. James initiated a study to investigate "differential effects of three supervisory methods in facilitating development of inductive-indirect teaching techniques by science student teachers." Under a heading "Conclusions," James writes, "The self evaluation group showed highest inductive-indirect performance and changed on more attitudes in a direction compatible with that teaching strategy." (15)

A variation on this theme is found in the style which reports as conclusions the outcomes of a statistical procedure. Thus statements such as "the null hypothesis was rejected at the .05 level of significance" is a type of remark that can often be found under a heading called "Conclusions."

IV. To cite a specific case of this variation, I turn to the research of H. R. Fulton. He states the hypotheses of his study in null form as follows:

> (1) There is no significant difference in achievement in biology as measured by the BSCS Comprehensive Final Examination, between students who have been exposed to two different approaches to teaching BSCS Biology.

Six pages and many tables later the conclusions are set down. They are written as follows:

> (1) The null hypothesis of no significant difference in achievement in biology, as measured by the BSCS Comprehensive Final Examination between students who have been exposed to two different approaches to teaching BSCS was rejected at the 0.05 level of significance. Students exposed to different approaches to teaching BSCS Biology varied in their achievement in biology as measured by the BSCS final. (10)

Perhaps using this style of research reporting represents a training that suggests researchers should not venture opinions - that researchers should remain objective and unbiased. Isn't it reasonable to expect more than that in a research report? If the purpose of an experiment is to test a hypothesis, couldn't the researcher let us know how he feels the hypothesis fared under the conditions of the experiment after considering the findings? One way to see the limitation, in my mind, of this style is to ask the researcher to differentiate between his findings and conclusions. To persons accepting this style of research reporting, there are no differences. As you leaf through the Journal of Research in Science Teaching you will find many authors who do not make such a distinction - many even omitting a "Conclusions" section from their report.

Such a practice may reflect the training science educators have received in educational research methodology more than that they have had as scientists. Many of us have been trained to write our hypotheses in the full form. Referring back to my earlier example, a researcher who believes deep in his heart that Method A is more effective than Method B - who has logic and previous research to support his belief, is encouraged to write as a hypothesis: Method A is not more effective than Method B. Some of my colleagues argue that this practice demonstrates the objectivity of the researcher - as if writing hypotheses one way rather than another changes the deep-seated convictions of a researcher. What can one say then, when one gets significant results? Usually, the conclusions in cases such as this assert that "the null hypothesis is rejected." Actually, such a style fails to distinguish between statistical hypotheses and research hypotheses - between findings and conclusions.

The problem becomes more complex if the statistical findings are not significant. What conclusion can one come to then? Often researchers

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write, "the hypothesis is accepted" (it's true) . . reverting to the first style described in this paper or they write ". . . the mean of group A is not significantly different from the mean of group B . ." thus failing to make a distinction between findings and conclusions. I would like to elaborate some more about the difficulty with working with a null hypothesis under an inductive methodology.

In the classical model of induction, while an affirming instance of a generalization only adds somewhat to the credibility of the generalization under scrutiny, a counter-example discredits or falsifies the generalization. In this sense, finding two persons with the same fingerprints would wreck the FBI theorem about fingerprints. Such evidence is very important since a single instance discredits the generalization. When the null hypothesis method of testing statistical hypotheses is used, and when the findings of the experiment are not significant, it is not appropriate to say that the null hypothesis is true, or that the generalization from which the null hypothesis was derived is invalid. A null result only indicates that if any differences exist between population means, the experiment did not pick them up. Therefore, if in the Method A vs Method B paradigm cited above, the researcher did not find significant differences between his groups, he cannot say that Method A is not more effective than Method B. He is restricted to saying that the hypothesis that "Method A is more effective than Method B" is not supported by the data of this experiment. The ambiguity of the null hypothesis method of decision making may account for a researcher's setting down findings as though they were conclusions. Again, there may be other reasons which account for researchers selecting this style.

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Conclusions as Trivia. A final style which I found used with some frequency in the Journal of Research in Science Teaching has to do with over-qualifying the statement of conclusions. Let me cite two examples which illustrate this way of reporting research, the first of which I have already referenced.

I. In the Schuck paper, the conclusions section is introduced with the following several sentences:

> This study employed a sample of 180 ninth grade students drawn from E. O. Smith High School, Storrs, Connecticut. Consequently, results of this study should be generalized to other situations only after definite relationships between those groups and the sample employed in this study have been clearly established. (24)

Schuck doesn't tell us how any definite relationships could be established - or what kind of relationships he has in mind.

II. R. A. Roberts and J. W. Blankenship preface a section entitled "Discussion and Implications" with the following caveat: The ability to generalize from the findings of this study is inherently limited to the nature of the sample and the restricted nature of the problem. Then tossing caution to the winds, the authors continue, "However, the following discussion, based upon the analyses, may have some implications for large populations." (23)

This style is found elsewhere in the educational literature, and it may simply be a reflection of over-zealous professors on oral examinations who serve as gate-keepers - blocking students who deign to over-generalize from ever entering the promised land. But, in my mind, this view seems to lead to errors almost as serious as those of the researcher who believes that a research design can prove his hypotheses true. Researchers who adopt this style of reporting seem to ignore the potential of the inductive process for generalizing beyond the findings of a particular study. It is this possibility which indeed differentiates it as a process of inquiry. As a learning psychologist studies pigeons in a learning experiment, he seems to generalize his results to laws of learning that are under test and not to the populations of pigeons living in the University coop. The act of doing research in a sense places a generalization (the hypothesis) in jeopardy. As the findings of the experiment support the hypothesis, the credibility of the hypothesis is advanced. As the data do not support the hypothesis, then either the hypothesis needs re-examination or modification or the research design needs to be made more precise or both. Actually, other responses to such a result might include rejecting any further research in favor of more productive and rewarding pursuits.

The fear of over generalizing has apparently paralyzed researchers to the extent they qualify their findings to meaninglessness. Homme has attacked such fears in the following passage:

> In our culture, each of us has grown up repeatedly hearing that humans are very complicated and that every human is different from every other one. Generalizations about human behavior are, therefore, if not altogether bad, at the least very risky. But one can make similar statements about a stone. No stone is like every other stone, and the micro-structure of stones is presumably quite complex. So we might conclude that stone generalizations are also very risky. However, the facts of the matter are that all stones, regardless of other individual complexities and peculiarities, obey certain laws - the law of gravity for example. (14)

If our thinking is so constrained about our research work that we can only "generalize" our findings to the students with whom we have experimented, then our work is clearly nothing but trivia. (I will admit that consumers of research - especially those non-researchers who are wont to lace their talks with phrases such as .. "research shows that" often over-generalize research studies, but there is no way that I know of to protect an author from having his research misused or misquoted. As far as I can tell, the "stop-signs" of over-qualification never signaled effectively to the research-distorters in our profession.)

So as not to paint an absolutely gloomy picture for those few of you who have accepted my views to this point, there are of course articles in the Journal of Research on Science Teaching that do seem to accept the ideas I am reviewing here. For example, Herron, although declining to use a major heading "Conclusions" does state the following: "On one of the three course examinations significant differences were found which support the hypothesis that students who receive objectives will perform better than students who do not have the objectives." (12)

Another example is given by two of my colleagues from the University of Maryland. Walbesser and Carter report as conclusions: "The research hypothesis is supported for each of the four integrated processes." (26)

Misperceptions of Science: An Explanation

I have tried to present three styles that are prevalent in the Journal of Research in Science Teaching. In my presentation of each style, I have suggested some explanations for why authors might choose one style over another, *e.g.* an editor, research training in a doctoral program, the constraints of the null hypothesis method, and some others. None of these explanations is particularly attractive to me nor do they seem especially powerful as explainers. A more likely account of why research reporting styles differ and why they manifest the properties I have described in the first section of the paper may lie in the authors' misperceptions of scientific endeavors. Again, I want to say that my explanation is tentative and untested; it is at best an attribution and may clearly not apply to those authors whose work I chose to illustrate the styles I have presented to you this morning.

It is my thesis that one of the major problems facing science teachers and students of science education is their misperceptions of the scientific endeavor. They seem to envision the muse Science bedecked in the white purity of truth, in the glamorous furs of progress and without the slightest decolletage to stimulate wonder on the part of her students. I contend further that such romantic views of Science are reflected in the ways science educators choose to talk about their own researches. Finally, I hypothesize that these views, communicated to teachers, can account in part for some of the poor teaching that is now taking place in our science programs. The paragraphs that follow will attempt to develop these theses.

Science and Truth. Many teachers of science seem to express the view that scientists deal with truth. They teach current explanations as though they were true. Students are rarely asked to describe the current explanation for a phenomena on a test or in class discussions. Instead they are asked to describe why something happens, without any qualification. You and I were probably a victim of this sort of teaching. We were told that neon was inert; that an atom was made up of a proton, neutron, and electron alone. We were told how light was propagated. None of our teachers probably qualified these so-called facts as explanations. Many of the facts that could be found as items on science tests in the thirties and forties are probably discredited by now. And yet, some science teachers seem unaware of the tentativeness of their own subject matter.

Is it likely that researchers in science education who share this view of science, that I am daring to call a misperception, tend to write their conclusions as though they were truths? I think that such a relationship is more than a possibility.

Science and Subjectivity. A second view that seems prevalent among science teachers is that science is characterized by the absence of subjectivity. If subjectivity exists to a degree in an experiment, these teachers seem to feel that the experiment has to that extent been weakened. It is difficult to find examples in textbooks which illustrate the subjectivity of science. One case may serve as an example. Almost twenty years ago, Dr. Jonas Salk announced that the findings of his research led him to believe that the polio vaccine was effective and safe. As one might guess, the data upon which those judgments were based were not absolutely free from ambiguity. (27) There were interactions between the dosages of vaccine and the types of polio studied with effectiveness rates ranging from 60 percent to 94 percent from one type of the disease to another. Variations in effectiveness rates were also observed from batch to batch of the vaccine. From these data, Dr. Salk arrived at his judgment. The point here of course is not to quarrel with the validity of Dr. Salk's decision, but merely to use this case as an example of the role subjectivity may play in announcing conclusions based on data.

Perhaps it is this view of science that leads researchers in the area of science education to eschew writing conclusions in their researches. Persons of this persuasion may choose instead to share findings with their colleagues in the media of print and to withhold making any judgments about the meaning of their data.

Science and Wonder. The idealization of science on the part of teachers and students of science education may also be reflected in a view of science

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that makes ignorance seem like an anomaly. As Green has described it for the teaching profession generally, teachers and authors of text materials have woven a fabric they call science from which any patterns of an ambiguous or puzzling nature have been cut away. (11) Some teachers suggest that the cutting edges of science can only be perceived after many years of hard study - perhaps only beyond the doctorate - and that it is unseemly for secondary school students or under-graduate students to grope with the unknowns that from time to time become apparent.

Persons holding such views of science seem to be especially distrustful of educational research. They may feel that since educational research doesn't control all of the variables and since the hypotheses tested in educational research rarely account for all of the observed variance, then the enterprise is not worth considering. This attitude may account in part for a retreat from experimentation on the part of some science educators. Since they cannot compete in terms of precision with real science, which, they feel, does control all the variables and which, they believe, does account for all the observed variance, they choose not to play the game.

A second response which may be attributed to this view of science may be that of over-qualifying one's conclusions. Such an act may be an attempt to communicate to readers a proper sense of humility. Of course, the argument that the style with which one chooses to report his research hypothesis is a reflection of one's views of science is as yet not tested, as far as I know.

Science and the Scope of Research. This topic might more correctly be called an issue within the science field rather than a misperception. Many scientists feel that understandings of nature are pieced together like a huge tinker-toy model, as Bronowski pictures it, from the pieces of empirical research contributed by anonymous scientists the world over. (4) That such a view is dominant among science educators can be explained perhaps by the following chain of reasoning: All of us, and I would guess science majors in particular, are especially aware of the great historical idols of science - men and women who have been responsible for tremendous breakthroughs. However, when science educators observe current scientists at work they see them carrying on activities classified by Kuhn as "normal" science. (17) According to Kuhn, "normal" science includes attempts to increase the accuracy and the scope with which facts are known; to determine regular relationships between variables already determined to be important; and to test the generalizability of an idea with phenomena closely related to those first used to validate the idea. In general, such activities are not glamorous or newsworthy regardless of the knowledge that develops from them. And yet, our science educators may argue it is from such work that dramatic breakthroughs develop. By the way, they may be correct. However, there are other views, views that by and large are unrepresented in our curricula. These other positions, set forth by Bronowski for one, and Oppenheimer for another, argue that the tinker-toy view of nature is taking creativity out of science. Persons sharing this position argue that what advances science is conceptualization - and concepts are by definition beyond the data - they are figments of men's minds. As someone who holds the tinker-toy view of the world, perhaps he reports only findings in his research report - hoping that some other researcher will be able to piece his small fact with many others to form a grand explanation or theory.

Summary. I have tried to describe to you several clear-cut styles which science educators apparently choose to report their researches. Also, I've tried to suggest that in part the selection of a particular style of research reporting may reflect the science educator's views of science - views that I have dared to call "misperceptions." I would like to digress briefly to discuss a possible source of these misperceptions and then to discuss ways these views might account for some poor practices in science teaching.

Sources of Misperceptions

Where do our colleagues acquire their romantic views of methods of science? One explanation is given by the Philosopher Thomas Kuhn: he suggests that it is the textbooks which advance unreal notions about the scientific endeavor. (17) A concept of science drawn from a textbook, a source designed to persuade and to teach, is no more likely to describe accurately the scientific enterprise, Kuhn suggests, than is a tourist brochure likely to portray realistically a national culture. Scientific education, writes Kuhn, makes use of no equivalent for the art museum or the library of the classical and the result sometimes is a drastic distortion in today's scientist's perceptions of his discipline's past. I would like to elaborate upon this point with some examples from textbooks to clarify my earlier comments about misperceptions and also to give some weight to the idea that one source of the misperceptions I have cited is the science texts.

Let me begin by citing a passage from a text entitled Elements of Science authored by a grammar school principal in 1959. (20) Perhaps this is a bad example - since it is a science book written by an educationist - but how many science texts in this century have been authored

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by a Teller or an Oppenheimer. This text was written in question-answer format - a style that I understand was quite popular in the nineteenth century. For purposes of clarity, I have taken some liberties with the text without, in my judgment, altering its intent.

> Q. From what does yellow fever arise?
>
> A. It arises from poisonous exhalations from swampy lands near the sea within the tropics . . . It is communicated by contagion. (p. 145).

As a second example, consider the textbook literature on magnetism. In the 1859 reference cited above, several fairly accurate descriptions of magnetic effects are included, but the source of magnetism is not one of the questions posed in the narrative. Another text, written almost 90 years later, explained magnetism as follows (again the explanation has been abridged but I think not distorted): Assume that the molecules or atoms of which any object is composed are in effect tiny magnets. When all of the tiny magnets are aligned, then the magnetic forces of all the tiny magnets sum to an observable magnetic force - and when they are perfectly aligned - the force of magnetism is optimized. (6) This explanation accounts for the effects of heat on a bar magnet; why magnetic effects are observed at points other than the poles of the iron bar; and why cutting a bar magnet in half produces two bar magnets. (By the way, this formulation was attributed to a German physicist W. E. Weber, 1804-1891.) (7) Of course, this explanation does not account for where the little magnets came from and what would happen if one of the little magnets were cut in half. From the middle of the 1940's to the present day, we have progressed to the point where modern texts, written in the 1970's, speak of electron spin as the mechanism for producing magnetic fields. (3) What's the problem with the explanation of the etiology of yellow fever or the various accounts of the source of magnetic forces? It is not that some of the accounts are more accurate, more acceptable, or more correct than others. My quarrel is that none of them is advanced as an explanation. Instead, they are presented in the texts as truth - in declarative sentences which carry overtones of authority. My guess is that you will find this kind of propaganda in science texts across time no matter which topic you examine, save one. Almost all c^f the texts I examined in preparing this talk presented the discussion of evolution with prefatory remarks about the following narative being "only theory." Students must wonder how scientists can know so much about so many things and at the same time know so little about evolution. (What are some explanations for this area of science being so properly qualified - in a manner different from, for example, magnetism. It is my arguement that we don't know - and can never really know which explanation we might offer is the more credible - we can only find data to support (or not) any explanations which are advanced.) In sum many (but not all) of the misperceptions identified above and attributed in this talk to science educators and science teachers may be seen as stemming from a single source - the inability or the unwillingness to separate findings from explanations. To see explanations for truth is to mistake current explanations for ageless axioms; to mistake judgments of scientists for automatic decisions of automatic men acting as scientists is to overlook the roles that subjectivity plays in science; to perceive findings and explanations as identical is to block students from having a vision of the mysteries of science. I have tried to document that these tendencies can be seen reflected in the research reports of science educators. In the next section I will try to show how they might also account in part for some of the practices we see in science classrooms in our nation.

Science Teaching and Attitudes Toward Science

I would first like to address myself to the contention, which I almost matter-of-factly asserted earlier in this talk, that science teaching is being poorly done. Is there any validity to this claim? Of course, like all generalizations, one can cite counter-examples. (It would be difficult to test the claim empirically unless at least two of us agree on a criterion of "good teaching".) Nevertheless, we certainly are aware of the furor over the failure of the schools, about the disenchantment of students and parents over the quality of programs being offered in the public schools and in colleges, and the concern of even some respected men such as Silberman (25) and Bruner (5) about the quality of education now available to the youth of America. Do any of these claims exempt science? I think not. They are talking about you and your students. Granted the claims may be wrong or even grossly exaggerated, but for the sake of argument, let us assume that they have a speck of validity. Let me examine two kinds of errors teachers might make in a science program that may be related to misperceptives of science: teaching explanations as facts and teaching only facts. Let me also suggest reasons why science teachers may reject educational research as a source to inform their teaching.

Science as Truth. A teacher in BSCS asked his class, "What happens to hypotheses over time?". Many persons in the class answered, in various ways, "They become discredited". "No," roared the teacher, "they become laws". Another teacher was introducing the idea of evolution to his class. One of the students suggested that perhaps the Adam and Eve theory of creation was an accurate one, and that the presence of animals of many different levels of complexity could be explained by an evolutionary trend of regression rather than progression. "If this were the case, how would the data presented in the textbook be different?", the student asked. The teacher told the student to stop asking foolish questions. The expectations and responses of both of these science teachers may demonstrate a view of science which interferes with their asking students for rival explanations, with their encouraging students to prize the doubt, with their stimulating students to inquire. After all, the truth is known, why go to the bother.

Science as Facts. Some teachers ask students to memorize fact after fact. For instance, one teacher just last week required students to know how many times a spider's eye magnified an object (The answer was 250 times). This teacher, and many others, convey a notion that science is knowing facts. If more concern could be placed upon the ways scientists know facts, the course might be more interesting. How did the author of the 7th grade science book know to say that a spider's eye magnifies an object 250 times? Not 245 times? Maybe teachers believe that when the student matures, he will be able to use all the facts he has learned to build an understanding of the world. Such preoccupation with facts of course are not only found in public schools. Two researches at the University of Maryland have found data to support the hypothesis that the leading and most respectable examinations in biology and in chemistry are made up of over 50% of factual type questions.

Science and Non-generalizability. I have illustrated the distrust found in science educators in the generalizability of their own research findings. If this skepticism is also found in other science educators and science teachers, it may explain their disdain for educational research: as studies for the past 40 years have discredited the idea that the mind is an instrument that needs honing - science teachers generally ignore them - and insist that by working hard students learn an intellectual discipline. Regardless of what research findings suggest about the predictability of the forgetting curve, teachers still give closed book tests and praise students for temporarily remembering discrete facts. Perhaps as teachers learn different attitudes about science, they will place more stock in the research that is available concerning teaching - and as a result their teaching practices will change.

I want to close this section by clarifying one matter. I am not arguing that by making distinctions between findings and explanations, by calling for students to suggest rival explanations, by asking questions about the source of truth, or by encouraging students to prize the doubt, teachers will somehow produce better students or even ones who score higher on the College Boards. I am making my argument based on ethical considerations. Our knowledge of the scientific endeavor morally requires us to carry out these acts in our teaching.

Summary

I have tried to suggest that some science teachers and science educators have mis-perceptions about the scientific endeavor. I have also tried to demonstrate ways these misperceptions may be reflected in the research reports of science educators and in the teaching of science teachers. Perhaps the only misperception I have shared with you today is my own - and that the real irony of my emperor's clothes metaphor is that I am too blind to see what science is all about. I truly and humbly consider that a possibility. Thank you for your kind attention.

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