DOCUMENT RESUME

ED 292 633	SE 048 979

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TITLE	The Understanding Held by Nigerian Science Teachers of Some Science Concepts.
PUB DATE	88
NOTE	25p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 5-9, 1988).
PUB TYPE	Reports - Research/Technical (143) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	Aptitude Tests; *Foreign Countries; Higher Education; *Misconceptions; *Preservice Teacher Education; Process Education; Science Education; *Science Teachers; Secondary Education; *Secondary School Science; *Teacher Evaluation; Testing
IDENTIFIERS	*Nigeria

ABSTRACT

In considering implications for teaching and learning found in research, a number of writers have urged teachers to probe students conceptions before teaching a concept. The purpose of this probing is to allow the teacher to begin instruction from the conceptual position or positions of the students. This approach carries with it the assumption that teachers themselves have an understanding of the concept which is congruent with the view of science. The fundamental purpose of this study was to explore the validity of this assumption about the nature of the understanding of high school teachers in Nigeria. It was based on a constructivist view of learning. Practicing high school teachers (N=251) took a written test on concepts that they had been teaching and 45 agreed to be interviewed following the test. Another group of 157 trainees was also given the test. Examples of questions and response patterns were given. The study concluded that teachers exhibit the same range of misconceptions as students. Teachers tend to use more sophisticated terminology and have a generally lower frequency of misconceptions. There were no systematic trends by teacher qualifications. Tertiary science teaching is suggested as the appropriate source of the problem. (CW)

The understanding held by Nigerian science teachers of some science concepts

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Paper presented at the meeting of the American Educational Research Association, New Orleans, April, 1988

The Understanding held by Nigerian science teachers of some science concepts

Introduction

Such has been the growth in explorations of conceptions held by students, particularly in the sciences, that to comment on the growth is almost passé. Of more significance than this growth of explorations has been the increasing concern with the implications for learning and teaching of this research. That is, many researchers have moved far from a cataloguing of students' ideas and explorations to various approaches to attempting to understand implications of the work.

In considering implications for learning and teaching to be found in this research, a number of writers have urged teachers to probe students' conceptions before teaching a concept (e.g. Champagne, Gunstone & Klopfer, 1983; Osborne & Freyberg, 1985). The purpose of this probing, it is argued, is to enable the teacher to begin instruction from the conceptual position(s) of the students. Such advocacy carries with it the assumption that teachers themselves have an understanding of the concept which is congruent with the view of science. The fundamental purpose of the study reported in this paper was to explore the validity of this assumption about the nature of teachers' understanding.

This research is based on a constructivist view of learning (e.g. Osborne & Wittrock, 1985). That is, the view that individuals construct their own meaning for concepts, experiences, etc. It has previously been argued (Gunstone & Northfield, 1986) that if one conceptualizes student learning and conceptual change in this constructivist way, then one should also apply the same conceptualization to teachers (and to researchers). In the context of the present study, this argument leads to the clear conclusion that teachers will have personally constructed meanings for concepts and explanations of natural phenomena. When teachers were themselves school students, it seems obvious that at least

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some would have held some of the alternative conceptions so commonly reported in the literature. Whether or not these alternative conceptions would be restructured or abandoned by teachers during their advanced study of science, and the nature of meaning constructed during this advanced training, are issues underlying this study.

The study then has explored the understanding held by a substantial number of Nigerian high school science teachers of a number of fundamental science concepts. The teachers involved had all taught at some time all of the concepts involved. This probing of teacher understanding has been undertaken with a methodology already widely used with science students. Hence the study also aimed to consider the appropriateness for probing teachers' ideas of a technique already widely used with children.

Before describing this technique and the specific instruments used, we make brief comment on terminology. The variety of labels used to describe students' ideas and beliefs has been frequently commented on. The important issue with this variety is the nature of the assumptions about students' ideas and beliefs which the label can imply (see for example, Gunstone & Champagne, 1988). To a number of writers, the term "misconceptions" carries particularly clear assumptions of error, wrongness, etc. which seem at odds with a constructivist position. We strongly concur with this view. However, given that the present study involves science teachers, we use the term "misconception". This seems eminently reasonable when discussing any alternative conceptions held by qualified science teachers about concepts they have taught.

The approach used to probe teacher understanding

The nature of the question which motivated the research (do science teachers hold misconceptions?) implies need for data from a substantial sample. Thus a written test was used. Recognition of the extent to which appropriate interviewing can provide very much richer data about an individual's conception led to interviewing of a subset of the group tested. This interviewing took place after the written test had been completed by the interviewee, and focussed on elaborating reasoning behind answers given by the respondent on the test.

In considering what form of test to use, it was decided that it should be as close as possible to some existing approach which had been used with students. This was a result of the way the basic research question had grown out of considerations of research on students' ideas and beliefs. Adopting an approach already used with school students would also allow comparisons between student and teacher conceptions. Other issues involved in choosing an approach are described in the reasons given below for selecting the approach which was used.

The written test used in the study was taken from existing written probes of students' ideas and beliefs produced by the New Zealand Learning in Science Project (LISP). This project has undertaken a large number of investigations of student conceptions in a wide variety of areas. Much of the LISP work is summarized in Osborne and Freyberg (1985). The project has commonly used one of two forms of interview to explore student conceptions, with the results of these interviews being used to guide the development of written probes of conceptions subsequently given to larger samples. The two forms of interview are termed Interview about Instances (IAI) and Interview about Events (IAE). With IAI, a number of instances (and perhaps non-instances) of a particular concept (e.g. animal) are shown, one at a time, to the interviewee who is asked if the example is, say, an animal and why. From the examples the criteria used by the interviewee to determine the concept involved are elicited. A similar approach is used with IAE, except that the focus is on events related to some concept (e.g. for "physical change", events such as the bubbles in boiling water, evaporating water, etc.). Here the interview focusses on eliciting the explanation the interviewee has for the event.

Selected questions from written probes developed by LISP were used in this study for several reasons.

(a) The answer format required was straight forward, as opposed to tasks such as concept maps or Venn diagrams, in that either a direct question was asked (e.g. "Is a worm an animal? Give your reasons") or a multiple choice question was given. Hence no learning was required of the teachers to understand the format of the questions, a most important issue when a substantial sample was sought.

(b) It was clear from their considerable use that the LISP written probes could reveal much of school students' ideas.

(c) As the written probes had been derived from interviews, it was a straight forward matter to reverse this process and use the written probe as the basis of subsequent interviewing.

(d) The considerable existing data from school students who had answered the same questions meant that student/teacher comparisons of performance were possible.

The test used explored aspects of understanding of nine science concepts ("animal", "plant", "living", "force", "friction", "gravity", "electric current", "light", "chemical reaction"). As implied above, two forms of question were used: direct questions (e.g. "Is grass a plant?", "Is there a force on the bicycle?") with reasons also asked for; multiple choice questions where distractors reflected common alternative conceptions among school students (e.g. "Some nails go rusty when put in or near water. <u>Before</u> such nails go rusty, where is the rust? (a) It has nor formed yet; (b) It is in the air; (c) It is in the water; (d) It is in the nail itself"). Asking for reasons for choosing a particular answer in a multiple choice question is very revealing. However it was necessary to balance the number of questions for which reasons for answers were asked against the number of concepts covered in the test. We judged breadth across concepts to be more important than more detailed information about one or two concepts. This judgement of the number of questions for which reasons were asked was also influenced by the time needed to complete the test. Most teachers took 40-50 minutes, as was the case during the trialling of the instrument. We believed the test should not take longer than this or there would be difficulties in finding participants for the study.

Before starting the test, respondents were asked to complete brief biographical details (e.g. sex, years of teaching experience, qualification(s) held, experience in teaching the concepts which the test explored, etc.)

The sample involved in the study

The populations on which the research focussed were qualified high school teachers of science in Nigeria, and trainee high school science teachers. Given the nature of the research it seems obvious that the sample taken from the practising teacher population could comprise only volunteers. Had this decision not been taken it would have been forced upon us, as there was considerable reluctance on the part of teachers to be involved. Indeed many refused to undertake the test. Consequently it was impossible to obtain any systematic sample, although teachers from a number of Nigerian states were involved.

A total of 251 practising high school science teachers undertook the test. The large majority of these completed the test individually within their school, while some answered the test while at summer in-service courses. Included in this sample were all four types of qualification found among Nigerian science teachers: three year B.Sc. from a university after completing A level at high school (A level is equivalent to the English A level);B.Sc. plus a one year teacher training program; three year National Certificate of Education (NCE) from a teachers college after completing O level at high school (O level is equivalent to the English O level);NCE plus B.Sc. All the 251 teachers were involved in teaching integrated science to the lower years of high school (and hence in teaching the concepts on which the test focussed), and many were also teaching specialist physics, chemistry or biology at senior years.

On completing the test, all 251 were asked to then participate in an interview. All who agreed were then interviewed. This totalled only 45, another strong indication of the reluctance of teachers to be involved. This reluctance was further emphasized by the failure of a substantial majority to give all the biographical data which was requested. Thus, for example, although the qualification of each respondent is known, the number of years of teaching experience is known for only a small number. It is not surprising that the biographical data which was readily given was that which gave no clues as to identity.

All trainee teachers who undertook the test did so during a class session normally devoted to their training course. A total of 157 trainees were involved. All were NCE students. None was interviewed.

All tests and interviews were undertaken by the first author.

The development of the instrument

The nine concepts on which the test focussed were selected from the Learning in Science Project as representing fundamental concepts in Nigerian science courses. Questions relevant to each concept were assembled and considered by a panel of post-graduate science education students at Monash University, and then by a panel of Monash science education academics. The questions remaining after these discussions were given to Nigerians temporarily resident in Australia to consider in terms of cultural appropriateness. The resulting test was then given to 42 students in a post-graduate one year science teacher training course at Monash University. The results of this trial administration, reported in Ameh and Gunstone (1985), led to the removal of questions seen to be ambiguous or unclear in any way.

In the use of the final form of the test in Nigeria, no indication of difficulties in terms of question wording, diagrams, etc. was evident. However it should be noted that the content and purpose of the questions caused some negative reaction. This was generally associated with the presence of misconceptions about a particular concept.

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Results

Here we consider only data from the 251 practising teachers, and concentrate on data relevant to the concepts "force" and "electric current" as illustrations. Some summaries of some other data are given after considering these two concepts.

The concept of force:

The understanding of aspects of the concept of force was assessed via two situations. The first involved a ball thrown straight up in the air. Line drawings of a person throwing the ball showed the ball in three positions: on the way up, at the top of its path, on the way down. For each of these three positions, respondents were asked whether the total force on the ball is down, up, or zero. (The question is shown in Osborne and Freyberg, 1985, p.45).

In considering the data from these three questions, patterns of responses across the three questions are significant. These patterns are shown in Table 1.

Place Table 1 about here

The proportion of teachers giving the scientific response to these questions (down in each case) is remarkably low: 6%. Just over half the teachers (51%) indicated that the force on the ball is "up" when the ball is rising, "zero" at the top of the path and "down" as the ball falls again. This set of responses has been argued in the literature to show a belief that motion requires a force in the direction of motion (e.g. Gunstone & Watts, 1985; Osborne & Freyberg, 1985). Explanations given by those interviewed certainly confirm this inference for a number of the teachers who gave this set of responses. For the case of the ball rising, those explanations included:

> When you throw a ball upwards, you apply a force when you are throwing it up. That force is still acting on the ball, that is why the ball is still progressing. If the force is not there, instead of going up it will start coming down. The influence of the force is still on the ball.

> When you throw something up, you have two forces acting - the force due to acceleration which you put and the force due to gravity which is pulling the object down. When the ball is moving up, the force of acceleration is more than that of the gravity.

> There are two forces acting on the ball, the thrust and that of gravity, but since it's on its way up, the thrust is higher than the force of gravity. The force of gravity continues to act on the ball till it reaches zero speed.

The logic expressed in the first of the above quotes (the force of the throw is still acting) was explicit in the responses of 5 interviewees. Other interview responses seemed to begin from the view that motion upwards means force upwards, and to then argue that an upwards force must be present. Examples of this form of response included:

> When the ball is on its way up, the force on it is upwards, because it's going against gravity and for it to be going against gravity, it means that there is a force pushing it upwards.
> (The argument in this, or very similar expressior, was given by 7 interviewees).

> Naturally, as the ball is being thrown upwards there will be a force of gravity acting on the body pulling it downwards and is opposing the upward motion of the ball but since the ball is going up that means the net force is in the upward direction.

> Every object on earth is acted upon by force of gravity which attracts it to the centre of the earth = $9.8MS^{-2}$. When an object is thrown up, it has a force which will tend to be greater than that of force of gravity until such a time as the force of gravity is exactly equal to the force with which you throw that object up. At that particular time the ball no longer moves, it stops and starts coming down and comes towards the gravity, now the force of gravity has overcome the initial force.

There were seven interviewees who had answered that the force was down as the ball rose. All gave adequate explanations.

For the case of the ball at the top of its path, only two interviewees had answered down. While one of these gave a concise and correct explanation, the other was very confused.

> When the ball has reached the top of its flight, it is no more proceeding by kinetic force, what we have at that point is, it will start to rest, it will rest momentarily before coming down. At that time it is producing another type of force. It starts to have oscillation force, that is, the time it will turn and start coming back.

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Answers of zero force at the top of the path were very common among the interviewees. Some explanations of this answer reflected a "no motion means no force" view, while others seemed confused. Examples of these explanations include:

> When it has reached the top of its flight, there is no force because the force pushing it upwards and the force, um...you see when it reaches up there, it stops momentarily before coming down, when it stops at that point, err...it means at that point that the force which was propelling it up and the force which is going to ... the force of gravity pulling it down at that particular point, they neutralize each other, they equalize ... at that point the force is zero because the velocity is zero.
>
> When the ball reaches its height, there becomes a point where the velocity is equal to zero, that means the motion stops temporary, momentarily.
>
> No force, at that moment there is no force because it has reached the maximum height and the force acting, pulling it down is equal to the force that took it up.
>
> No force, the only force it has is force of gravity and . is only when it comes down that force is acting. When it is up the force there - it doesn't move, the force is zero.
>
> When it gets up, the force due to gravity balances the upward force, that is why it stops there, both of them cancel each other and no force is acting.
>
> Because at the maximum position there, the velocity is zero and the force itself is proportional to the velocity - so when the velocity becomes zero it means there is no force acting upon it at that particular time, that's why it stops momentarily.
>
> The force there is zero, that is the acceleration is zero because it has reached its peak, cannot move again, no force acting on it.
>
> No force because when an object is moving up, it possesses potential energy but on getting to a certain height, it attains a position which is very stagnant but it is not observed because it will just ... the time change is negligible, so at that particular point, there is sort of change in energy which is kinetic energy due to position. At that point there is no force on that object.
>
> Because there is no force, the ball has stopped, the force finished.
>
> There is a sort of equilibrium between the forces acting on it. The kinetic energy pushing it up is exhausted, the force of gravity is greater now.

There are a large number of issues revealed in these quotes: views alien to an impetus view of force and motion; the equating of force and acceleration, strange uses of concepts such as kinetic energy and potential energy, beliefs that force is proportional to velocity, and so on. Certainly any suggestion that the poor performance on these questions is somehow a function of inadequacies in the question has no support from the interviews. The understanding of these concepts, at least among this sample, is very poor.

Even for the case of the ball falling again similar misconceptions were revealed. Among the reasons given to support the correct answer "down" in this case were

> The force at this time will be equal to the force it is coming down with plus that of acceleration due to gravity.
>
> Now the gravitational force is over the pulling force.

Table 1 shows that only 6% of teachers gave correct answers to all three positions (and the interviews show that not all of these answers would have been based on correct reasoning). The answer sequence "up, zero, down" was given by 51%. The same set of questions has been used by Osborne (Osborne, & Freyberg, 1975, pp.45-46) with large samples of students aged 13 - 17 years. His data show, for example, 66% of 15 year olds answering "up, zero, down". Among 16 and 17 year olds, all studying physics, the proportion giving this answer sequence was still over 50%. The answers given by teachers in this sample are very similar to those given by Osborne's students in New Zealand.

The second situation used to probe understanding of force involved a bicycle. A line drawing of a person riding a bicycle labelled "no brakes, no pedalling, slowing down", was given. Respondents were asked "Is there a force on the bike? Yes/No. Give reasons". (The question is shown in Osborne and Freyberg, 1975, p.42). Data from this question are considered more briefly, as much of what was written as reasons for answers complements the data given above for the previous questions. It should be noted that the phrasing of the question means that an appropriate response involves giving only one appropriate force. That is, the question does not require giving all appropriate forces acting on the bike.

A total of 192 teachers (76%) answered "yes" - there is a force on the bike. "No force" on the bike was given by 49 (20%) and 10 (4%) gave no answer. Of the 192 responses indicating a force on the bike, only 92 gave reasons which could by generous interpretation be seen as reasonable. Reasons given by the remaining 100 were quite evenly divided into three groups:
(i) "initial force" or "force exerted by the rider" (e.g. "Yes, the force acquired as a result of the initial velocity and the mass of the bike"; "Yes, the pedalling is the force"); (ii) "because it is moving" (e.g. "Yes, because the bike needs force to go"); (iii) confused or uninterpretable responses (e.g. "Yes, it moves on the slope"; "Yes, a force of gravity and centrifugal force").

Again, the patterns of responses are broadly similar to those given by students who answered the same question.

When responses across all four force questions were considered, only 10 respondents gave adequate answers in all cases - a staggeringly low figure.

The concept of electric current

Five multiple choice questions relevant to this concept were used. Three of these explored ideas about current in different situations (three batteries in series; an incomplete circuit; an unconnected car battery). The remaining two questions are a pair, focusing on the magnitude and direction of current in a simple circuit and, taken together, suggest the model of current flow used by the respondent. This latter pair is considered first.

The pair are shown in Osborne and Freyberg (1985, p.174). In brief, the two questions relate to a diagram of a torch (flashlight) globe connected to a D.C. cell. The wire from the top of the cell to the globe

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is labelled A and carries an arrow head to show that current flows from the cell to the globe in this wire. The second wire is labelled B, and no indication of any current direction is shown. Two multiple choice questions then follow. The first is about the magnitude of the electric current in wire B (with alternatives: zero, less than in A, equal to A, more than in A), the second about the direction of current in wire B (with alternatives: no direction because no current, from cell to globe, from globe to cell).

Taken together, answers to these questions can be used to determine which of the four models for electric current described by Osborne (Osborne & Freyberg, 1985, pp.23-24) is being used by the respondent. These four models, identified from probing of students, are the Extinction model (all current used in the globe and therefore none in wire B), the Clashing model (current in wire B is from cell to globe), the Diminishing model (some current is used in the globe, hence current in wire B is less than in A, and flows from globe to cell), and the Equal Current model (the model held by physicists) Table 2 shows the models used by the 251 teachers, as inferred from their responses to these two questions.

Place Table 2 about here

In this case, teacher performance is a little better than that of New Zealand students answering the same questions. Of these students 26% exhibited an equal currents model, with 32% showing a diminishing model, 38% a clashing model, and 4% an extinction model. Nevertheless, only just over one third of these teachers has answered both these questions correctly.

Again, interviews sought to establish reasons used by respondents, and again these reasons covered the same spectrum as those of students. Examples of reasons given in support of incorrect answers to the first

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question (magnitude of current in wire B) include:

> No current in wire B because it's not attached to the top of the battery. I don't see how the current can be drawn from the bottom.
>
> The current coming from the wire A due to potential difference, there is some electric current in B but less than A...A generates the electric current, goes through the bulb, whatever is left from the torch after it glowed is the one that goes through B back to the battery which is definitely less than that of A...the bulb has used up some.
>
> The current now going into the bulb will, some it will be used up to light the resistant wire, which collects the current, which resists the movement of the current which uses some of it to light. By the time it leaves the bulb and going into the battery, I expect that some of it has been used up.
>
> There is a drop partly in B because there must be potential difference before the current would flow, so the lighting has already consumed some current, so moving from positive to negative it means the potential at A is better than at B.
>
> B will be less than A because some of the current has been converted into energy used by the bulb.

The notion that electric current is somehow consumed within an appliance such as a light globe, with this consumption being the explanation for the globe functioning, has been found to be common among school students. It has been argued (e.g. Shipstone & Gunstone, 1985) that this interpretation arises from a failure to discriminate between energy and current. The application of a rather meaningless single broad concept embracing all aspects of electricity to phenomena such as globes lit by cells appears to lead to the view that this broad concept is used in the globe. The terminology used by students to describe this unreasonably broad concept is sometimes "electricity", but is sometimes "current" or "voltage" or "power" and so on.

The interview data obtained in the present study suggest that many of these teachers are also failing to adequately discriminate energy and current.

One positive aspect did emerge from the interviews. When the second of this pair of questions was considered (the direction of current flow in the second wire), all interviewees who had answered the question correctly gave appropriate reasoning to explain their answer.

The remaining three multiple choice questions probing the concept of electric current involved (i) a flashlight with three cells in series with alternatives about the relative magnitudes of current in the three cells; (ii) an empty electric light socket with alternatives about whether or not there is a current in such a socket, and reasons; (iii) an unconnected automobile battery with the yes/no question "Is there a current in the battery?". Each question contained a line drawing of the situation. The questions were as shown in Osborne and Freyberg (1985, pp. 173-174). A summary of the data obtained is shown in Table 3.

Place Table 3 about here

Space precludes a detailed listing of interview responses relevant to these three questions. For the first two, the reasoning used to support an incorrect answer was very commonly as would be inferred from the answer. For example, reasoning behind stating that the cell nearest the globe in the flashlight question had the greatest current was invariably based on some sort of cumulation view; reasoning for incorrect answers to the empty light socket question were rarely anything other than a restatement of the reasoning given in the alternative chosen.

As was the case for the concept of "force", the data show that many teachers had misconceptions about electric current. These misconceptions are of generally similar form to those found among students, but are often expressed in much more scientifically sophisticated language than is used by students.

Data summaries for some other concepts:

Of the other seven concepts probed in the test, only the concept "living" was widely understood. Some data summaries are given below for three of the remaining six concepts in order to illustrate that the data above for "force" and "electric current" are broadly typical of performance on eight of the nine concepts.

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The concept of "animal": Understanding of this concept was probed via a series of sixteen questions. For each question, a line drawing of an example (e.g. a cow) was given, followed by the question "Is the [e.g. cow] an animal? Yes/No. Give reasons." Four of the examples were not instances of animal, the remainder were animals. Responses for each subject were considered across all examples, firstly in terms of whether or not the example had been correctly classified as animal or not animal, and secondly in terms of the reasons given. The reasons were considered particularly in terms of whether or not they were identifying characteristics of animals rather than characteristics of all living things. Appropriate understanding was arbitarily judged to be shown by the provision of at least two identifying characteristics of animal at some point in the sixteen sets of reasons, as well as categorizing all sixteen examples correctly. The data for "animal" are summarized in Table 4.

Place Table 4 about here

The concept of "plant": This was probed by questions of the same form as for animal. In this case, five instances and two non-instances were given. Data were analyzed in the same way as for animal, and results were very similar. Only 30 teachers (12%) classified all examples correctly and gave two or more identifying attributes of plant across the seven examples, while 23 (9%) did not classify all examples correctly.

The concept of "friction": Difficulties with this concept were expected, but the nature of the misconceptions which were found was sometimes surprising. Five of the friction questions involved a person on a slide, in three different situations - coming down the slide and speeding up, coming down the slide at a steady pace, and stationary half way down the slide. For each of the three situations respondents were asked if friction was present, and to give reasons for their answer. Two other questions asked for comparisons of the magnitude of friction (if any) for the speeding up and steady speed cases, and for the steady speed and stationary cases. For the speeding up situation, only 133 teachers (53%) indicated that they believed friction was present. Of these, 21 (8% of sample) gave no reason for their answer and 18 (7%) gave uninterpretable reasons. Interpretable reasons were more predictable, and included contact (41, 16%), movement or relative motion (41, 16%), and opposition to motion (5, 2%). Reasons using only gravitational force in some unexpected way were given by 3 (1%). Among the staggeringly high proportion who did not believe friction was present the most common reason given to support this view was that the person was speeding up on the slide. For the case of coming down at a steady speed, 194 teachers (77%) indicated that friction was present (a surprisingly low figure which only appears reasonable when compared with data from the other two questions). In the third case, stationary on the slide, only 155 teachers(62%) indicated that friction was present. The most common reason for arguing no friction in this case was the absence of movement. The questions asking about relative magnitudes of friction in the different situations were even more poorly answered.

<u>A general comment:</u> These data summaries for "animal", "plant" and "friction" imply a situation very similar to that already elaborated for "force" and "electric current" - the relatively common existence of a range of misconceptions of very similar nature to those found in school students. This implication is certainly suported by the raw data, both written and interview transcript.

Discussion

Clearly these results are alarming. The most obvious conclusion to draw from these data is that teachers exhibit the same range of misconceptions as has been found in students. When the teacher data are

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compared to student interview and written data from the same questions, there are only two clear differences. The frequency of misconceptions among teachers is generally a little lower, and teachers tend to use more sophisticated language (including science terminology) to express their misconceptions.

We comment on an important implication of these results in the conclusion below. Before that, two other modes of analysis of the data and the extent to which the data might be generalized are considered.

The data were considered by teacher qualification of the four forms outlined previously. There were no systematic trends by qualification, the small variation which was present for some concepts only seems quite random. An attempt was also made to consider understanding of concepts as a function of teaching experience. This was considerably inhibited by the failure of many teachers to provide the biographical data necessary for this analysis. Hence it can only be asserted that there is a very weak trend for reduced frequency of misconceptions with increased teaching experience. This weak trend is also consistent with the weak trend for practising teachers as a whole group to have somewhat better understanding than the sample of trainee teachers who were also involved in the study.

Those not involved with Nigerian education may be tempted to see the major finding of this study, the startling frequency and range of teacher misconceptions, as specific to Nigeria. That is, it may be tempting to assume that such range and frequency of misconceptions would not be found among science teachers in some other countries. This possibility we reject, on a number of grounds. Firstly, data from written tests given to a small sample of New Zealand teachers (reported by Osborne & Freyberg, 1985, p.139) is broadly consistent with the findings reported here. This New Zealand investigation involved only written testing, and could reasonably be described as a preliminary study. Nevertheless, the patterns of responses found there are similar to the Nigerian data. Secondly, there is general similarity between the Nigerian data and the trial data obtained from written tests undertaken by 42 science graduates in a teacher training course at Monash University (These Australian data are reported in Ameh & Gunstone, 1985). This similarity is further reinforced by the nature of misconceptions revealed during the interactive teaching which is used in the Monash teacher training course (see Champagne, Gunstone & Klopfer, 1985; Gunstone & Northfield, 1986). Thirdly, and we believe most importantly, there is the consistent similarity between the nature of Nigerian science teacher misconceptions and the ideas/beliefs found among students in western countries. This similarity suggests that, for at least a number of teachers in western countries, misconceptions they held as school students will be retained. Certainly, for a high proportion of the Nigerian teachers in this study, their misconceptions have been relatively unaffected by their advanced science study. We return to this issue in the conclusion.

In considering the generalizability of these Nigerian data then, we assert that the best interpretation of the available evidence is that the situation will be similar in other countries. No doubt there will be differences in detail, but the same broad patterns of misconceptions are most likely.

Conclusion

As we have already suggested, the situation described in this paper is most serious. A narrow view of this situation might well lead to a burst of what is known in Australia and elsewhere as "teacher bashing". However to castigate teachers is to choose quite the wrong target. All teachers in this study have been taught, and assessed, by tertiary science lecturers, professors, etc. All teachers in the study had passed these assessments and had thus been accredited as science experts by their instructors. Here, we assert, lies a much more appropriate target for considering the problem.

Many of us involved in science education have had cause to consider inadequate some aspects of tertiary science teaching with which we have had contact. Anecdotes about poor teaching and inappropriate assessment are not hard to find. The results of the present study point to these science teachers having acquired considerable "text book" knowledge during their tertiary science courses - all the sample had passed conventional examinations. However these teachers often had little ability to apply such knowledge to interpret and explain common situations.

The notion that the origins of the problem lie in tertiary science teaching is strongly supported by a preliminary study conducted in conjunction with the probe of science teacher understanding. A small number of those teaching science in Nigerian teachers colleges were interviewed about their teaching. These interviews produced disheartening data, but data which confirm the thrust of our arguments here. Views of how their students might learn were hard to find among these tertiary science instructors. Commonly expressed beliefs of importance to our arguments included seeing knowledge of definitions and solution of standard problems as the focus of instruction and assessment, asserting that what had previously been taught should be understood (even for the most abstract and difficult of concepts), denying any role for previous experience or cultural issues in forming a student's understanding (even by an instructor who subsequently indicated to the interviewer that his understanding was affected by these factors), seeing a text book as the single most important factor in student learning, and so on.

Changes in these beliefs and practices are what is needed to effect change in understanding among the graduates of tertiary science courses.

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Table 1. Summary of responses to questions about force on a ball thrown in the air

Direction of force on ball as ball rises, at top of path, as ball falls.		Number giving these responses (percentage of sample)
Force is	down; down; down	16 (6%)
	up ; zero; down	128 (51%)
	down, zero; down	9 (4%)
	up ; down; down	24 (10%)
	up ; up ; down	23 (9%)
	down; down; up	5 (2%)
	down; up ; down	8 (3%)
	other responses	9 (4%)
	no response to one or more questions	29 (12%)

Table 2. Models of Electric Current used by respondents

Model	Number (%) of respondents
A. Extinction	31 (12%)
B. Clashing	84 (33%)
C. Diminishing	24 (10%)
D. Equal	91 (36%)
No response to one or both questions	21 (8%)
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Table 3. Summary of responses to three situations involving electric current

Question/Alternative	Number (%) of respondents
(i) [Given diagram and explanation of flashlight with 3 cells in series, switched on; 5 alternatives given as 5 student ideas.] Which one of the following ideas do you think is the best idea?	
A. No. 1 [furthest from globe] will have the most current.	5 (2%)
B. No.2 [middle] will have the most current.	3 (1%)
C. No.3 [nearest to globe] will have the most current.	41 (16%)
D. Nos. 1 and 3 will have more current than No.2.	14 (6%)
E. They will all have the same current.	168 (67%)
No response	20 (8%)
(ii) Is there a current in an empty light socket?	
A. No because there cannot be a current flowing.	30 (12%)
B. Yes because if you touch it you get a shock.	80 (32%)
C. Yes because if you put a globe there it will glow.	87 (35%)
D. Yes because the current would be going out from the prongs.	34 (14%)
No response	20 (8%)
(iii) Is there a current in an unconnected car battery?	
A. No	78 (31%)
B. Yes	121 (48%)
No response	52 (21%)

Table 4. Summary of data for concept "animal"

Nature of Response	Number (%) of respondents
Did not classify all examples correctly.	46 (18%)
Classified all examples correctly - listed only characteristics of living things.	92 (37%)
Classified all examples correctly - gave only one identifying attribute of animal.	7 (3%)
Classified all examples correctly - gave two or more identifying attributes of animal.	34 (14%)
Other forms of responses (including uninterpretable).	58 (23%)
No response to one or more example«	14 (6%)
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