The Philosophy of Science held by Secondary School Science Teachers in Trinidad

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Purpose of the Study

The purpose of this study is:

> To examine the philosophy of science held by a sample of science teachers who teach in secondary schools in Port-of –Spain and environs in relation to, issues relevant to science teaching and, changes in the wider programme of science education.

Current Status of Science Education in Trinidad and Tobago

Science in the Trinidad and Tobago School Curriculum

The provision of skills which allow for "… greater appreciation and understanding of science …" (Trinidad and Tobago. Ministry of Education, 1995) is an educational commitment espoused by Trinidad and Tobago. Within the primary (ages five to eleven years) and secondary (ages 11 to 16 years) sectors of the school system the curriculum provides for science education in keeping with this commitment. The quality of science instruction provided is affected by the teachers' level of professional training, knowledge of science and the availability of resources.

In the primary sector the level of professional training and knowledge varies from teachers with the locally certified Teaching Diploma to those who do not have a C.X.C. (Caribbean Examinations Council) pass in any science subject. Some students are still taught science in cramped classrooms, while others have specially assigned laboratory space.

Within the above context students enter secondary school with widely varying knowledge levels about and attitudes towards science. The situation is exaggerated by the attitudes towards science in the home and the influence of science-based television programming, toys and activities.

The secondary sector is staffed mainly with teachers who graduated in science, some of whom have professional qualifications such as the Diploma in Education (certified by The University of the West Indies). In most schools subject choices for the C.X.C. examinations are made at the end of the second year, therefore it is possible at this stage for a student to cease all formal science instruction.

The Significance of the Teacher's Philosophy of Science

Secondary school teachers are seen as subject specialists and as such have tremendous influence on their students' beliefs about their particular discipline. In the case of science teachers the aura which surrounds the discipline, such as the use of a laboratory, amplifies the teacher's influence as an authoritative source of beliefs about science.

Matthews (1992) notes that teachers' beliefs about the nature of science affect their classroom behaviour and can be conveyed categorically and by inference. A teacher's philosophy of science may be implicit only or implicit and explicit. An explicit philosophy of science requires an awareness of the conflicting accounts of the truth of scientific knowledge, and therefore some knowledge of the philosophy and history of science. The less explicit the teacher's philosophy of science the greater the possibility of self-contradictory claims and non-reflective teaching.

Ultimately the quality of life students will enjoy as adults on both the personal and social levels is affected as they attempt to transfer the scientific beliefs gained within the classroom to address various concerns. The less coherent these beliefs the more difficult the task of transferability and the less able students will be to fully engage in discussions and thus influence scientific policy decisions. The latter is an essential function of responsible citizenship in a democratic society.

There is therefore a need to investigate the implicit and explicit philosophy of science held by secondary school science teachers. From this investigation recommendations can then be made to address any concerns though teacher education.

Research Questions

1. What are the opinions held by science teachers in secondary schools in Port-of-Spain and environs as to the aim(s) of science?
2. What are their views on the nature of scientific progress?
3. What are the opinions of these teachers on the areas of scientific methodology; observation, experiment, concepts, theories, laws, explanation and prediction?
4. How do these opinions affect their approach to teaching?
5. What is the level of consistency among the beliefs held by these teachers?
6. What significance does the overall coherence of teachers' views of science have for the effectiveness of a school science program?

The Philosophical Basis of the Instruments of Investigation of the Present Study

The philosophy of science is concerned with scientific concepts and beliefs and the ways in which these are justified. To be effective practitioners, teachers must be able to justify their beliefs about the aim(s) of science, scientific change and scientific methodology. Justification of these beliefs provides the teacher with the means to address epistemological concerns about the nature of science and therefore assists in the determination of lesson content and instructional approaches. For this reason, the philosophical literature guided the construction of the questionnaire and the formulation of the interviews which were the instruments of investigation of the present study. In the following discussion the questionnaire response numbers are given in brackets next to the relevant literature.

The Aims of Science and Scientific Change

Not only do opinions differ on the aims of science and scientific change but, as Papineau (1996b), notes a number of related terms, such as positivist, pragmatist and instrumentalist vary in meaning according to the philosopher using them. Newton-Smith (1981) refers to realists, instrumentalists and relativists whereas Laudan (1990) identifies the realist, pragmatist, relativist and positivist. All these categorizations are related to the correspondence theory of truth. Using the same platform it is possible to categorize crudely, scientific aims and progress as being from either realist, pragmatist or relativist frameworks.

It is unlikely that any teacher will adhere strictly to one of these three perspectives hence, no attempt is being made to categorize teachers. While a teacher may subscribe largely to one she may use the other perspectives to encompass certain beliefs. Further, the perspectives are not mutually exclusive as some beliefs qualify for two perspectives.

Realism.

Scientific realists believe the aim of science is to provide greater understanding of the world. The world is seen as being independent of human conceptions and perceptions. The objective is therefore to discover this world and produce true theories.

For the realist science seeks not only to enable prediction but also explanation. Scientific theories are seen as being cumulative because they place us in a better position to make predictions than in the past (Popper, 1974; Newton-Smith, 1981). Popper (Papineau,1996a), who is particularly concerned with the demarcation of science, notes that if a theory is experimentally falsified then science will seek some alternative otherwise, the theory is upheld as undefeated conjecture.

Scientific change/progress is marked by rationalism which is based on choosing the most explanatory, simple, and unifying among competing theories (Papineau, 1996b).

Pragmatism.

The pragmatists are concerned with the usefulness of scientific theories in solving problems through their predictive power. Truth has no explanatory use and beliefs being made true is a misleading idea (Rorty, 1991).

Scientific change is considered progress towards the realization of certain ends. According to Laudan (Loving, 1992) this occurs when successive theories display increasing problem–solving effectiveness.

Relativism.

The relativists view science as being socially constructed; scientific truth and progress are relative to particular groups, cultures and periods. Within this perspective beliefs vary depending on their purposes (Barnes and Bloor, 1982).

Kuhn (1970), who denied he was a relativist, sees scientific change as involving paradigm shifts due to reduction in theory fertility, each shift being the culmination of a revolution. During the revolutionary period social and cultural factors play a large part in determining theory choice; there is no place for universal rationality. Further, he suggests that successive stages of science may address different problems therefore the paradigm of a new normal science may be incommensurable with that of the preceding paradigm (Hacking, 1981).

Scientific Methodology
Scientific methodology is concerned with the justification of scientific beliefs. In the 17th and 18th centuries scientific methodology was expected to provide a mechanical book of rules for solving problems however now it refers to rules for appraisal of theories (Lakatos,1981). There is no agreement as to exactly what these rules are since there is no agreement on the aims of science and therefore the decision to accept or reject them is a matter of convention among scientists (Laudan, 1990; Lakatos, 1981).

The areas of scientific methodology which impact on the classroom are discussed below. Concepts, laws and theories form the pedagogical basis of science while explanation and prediction are still considered major scientific goals.

The three frameworks used before are less appropriate for a discussion on scientific methodology since few if any of these methodological positions can be confined to a single perspective.

Observation and experiment.
Empiricist methodologies are based on the premise that observational sentences provide bona fide tests of theories (Papineau, 1996b). Within this view observation and experiment can be used inductively or deductively to test theories. In the orthodox position of inductive empiricism, scientific methodology is seen as consisting of an hierarchy of levels with statements that record instrument readings at the base followed by values and concepts, laws then theories (Losee, 1993). Experiments are used to provide confirmation or refutation of a theory.

Deductive empiricism arose from the effort to address the problem of induction, as first formally proposed by Hume (1711-1776). Popper (Papineau, 1996a) denies that scientists start with observations then infer a general theory. Rather they first put forward a theory as initially uncorroborated conjecture and then compare its prediction with observations (11c, 16c, 16d, 17c).

The empiricist view of observation is that it was theory-independent and observational sentences provided genuine tests of theories, making the theoretical level wholly dependent on the observational level (Losee, 1993). The ideal is a disinterested objective observer who is free of the limitations of assumptions (Loving, 1995). However, as Kitcher (1993) acknowledges, observation is dependent on the cognitive state of the observer. Thus, observation is not theory neutral because theory choice influences which observations are taken and their interpretation (Brickhouse, 1990).

This is reinforced by the Duhem-Quine thesis which supports observation reports having no status apart from the theoretical setting in which they occur, consequently no experiment can test only one theory and more than one theory can account for the experimental data (Losee, 1993). Hodson (1992) suggests that experiments are contrived, each with its own theoretical setting, and limited by the theoretical assumptions which govern the design of instruments used.

The status of unobservables such as radio waves and electrons remains controversial. The traditional view is that observable facts provide good indirect evidence of these unobservable entities (Papineau, 1996a). While the conflicting view is that due to lack of sensory awareness of these entities then related arguments/theories are just useful for solving problems and are not based on truth.

Concepts, laws and theories.

Concepts, laws and theories are linked in science, with concepts being constituents of laws and laws being incorporated into theories.

Scientists use scientific concepts to refer to nature and that which can be specified (Kitcher, 1993). These concepts are formulated in, and therefore limited by, language. Kuhn (1970) and Feyerabend (Losee, 1983) note that different communities of scientists working in the same field may organise the aspects of nature that concern them in different ways resulting in concepts which are relative to a particular theory and time. However Kitcher (1993) proposes that across communities we were able to recognise concepts using their reference potential.

For Bird (1998) laws are facts as opposed to theories which are human creations. He makes a distinction between law and regularity by noting that the former explains its instances but the latter cannot. Herschel (1738-1822) notes that laws apply only within certain boundaries of conditions (Losee, 1993).

The empiricist view of a theory is that it is a collection of sentences, which explain experimental laws by using deductive arguments (Losee, 1993). From this, empiricist philosophers subscribe to the idea of reduction (Losee, 1993). However, this position is suspect because of the thesis of underdetermination (Laudan, 1990).

Kitcher (1993) proposes a dynamic model of human knowledge which allows for the reformulation of many of the insights of the theories of confirmation and introduces the notion of an individual practice to capture the complexities of scientists' activities.

Explanation and prediction.

In science the best explanation involves a series of laws and the ideal is for ongoing improvement (Redhead 1998). Van Frassen submits that a good explanation should provide an understanding of what is being explained and that it should be causative (Gasper, 1998).

Hempel's covering-law model of explanation, attempts to provide a template for causative explanations. This model addresses the reasons we value explanations by suggesting that a satisfactory explanation often has the same logical structure as a prediction, on the basis of a theory (Gasper, 1998).

Probabilistic explanations, according to a version of Hemple's model, are based on long-term repetition of a phenomenon. They may facilitate prediction but do not provide a good explanation and some events can be explained but not predicted (Redhead,1998).

Alternatives to the covering-law model have been suggested though none as fully developed. Van Fraassen suggests that explanations involve descriptions of preceding events and the choice of events is determined pragmatically (Gasper, 1998). Smith (1998) proposes that biologists accept causal and functional explanations. The latter, based on evolutionary theory and using teleological language for brevity, to be valid must contribute to the survival and reproduction of an entity. While Redhead (1998) posits that physicists are no longer interested in causal explanations but in those of functional dependence among physical magnitudes.

Significance for teachers

The teacher

Science educators with inadequate exposure to history and philosophy of science could be the source of much of the misinformation about the nature of science (Loving, 1995). Therefore, awareness of the different perspectives on scientific aims and change, and issues in scientific methodology will enable teachers to clarify their position on the aim and purpose of science education. This will enhance students' awareness of the controversy and conflicts inherent in science and how scientists really work (Matthews 1992; Silverman, 1992).

Matthews (1997) notes that by teachers being aware of the various points of view on the philosophy of science and by translating these intelligently into classroom practice some level of educational progress will be achieved. He sees this as being distinct from indoctrination as the students will have a concern for reasons and justification of beliefs which depend on free and informed inquiry and support intellectual autonomy.

The curriculum

Previously science curricula emphasised that students learned science by doing. However, this is ineffective and students also need to be taught science explicitly (Abd-El-Khalick, Bell and Lederman, 1998). Constructivism, the source of discovery learning, is a teaching method which has extensive support among science teachers, where students are encouraged to develop their own concepts through interaction with various physical resources. As Suchting (1992) and Matthews (1997) note, constructivism is a traditional form of empiricism because of the correspondence between sense data and scientific constructs. This approach to the teaching of science is inadequate because it has failed to explain how sense data can assist a student to discover concepts about unobservables or how concepts can be independent of language.

Matthews (1992) calls for history and philosophy of science themes to be incorporated into scientific subject matter and teaching of the curriculum. The argument is for a contextualised approach where science is taught in its philosophical, social, historical, ethical and technological contexts.

Method

The target population was teachers who taught science in government and government-assisted secondary schools in the Port of Spain and environs education district, Trinidad. Questionnaires were administered to the population and from this a stratified sample of ten teachers was taken. Interviews were then administered to this latter sample.

Target Population

Port of Spain and environs is the largest education district in Trinidad and Tobago in terms of number of schools. In the academic year 1999-2000 there were 14 government and nine government-assisted secondary schools.

The teachers had been assessed by the employer to teach one or more of the sciences. Within the group were those who had been assessed as mathematics teachers but who also taught physics. The target population consisted of 134 science teachers of whom 74 responded to the questionnaire. All who responded were science graduates and 41 percent of these had the Diploma in Education.

Stratified Sample

Using biographical data requested in the questionnaire the teachers in this sample were chosen according to gender, age group, subject taught, professional qualifications and years of teaching experience, in an attempt to provide balance and variety (Stake, 1994). Each of the ten teachers chosen was interviewed twice.

The Questionnaire

Previous efforts by Pomeroy (1993) and Alters (1997) to categorise educators resulted in the loss of responses which may have been relevant to teachers' opinions. Further, both authors utilised a Likert-type scale but these scales did not promote integrity in the aggregation of scores across items.

Bearing in mind the aforementioned the questionnaire for this study had the following features: (a) For issues within a topic the various opinions noted in the literature were given, and (b) teachers were given the option of agreeing, disagreeing or being uncertain for each response.

After the questionnaire was piloted minor changes were made to the design and content. The final questionnaires were administered in the first term (September to December) of the academic year in an effort to avoid the difficulties which traditional school activities could pose for distribution and collection.

The responses were evaluated using small sampling theory . Therefore, the Chi-square and Student's t statistical tests were used in addition to analysis of variance, arithmetic mean and percentages, to generate some inferences about the sample. In accessing the level of inconsistency among teachers' beliefs, pairs of response choices which cohere were examined and an inconsistency percentage calculated for each pair where the higher the percentage the greater the frequency of inconsistent responses.

The interviews.

The purpose of the interviews was to clarify the responses on the questionnaire and to investigate the beliefs about science which impacted upon each teacher's practice.

The first interview dealt with the aims of teaching science and the topics investigated in the questionnaire as they related to teacher practice.

The second interview was concerned with gaining a greater understanding of how and to what extent the teachers' beliefs affected their behaviour with respect to laboratory work; one of the more obvious scientific practices. This interview presented a contextual dilemma, in relation to a regularly conducted laboratory exercise, in which a student gets unexpected results and therefore voices doubt about the related laws/theory.

For the biology teachers the dilemma used was based on osmosis. The chemistry teachers were interviewed about rates of reaction while the physics teachers were asked about variation of the amplitude of the pendulum. For the integrated science teachers the exercise was based on the germination of seeds under varying conditions. These laboratory exercises were regularly done therefore it was expected that the teachers would have been comfortable discussing them and would have determined the purpose of the various concepts, laws and theories which impacted on them, as opposed to a less familiar exercise.

The data from the interviews were analysed using codes in an attempt to elicit themes, and the interpretation was based on these themes.

Analysis of the Results

The Questionnaire

Aims of Science

Of teachers in the sample 70% give their strongest support to a realist construal of the aims of science. Science is seen as aiming to investigate the world and providing truthful predictions of changes in our world. The pragmatist position is bolstered by the aims of science being equated with the aims of technology by many and support for science as a problem-solving activity. At all stages there is a denial of the influence of individual choice or group action.

While 70% feel that their views should guide their teaching the average level of uncertainty for the aims of science is 40 percent, so there remains doubt as to what are the views which will be used to guide teaching. The uncertainty, which plagues many, is manifested in the inconsistency percentages which range from 48 to 83.

Scientific Progress and Change
As with the aims the strongest support is given to a realist stance. The majority, 70%, believe science has progressed by the accumulation of theories in a rational manner.

Though this conservative version of scientific change is upheld there is some contradiction as teachers generally believe that science has social value and its claims are subject to correction. These doubts are reflected in a 40% level of uncertainty and all the inconsistency percentages being above 50.

The endorsement of a relativist position is more noticeable where biographical factors significantly influence response choice. Chemistry, integrated science and physics teachers strongly support the influence of social and historical factors on what constitutes scientific truth.

Scientific Methodology
The majority of teachers, 85%, support the view that scientific methodology consists of rules to guide scientific inquiry so that scientific aims can be met. Only 16% support the application of scientific methodology to the demarcation of science, currently an influential factor in the appraisal of theories.

Observation
The empiricist version of observation as being the basis of theory development is predominant in the sample at 73%. 58% of the teachers feel it is possible to have a successful observation without prior assumptions, and about half are uncertain of observation being dependent on prior knowledge

The majority, 78%, believe that instruments can be used to improve observation but many are unaware that once instruments are employed assumptions have been made as only about a quarter agree that these observations are dependent on the theories used in constructing these instruments.

Although the uncertainty is only 27% the levels of inconsistency remain above 50%.

Again subject taught is a significant influence with all the teachers except those who teach biology, agreeing strongly that in laboratory classes students should be left to make their own discoveries.

Experiment
The empiricist viewpoint is again prominent among teachers. Experiments are seen by 90% of the teachers as the basis of scientific knowledge and are believed to provide us with information about the world. The Duhem-Quine thesis is rejected and Popperian falsification receives little support.

The level of uncertainty is almost the same as for observation and generally there are lower levels of inconsistency among response pairs. The lower levels involve agreement with experiment being the basis of scientific knowledge and the use of experiments to construct a theory; the empiricist position.

The significant influence of subject taught on response choice shows the use of experiments to construct theories is strongly supported by chemistry, integrated science and physics teachers with biology teachers being largely uncertain although none of them disagree.

The constructivist stance receives tremendous support with the majority opinion, 73 percent, that students should be left to make their own observations and the use of experiments in the teaching of science to help students make discoveries.

Formation of scientific concepts

The opinion that concepts are constructed ideas which become more clearly defined with further research receives 65% support. Even though this position means that concepts are defined within the context of language and therefore subject to social influence there is little support, less than 10%, for the impact of groups of scientists on the modification of concepts.

Uncertainty is at its highest at 49% and the response inconsistency remains high, over 95%.

While all subject teachers agree that scientific theories use any concepts which facilitate successful predictions, physics teachers have an almost 80% agreement while the others are below 50%.

Laws and theories.

The level of inconsistency is generally greater than 60%. However the pairs are for the most part confined to opinions on the truth of scientific laws. The average uncertainty remains high at 45%.

58% of the teachers believe that laws are subsumed under theories while 65% support laws being true under certain conditions. This latter position is significantly influenced by professional qualifications, with 70% of the professional sub-group agreeing while the non-professionals are less in agreement and more uncertain. Teachers with professional qualification are also more aware of the evaluation of theories by consensus among scientists, which is generally the current practice. Over 50% of the professional sub-group agree with this as opposed to about a third of the non-professionals.

Half the physics teachers disagree with a law being a universal truth while the remaining teachers are uncertain.

Explanation and prediction.
Teleological explanations receive just 28% support from biology teachers. Explanations of functional dependence receive a similar level of support from physics teachers. Interestingly, physics teachers show a greater level of support for teleological explanations than do biology teachers. While there is little support for the covering-law model the version related to probabilistic explanations is endorsed by over half of the sample. The constructivist influence is still present though weakly, at 45%, as there is more support for students devising their own methods of explanation than being taught the current methods. While prediction being dependent on explanation and not necessarily increasing human control of nature receives 59% support.

The level of uncertainty for this sub-topic is as high as that for the formation of scientific concepts at 49% while the inconsistency is generally above 55%.

Relevance of the Questionnaire
The teachers see the issues being raised in the questionnaire as being relevant to science teachers and philosophers. The subject taught is the only biographical factor which significantly impacts on the overall uncertainty for the questionnaire with the biology teachers exhibiting greatest uncertainty.

The Interviews
The Teachers
All the teachers are passionate about science and consider it worthwhile. Shoba explains, "Somebody without a science background has been denied some part of their life."

The biology teachers.
John teaches at a highly regarded all-girls government-assisted school while Maria is at a less well regarded coeducational government school. Maria, who completed her professional qualifications in 1977, did not find the Diploma in Education (Dip. Ed.) useful in helping her to address the issues raised by the questionnaire.

The chemistry teachers.
Peetam teaches at a coeducational government secondary school which is severely over-crowded and dilapidated. Karen's situation is quite different, her all-girls school is considered one of the prestigious government-assisted schools. Karen gained her first professional qualification in 1991 while Peetam gained his in 1988, both deemed the Dip. Ed. useful in assisting them with responding to the questionnaire.

The integrated science teachers.
Nisha, Ralph and Michael all teach at government coeducational schools.

Ralph, who gained his Dip. Ed. in 1996, and Michael, who gained his in 1993, found it did not address the issues raised by the questionnaire.

The physics teachers.
Shoba, Anne and Azard are at government coeducational schools. Anne is a mathematics teacher who also teaches physics. Shoba and Anne who completed their professional qualifications in 1992 and 1988 respectively think the Dip. Ed. proved useful in responding to the questionnaire, even though Anne's is in the teaching of mathematics.

The Themes
Theme one: The aims of teaching science rarely resemble the aims of science.
The strongest support is for utilitarian aims of teaching science such as, in order of emphasis, passing examinations, choosing careers, learning scientific skills and understanding technology.

While the teachers' responses from the questionnaire showed a realist bias this does not influence their reasons for teaching science. For example in the questionnaire, all the teachers agreed that the aim of science was to give truthful descriptions of the universe. However, only Karen and Peetam support Anne's view that teaching of science, "… helps to explain what happens around us".

Theme two: Concept, law or theory?
Two out of three of concepts, laws and theories are taught by all teachers.. They are uncertain however as to what these are and all fail to recognize the full range of concepts and laws which pertain to their respective dilemma, although the physics teachers are less unsuccessful at this. Knowledge of concepts is seen as influencing the success of an explanation in an experiment.

Unobservables are presented as true by all the teachers and are represented as such to the students. According to John, " There is nothing in the experiment that is inaccessible to observation."

The biology and chemistry teachers feel their subjects have only a few laws/theories while all teachers believe that laws/theories offer true descriptions of nature. Explanations are considered to be causal and dependent on laws or observations.

Theme three: Karen, "Lab activity is almost like a recipe you are following, you are not really experimenting, its like prescribed."
The teachers stress the use of experiments to develop observation skills and ensure retention or enhance learning of topics covered by the syllabus. This supports their utilitarian aims for teaching science.

For the dilemmas the teachers believe the students must have prior preparation and the necessary observation skills. The explanation is expected to support the theory and account for the observations. Peetam and Michael think the prediction rests on the explanation but Karen believes that a prediction is not required for laboratory exercises.

The teachers judge the students in the dilemmas to be wrong and that there is no basis for them rejecting the law or theory because as Michael explains, "We do it to reinforce the law, to prove the law is correct, so that's why we tend to make it work." They agree that the experiment demonstrates what occurs in nature.

Discussion

The teachers endorse a questionable version of realistic aims of science and scientific progress. This account of realism is in keeping with Kitcher's (1993) "legend" as evidenced by the willingness to accept the truth of unobservables currently incorporated into scientific theories and the uncertainty or opposition to the influence of social factors. Many teachers, who are not biology teachers, support a more enlightened view of realistic scientific progress which recognises the influence of social factors. However, these positions are not consistent and often contradictory. The effect of this confusion is noted in the interviews where the teachers are unable to transfer the aims of science into the aims of teaching science.

The teachers' beliefs about scientific methodology are marked by support for empiricism. The trend is away for the current acceptance of the concept-ladenness of observation and toward the Baconian ideal of an independent observer, free of preconceptions. However, the teachers contradict themselves in that they agree with teaching observations skills, which is inconsistent with their version of empiricism, and teaching concepts which conflicts with their support for discovery learning.

The so-called experimentation done in schools has no connection to how scientists perform experiments, as recognized by John and Karen, yet it is presented to students as authentic science. Therefore students are unaware of how the related concepts are often redefined by further research and how they are limited by the evidence presented in support of them. This is reinforced by the agreement among the interviewed teachers that the student in the contextual dilemma has erred, suggesting that theories and laws are sacrosanct and what is done in the classroom is really to practice ways to support these.

There is confusion as to what constitutes concept, law and theory and their influence on explanation and prediction. By assuming all explanations are causal the teachers present science as unchanging as the assumption is that all claims can be supported by present observational evidence.

Thus, consistency among the more theoretical beliefs is inadequate suggesting lack of information and the necessary personal reflection. The result of this scenario is that a school's science programme becomes more centered on certification and its attendant concerns such as the focus on observation skills and experimentation for reinforcement.

The preparation for the examination is a place where teachers, parents and students can unite because of their common concern; passing the examination. There is then, for the teacher, a feeling of being supported in her efforts. It is a place for galvanising action, such as getting parents to lobby politicians for improved laboratory resources. Whereas a more authentic view of science represents a lonely place, where one has to determine a personal philosophy of science and methods of translating that into the aims of teaching science and scientific methodology appropriate for the classroom. For this there is no manual or even a syllabus.

The main problem is that our students are being given a version of science that limits their ability to make informed decisions and effect change in the society. This approach has not worked for our current crop of adults who are often overwhelmed by science based information and willingly accept what doctors, engineers and other science-trained professionals say without the confidence to question their aims, political influence and methodology.

If the findings of the stratified sample are any indication, teachers are unhappy with examinations being the focal point of school science. They would prefer to spend more time exposing students to science in our everyday lives and engendering an appreciation of the environment.

The above is not the only sign of hope for change. The levels of uncertainty mean that many teachers are not wedded to the discredited versions of scientific aims, progress and methodology. Therefore, less effort is needed to convince them to consider new ideas.

Concluding Remarks

Philosophy of Science and the Teaching of Science

If schools are expected to enable responsible citizenship in a democratic society then the forms of knowledge, which for a variety of reasons have been deemed essential, must be presented honestly. While scientists may not be overly concerned with philosophy of science, teachers who seek to expose students to scientific knowledge must be aware of the means by which it is built, sustained and, no matter the controversies, molded into a coherent whole.

Where the teacher's philosophy of science rests on utilitarian beliefs, the student ceases to view science as being relevant to his life beyond the confines of passing an examination. As was noted in this study these beliefs may be consistent but the student gains little understanding of the processes by which science operates and does not gain an appreciation of the relevance of science.

Where the students' knowledge of science is confined to a bag of tricks for passing examinations, students' confidence in addressing new scientific issues is severely limited. Scientific change is inevitable as are societal concerns which occupy scientists. The focus on evolutionary psychology, neuro-science and human genome research, to name a few, would not have been considered for classroom discussion up to maybe three years ago. For students to adjust to change in research focus and methodology they require a more all-embracing view of science.

Some Responses

Transformation of the teaching of science is essential. The change is needed on various levels, the science syllabi, undergraduate teaching for science and professional development.

The science syllabi currently make some effort to address these concerns. The C.X.C. attempts to encourage discussion of how scientists work through the planning and design component of the school-based assessment and, in physics, exposure to theories which are currently viewed as invalid. The revision of syllabi to incorporate the philosophy of science should persuade teachers to investigate their own implicit beliefs and develop them into a consistent whole bearing in mind comparison to other frameworks.

For teachers to support a more honest approach to the teaching of science, revision of undergraduate teaching and professional development programs for teachers is required. The teachers in the sample were, in the main, graduates of The University of the West Indies. Yet, even the younger teachers were unaware of the issues raised and were generally as uncertain as their older colleagues. This suggests that our university is not providing its science graduates with an authentic view of science.

If a revision of undergraduate teaching cannot assist teachers in developing a philosophy of science congruent with the teaching of science surely teacher professional development should. All the teachers with professional qualifications have the Dip. Ed., yet they are generally just as uncertain and confused as the remainder of the sample. This suggests that some of the issues may have been raised but were not dealt with in a comprehensive manner and probably not assessed during teaching practice.

Teachers require not only knowledge of science in its historical and present context so they can develop a consistent body of beliefs about science and appreciate the inherent conflicts, but also skills for linking their philosophy of science to their teaching of science.

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