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ABSTRACT

Science educators agree that learning science involves learning about the body of scientific knowledge, about how that knowledge is generated, and about how it is socially constructed. However, the emphasis in many science curricula has been on learning about the body of knowledge to the neglect of the epistemology and sociology of science. The purpose of this study was to assess the beliefs of university science professors and students and high school science teachers and students about the sociology and epistemology of science. Subjects for this study were 24 university professors, 124 high school teachers, 118 university students, and 572 high school students from universities and schools in Lebanon. Participants in the study filled out a questionnaire composed of 15 items selected from three components (science and technology, social construction of scientific knowledge, and nature of scientific knowledge) of the Views of Science-Technology-Society (VOSTS) instrument. Results suggest that most Lebanese university professors, high school teachers, university students, and high school students subscribe to a traditional view of science. The findings of this study, together with previous findings with Lebanese middle school students provide support to the notion of a culture of academic science that permeates the educational system in Lebanon. Contains 20 references and 5 figures of data. (Author/JRH)

Running head: EPISTEMOLOGY AND SOCIOLOGY OF SCIENCE

Epistemology and Sociology of Science According to Lebanese Educators and Students

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Paper presented at Annual Meeting of the National Association for Research in Science Teaching, St. Louis, Missouri, March 31 - April 3, 1996.

Abstract

The purpose of this study was to assess the beliefs of science university professors and students and high school teachers and students about the sociology and epistemology of science. Subjects for this study were 24 science university professors, 124 science teachers, 118 science university students, and 572 high school students from universities and schools in Lebanon. Participants in the study filled out a questionnaire composed of 15 items selected from three components (science and technology, social construction of scientific knowledge, and nature of scientific knowledge) of the Views of Science - Technology - Society (VOSTS). Results suggested that most Lebanese university professors, high school teachers, university students, and high school students subscribe to a traditional view of science. The findings of this study, together with previous findings with Lebanese middle school students, provide support to the notion of a culture of academic science that permeates the educational system in Lebanon.

Epistemology and Sociology of Science According to Lebanese Educators and Students

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Introduction

Science educators agree that learning science involves learning about the body of scientific knowledge, about how scientific knowledge is generated -- that is the epistemology of science, and about how scientific knowledge is socially constructed (Millar, 1995). The emphasis in many science curricula worldwide, however, has been on learning about the body of knowledge to the neglect of the epistemology and sociology of science. Science educators agree that learning science involves learning about the body of scientific knowledge, about how scientific knowledge is generated, that is the epistemology of science, and about how scientific knowledge is socially constructed (Millar, 1995). The emphasis in the science curricula worldwide, however, has been on learning about the body of knowledge to the neglect of the methods and sociology of science. Moreover, when discussing the methods of the generation of knowledge, the Baconian, idealistic views of science and the scientific method have been accentuated.

Students' and teachers' perceptions of the traditional and modern views of the nature of science recently received considerable attention in the science education literature (i.e., Cleminson, 1990; Duschl, 1990; Pomeroy, 1993; Ryan & Aikenhead, 1992; Loving, 1995). Specifically, this literature has discussed

students' and teachers' beliefs about the scientific enterprise - its epistemological and social character - (e.g., Pomeroy, 1993; Ryan & Aikenhead, 1992) and the influence of society and culture on science (e.g., Duschl, 1990).

Science educators have asserted that understanding the epistemology and the social context of science is essential for a scientifically literate individual. These educators underscored the importance of this understanding for teachers who use a Science/ Technology/ Society approach or the history of science in science teaching (American Association for the Advancement of Science, 1989; Lederman, 1992). Likewise, Carey and Smith (1993) suggest that understanding the nature of science provides students with interests, beliefs, and attitudes necessary for science-related informed decision making and helps learners to benefit from curricula designed to foster conceptual change.

Research has shown that students and teachers at all levels possess traditional views of the nature of science (BouJaoude & Abd El Khalick, 1995; Lederman, 1992; Pomeroy, 1993; Ryan & Aikenhead, 1992). Pomeroy (1993), has also shown that even scientists have this traditional view. This research suggests that students believe that scientific knowledge cannot be questioned and that science's primary aim is to uncover natural truths. Lederman (1992) suggests that science teachers think that science is not tentative. Pomeroy (1993) claims that some scientists and science university professors have a traditional Baconian view of the nature of science that is communicated through teaching and evaluation practices to science teachers who, in their turn, transfer it to their students.

Traditional instruments used to assess beliefs about the nature of science have been criticized because they have been used with the erroneous assumption that research participants interpret statements used in these instruments the same way (Lederman & Omalley, 1990). Aikenhead, Ryan, & Fleming (1989) developed the Views on Science and Technology and Society (VOSTS) instrument to address the problems inherent in traditional instruments. The VOSTS items were derived empirically from students' viewpoints about science, technology, and society.

Using VOSTS, Ryan and Aikenhead (1992) showed that Canadian high school students were "divided between the content and process perspectives of science. They all but ignored the social aspects of science" (p. 562). These students confused science with technology and believed that science was an instrument of social change. Moreover, they manifested creationist beliefs and exhibited ontological rather than epistemological views about scientific knowledge. Almost on fifth of the students believed that scientific models were copies of reality and a majority held the simplistic belief that hypotheses become theories and theories become laws. Finally, Canadian students seemed to ignore the traditional textbook scientific method and subscribed to the vague notion that "the scientific method was "questioning, collecting data, and concluding"(p. 573) and believed that scientific knowledge was tentative.

Except for one study investigating middle school students' views of the nature of science conducted by BouJaoude & Abd El Khalick (1995), beliefs of Lebanese educators and students about the nature of science, and more specifically about the sociology

and epistemology of science have not been examined. Consequently, the purpose of this study is to assess the beliefs of science university professors and students and high school teachers and students about the sociology and epistemology of science.

Preexisting beliefs and perceptions influence individuals' relationship to knowledge (Brown, Collins, & Duguid, 1989; Schilk, Arewa, Thomson, & White, 1995). These beliefs and perceptions may not be changed as new information is encountered, especially if this information conflicts with well ingrained beliefs (Von Glaserfeld, 1984). Consequently, educators' and students' beliefs about the sociology and epistemology of science are essential information for curriculum developers, if existing beliefs about these topics need to be addressed and if curriculum is to prepare students with the interests, beliefs, and attitudes necessary for science-related informed decision making (Carey & Smith, 1993). This information is especially important in Lebanon that is in the midst of educational reform in science, reform that aspires to prepare students for the 21st century.

Methods and Procedures

Subjects

Subjects for this study were 24 science university professors, 124 science teachers, 118 science university students, and 572 high school students. The University professors and students came from two universities in Lebanon in which English is the medium of instruction. These professors taught biology, chemistry, physics, or geology. The university students came from these same majors and were juniors or seniors with very few sophomores. The high school students came from seven high schools

throughout Lebanon in which English is the medium of science instruction. These students came from Grades 12 & 13, the last two years of high school in Lebanon. The high school teachers came from 16 schools, seven of which provided the high school students who participated in this study. The teachers taught biology, chemistry, physics, or general science.

Instrument

The questionnaire used in this study consisted of 15 items. The items came from three components (science and technology, social construction of scientific knowledge, and nature of scientific knowledge) of the Views on Science - Technology - Society (VOSTS) inventory Form CDN.mc.5 developed by Aikenhead, Ryan, & Fleming in 1989. Because VOSTS form CDN.mc.5 is a pool of items, any selection of items related to viewpoints to be assessed may be used (Aikenhead & Ryan, 1992). Modified versions of VOSTS were used in the United States and other parts of the world with high school science teachers and students and with university students (Aikenhead & Ryan, 1992, Fleming, 1988, Rubba, Schoneweg, & Harkness, 1994, Zoller, Donn, Wild, & Beckett, 1991). VOSTS uses multiple choice items with possible responses derived empirically from students' viewpoints instead of a theoretical viewpoint. These items deal with students' informed viewpoints rather than their feelings regarding certain issues. This strategy was used in the development of VOSTS to diminish the problem of ambiguity that has influenced the results of previous research on students' conceptions of a variety of science related topics (Aikenhead & Ryan, 1992).

Because VOSTS was developed in Canada and because of possible

cultural differences between Lebanese and Canadian research subjects there was a need for some adaption. The items used in this study were read by the investigator and several science education graduate students and words referring to Canada or the USA were changed. Furthermore, the items were pilot-tested with ten university students and ten high school students to assess their understanding of the language and content of the items. Students participating in the piloting and science teachers who read the items informally reported finding the language and content of the items understandable. These students and teachers did not participate in the study.

According to Aikenhead (Personal communication, August 2, 1994) views of the nature of science can be categorized as realistic or naive. Views that converge with the more recent conceptions of the nature of science can be categorized as realistic. These views are in line with conceptions of science advanced by such philosophers of science as Kuhn. Views that converge with those of logical positivists can be categorized as naive. Logical positivist suggest that science endeavors to reveal absolute truths independent of the scientists' personal, social and cultural attributes. Moreover, they suggest that validity in science is only guaranteed by the scientists' use of the inductive scientific method (Ryan & Aikenhead, 1992).

Procedures

The questionnaire was distributed to 60 university professors and 200 high school teachers. The university professors were contacted by phone to encourage them to respond to the questionnaire. Approximately one month after the questionnaires

were distributed, a letter thanking those who responded and encouraging the non-respondents to respond was mailed to all university professors and teachers. The response rate was 40% for university professors and 62% for high school teachers. The high school students came from intact classes in seven schools from which teachers responded to the questionnaire. The questionnaire was administered to the students by the investigator or his assistant during one regular class period. College students came from course sections specifically designed for majors in each of biology, chemistry, geology, or physics. The questionnaires were administered to students by the investigator or his assistant during one lecture session.

Data Analysis

Frequency counts and percentages were computed for each item for each group and graphic representations of group and position profiles were constructed. Moreover, respondents' views were categorized as realistic or naive. As indicated in the instruments section above, views close to the traditional, Baconian views were categorized as naive, while those close to the recent views of science were categorized as realistic.

Results

Definition of Science

Many participants defined science as a study of fields such as biology, chemistry and physics or a body of knowledge. However, two other definitions appeared in significant numbers. These were: science is finding and using knowledge to make the world a better place, and science is exploring the unknown and discovering new things (Item 10111, Figure 1). Approximately 38%

percent of the university professors, 28% of the teachers, 40% percent of the university students, and 34% of the high school students defined science as a study of fields such as biology, chemistry and physics or as a body of knowledge. Moreover, approximately 25% of the professors, 35% of the teachers, 22% of university students, and 23% of high school students believed that science was finding and using knowledge to make the world a better place. Finally, 25% of the professors, 25% of the teachers, 27% of the university students, and 21% of high school students defined science as exploring the unknown and discovering new things.

Nature of Scientific Knowledge

Educators' and students' perceptions of the effect of scientists' theories on observations was assessed by item 90111 (see Figure 2). Fifty four percent of the professors, 66% of the teachers, 67% of university students, and 59% of high school students held the naive belief that scientific observations were not influenced by theories. Most of the respondents thought that observations were not influenced by theories because competent scientists always have similar observations.

On the other hand, 25% of the professors, 28% of the teachers, 22% of the university students, and 33% of the high school students held the realistic belief that theories influenced observations. The respondents who said that theories influenced observations were almost equally divided between those who said that scientists' experimental methods determined what is observed and those who said different thinking approaches produced different observations. It is noteworthy that 21% of the

university professors decided that none of the options represented their basic viewpoint and provided their own alternate understanding of this issue. These understandings, however, were reworded versions of the option that said that competent scientists observed similarly irrespective of their theories.

Three views about scientific models emerged from the data (Item 90211, Figure 3). Approximately 25% of the university professors, 9% of the teachers, 25% of university students, and 24% of high school students held the naive belief that models were copies of reality, while 25% of the professors, 31% of the teachers, 42% of the university students and 31% of the high school students held the realistic belief that they were not. Furthermore, 42% of the professors, 47% of the teachers, 31% of university students, and 32% of high school students thought that models were close to being copies of reality, which can be considered a naive belief. Participants' views on classification (Item 90311), however, were opposite to their views on models. Approximately 75% of the professors, 87% of the teachers, 71% of the university students, and 80% of the high school students held the realistic belief that classification schemes were not copies of reality.

Most respondents thought that scientific knowledge changed, a belief that converges with recent, realistic views of science (Item 90411, Figure 4). This change either happened by disproving theories or discoveries of old scientists by using new methods and materials -- the falsificationist position -- or by reinterpreting old theories. Twenty five percent of the professors, 44% of the teachers, 25% of the university students, 40% of high school

students held a falsificationist position. Moreover, 42% of the professors, 34% of the teachers, 34% of the university students, and 26% of the high school students asserted that scientists reinterpreted old theories in light of new discoveries. Nevertheless, Several participants held on to the naive position that scientific knowledge appeared to change. This position was held by 25% of the professors, 19% of the teachers, 39% of the university students, and 25% of the high school students.

Most respondents believed in a naive hierarchical relationship among hypotheses, theories, and laws. This belief suggests that scientific ideas develop from hypothesis to theories to laws (Item 90511). Believers in this views neglect the qualitative differences between theories, which explain, and laws, which describe. Three quarters of the professors, 88% of the teachers, 75% of the university students, and 53% of the high school students held this belief. The relatively low percentage of high school students who held this belief resulted from almost 38% of these students thinking that they did not know enough about the subject to make a choice.

Responses to items 90611 and 90621 show that while participants ignored the textbook definition of the scientific method, they believed that there was a definite pattern in doing science (Figure 5). Responses to item 90611 show that approximately 67% of the professors, 55% of the teachers, 39% of the university students, and 45% of the high school students defined the scientific method as questioning, hypothesizing, collecting data, and concluding. Moreover, 17% of the professors and 15% of university students defined the scientific method as

postulating a theory and conducting experiments to prove it and 17% of professors, 16% of the teachers, 12% of the university students and 13% of high school students thought that the scientific method involved testing and retesting to prove something true in a valid way. Responses to item 90621 show that 79% of the professors, 92% of the teachers, 60% of the university students and 57% of the high school students believed that scientists follow the scientific method with the possibility of using creativity and originality. It is noteworthy that approximately 21% of the university students suggested that scientists selected the best method to get favorable results and 25% of the high school students believed that many scientific discoveries were accidental.

Approximately 50% of the respondents held the naive belief that scientific laws are discovered while 34% of the professors, 39% of the teachers, 36% of the university students, and 36% of the high school students held the realistic belief that scientists invent laws. Those who believed that scientific laws were discovered were almost equally divided between those who said that laws were in nature and have to be found, those who said that laws were discovered because they are based on scientific facts, and the rest who said that scientists invented methods to be used in finding laws (Item 91011).

Participants were split on the role of a supernatural being in the world (Item 90921). Almost 34% of the professors, 45% of the teachers, 32% of the university students, and 43% of high school students acknowledged the possibility of a supernatural being altering the natural world. Conversely, 34% of the

professors, 36% of the teachers, 32% of the university students, and 32% of the high school students believed that a supernatural being did not alter the natural world. A few participants, however, suggested that what scientist thought about a supernatural being was left to the individual scientist.

Social Construction of Scientific Knowledge

Respondents' conceptions of the universality of science were assessed by item 70721 (Figure 6). Approximately 33% of the professors, 35% of the teachers, 20% of the university students, and 42% of the high school students naively believed that scientists worldwide conducted their work similarly because of the universality of science or because they shared ideas regularly. Thirty-three percent of the professors, 11% of the teachers, 37% of the university students, and 23% of the high school students believed that scientists from different countries conducted their investigations differently because of the differences in available technology or educational background. Finally, 33% of the professors, 54% of the teachers, 42% of the university students, and 22% of the high school students suggested that scientists within a team conducted their work similarly irrespective of their country.

When asked about the effect of a country's educational system or culture on scientists' conclusions (Item 70711, Figure 7), approximately 33% of the professors, 51% of the teachers, 58% of the university students, and 45% of high school students said that the educational system of a country made a difference, while 17% of the professors, 19% of the teachers, 17% of the university students, and 28% of the high school students suggested that the

educational systems made a difference for some scientists while it did not for others. Most of those who said that the educational system made a difference, related that difference to the fact that culture influences all aspects of life, including science. Conversely, 50% of the professors, 19% of the teachers, 17% of the university students, and 17% of the high school students said that the educational system did not make a difference because scientists use the same scientific method or personal ways of doing science.

Respondents had similar views concerning the necessity and method of achieving consensus in science (Item 70231). Sixty-six percent of the professors, 71% of the teachers, 64% of the university students and 67% of the high school students were convinced that scientists who propose a theory must convince others about the truth of that theory. Almost one third of the participants asserted that scientists convince others by showing them conclusive evidence about the truth of a theory. Twenty-nine percent of the professors, 26% of the teachers, 18% of the university students, and 27% of the high school students asserted that scientists who propose a theory do not have to convince others because supporting evidence speaks for itself or because scientists continue using a theory despite what other scientists believe.

Discussion and Conclusions

Except for their beliefs that science changes and that classification schemes are not copies of reality, most Lebanese university professors, science teachers, university students, and high school students subscribe to a traditional view of the

epistemology and sociology of science. Some of these beliefs are similar to the ones identified by Ryan and Aikenhead (1992). Most of the study participants define science as a collection of subject areas, believe that theories do not influence observations, that models are either copies of reality or close to being so, that hypotheses become theories then laws, and that laws are discovered rather than invented. Moreover, they believed that there is a definite pattern to doing science that includes questioning, hypothesizing, collecting data, and concluding, a belief close to the traditional definition of the scientific method. Finally, many respondents acknowledged the role of a supernatural being in changing the world.

Most of the participants believed in the universality of methods of science, in the effect of a country's educational system on science, and on the role and methods of consensus in the scientific community. According to them the differences between scientists were not necessarily due to social and cultural conditions but to differences in available technology or idiosyncrasies of teams. Besides, they believed that the educational system of a country affected the way scientists' worked. Finally, they believed that evidence plays an important role in reaching consensus among scientists. This evidence is either provided by scientists who propose a theory or is pursued by interested parties.

Students' and educators' beliefs about the epistemology and sociology of science may be a consequence of their long experience in Lebanese educational system. The Lebanese curriculum and evaluation policies suggest that science is a body of knowledge.

The official science curriculum at the elementary, middle, and high school levels provides teachers with lists of topics to be covered and the official exams test for these topics. Textbook writers use these topics to write textbooks that are devoid of any mention of the epistemology and sociology. There are two places where the scientific method is mentioned: in the science textbook of the Grade 7 and the psychology textbook of the Grade 13 (The Lebanese education system is a K-13 system). In both places students are exposed to the steps of the traditional scientific method, but the do not get experience using this method. Finally, teaching is reflective of the curriculum, evaluation, and the textbooks in that it adopts a transmission philosophy of science teaching with very little emphasis on laboratory and hands-on experiences.

Both of the universities from which the respondents came are American universities chartered in the State of New York. Their programs are very similar to those of American institutions. Science at the undergraduate level in these two institutions is taught in the traditional lecture/laboratory method. An inspection of the syllabi, textbooks, and tests of the physics, chemistry, biology, and geology courses give the impression that science teaching follows the dissemination approach, with emphasis on product rather than process.

The social-cultural environment supports the goals of teaching science implicit in the above description. Parents and school administrators alike overemphasize official examination

results[1] at the middle and high school levels. Moreover, college students and their parents underscore science examination results. Achieving high grades in science at all levels is seen by all concerned as the vehicle for upward mobility and a better life. A final social-cultural influence may come from respondents' religious beliefs. This is evident in the number of respondents who believed that a supernatural being alters the natural world[2].

In conclusion, without explicit curricular goals regarding the epistemology and sociology of science, what is socially and academically valued is taught and tested in schools and universities, to the neglect of other important dimensions of science. This results in students at all educational level possessing a strong science content background but lacking in knowledge about the nature of science, the role it plays in history, and the interrelationships among science, society, and technology. In some cases, these students are unable to use science to make personal and social decisions and are not aware of current events as they relate to science.

The findings of this study, together with BouJaoude's and Abd El Khalick's (1995) findings with Lebanese middle school students,

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[1]Lebanese students sit for two official examinations, one at the end of the middle school cycle (equivalent to Grade 10) and the other at the end of the high school cycle (equivalent to Grade 13). These exams in general cover the topics studied in the year of the exam. Because of the overemphasis on getting good examination results, schools cancel parts of the curriculum of earlier years to teach material required by the exam.

[2]Dagher & BouJaoude (1995) found that Lebanese college biology majors' beliefs about evolution were influenced by their religious beliefs, which may be an indication of the possible influence of religious beliefs on science related ones.

provide support to the notion of a culture of academic science that permeates the educational system in Lebanon. These findings are expected in the Lebanese context, in which there is an undue emphasis on passing traditional, content oriented national examinations and in which science examinations at the university level are used to admit students into professional schools. The findings are, however, important to consider seriously at a time the country is attempting to reform its educational system to align it with recent international trends in science education. The attainment of specific goals related to the epistemology and sociology of science should be a priority of the new science education reform. If the existing beliefs are not addressed directly in all aspects of the new science curriculum, as well as in evaluation policies, textbooks, and teaching methodologies, they are likely to persist with students even after acquiring new scientific information.

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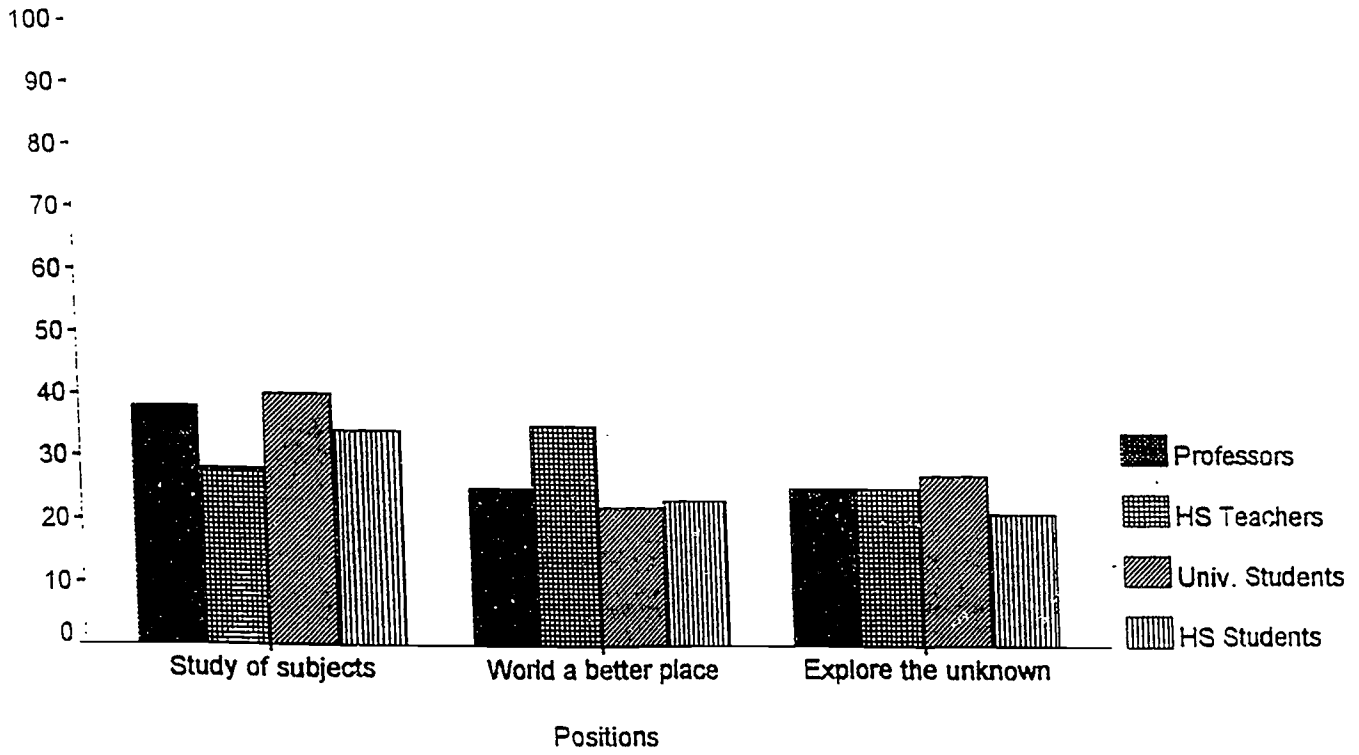
Figure 1. Definitions of science.



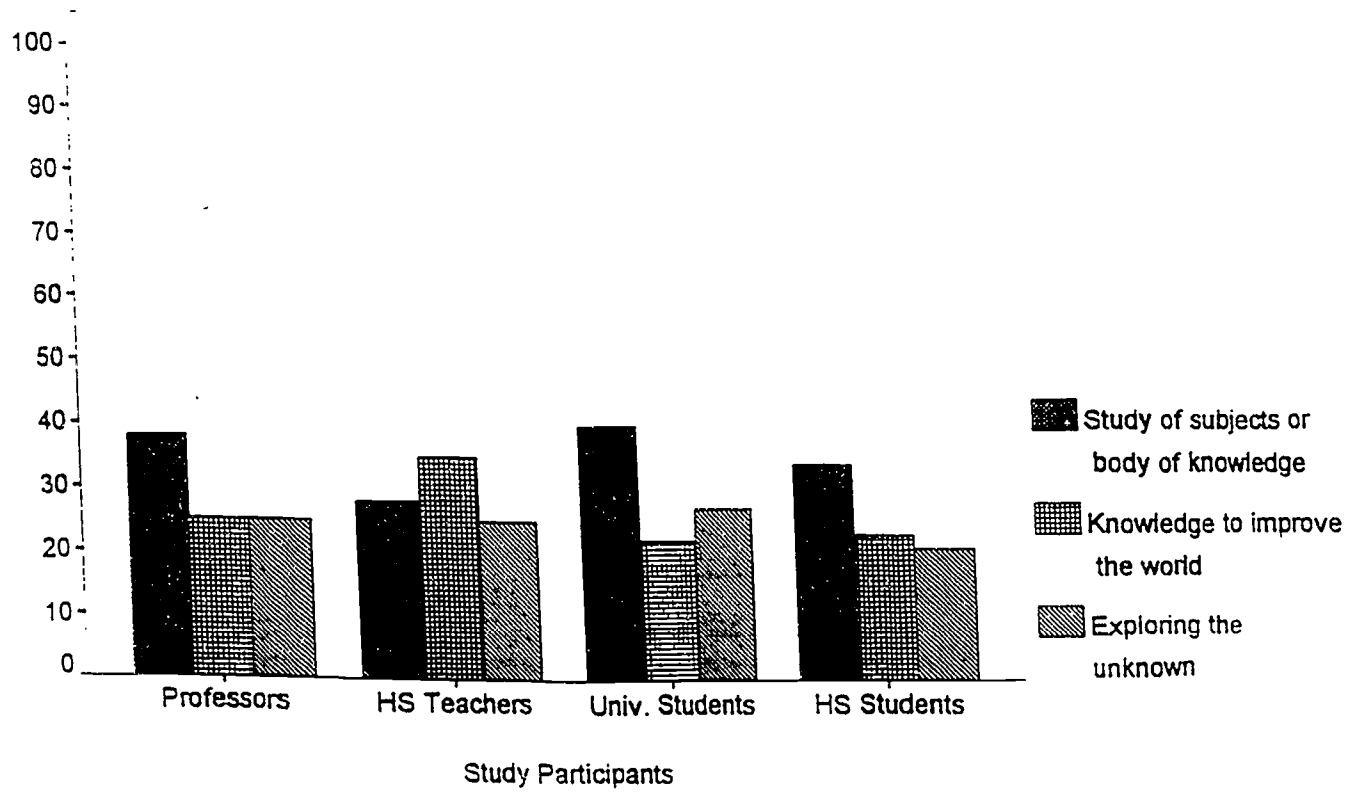


Figure 2. Effect of theories on observations.

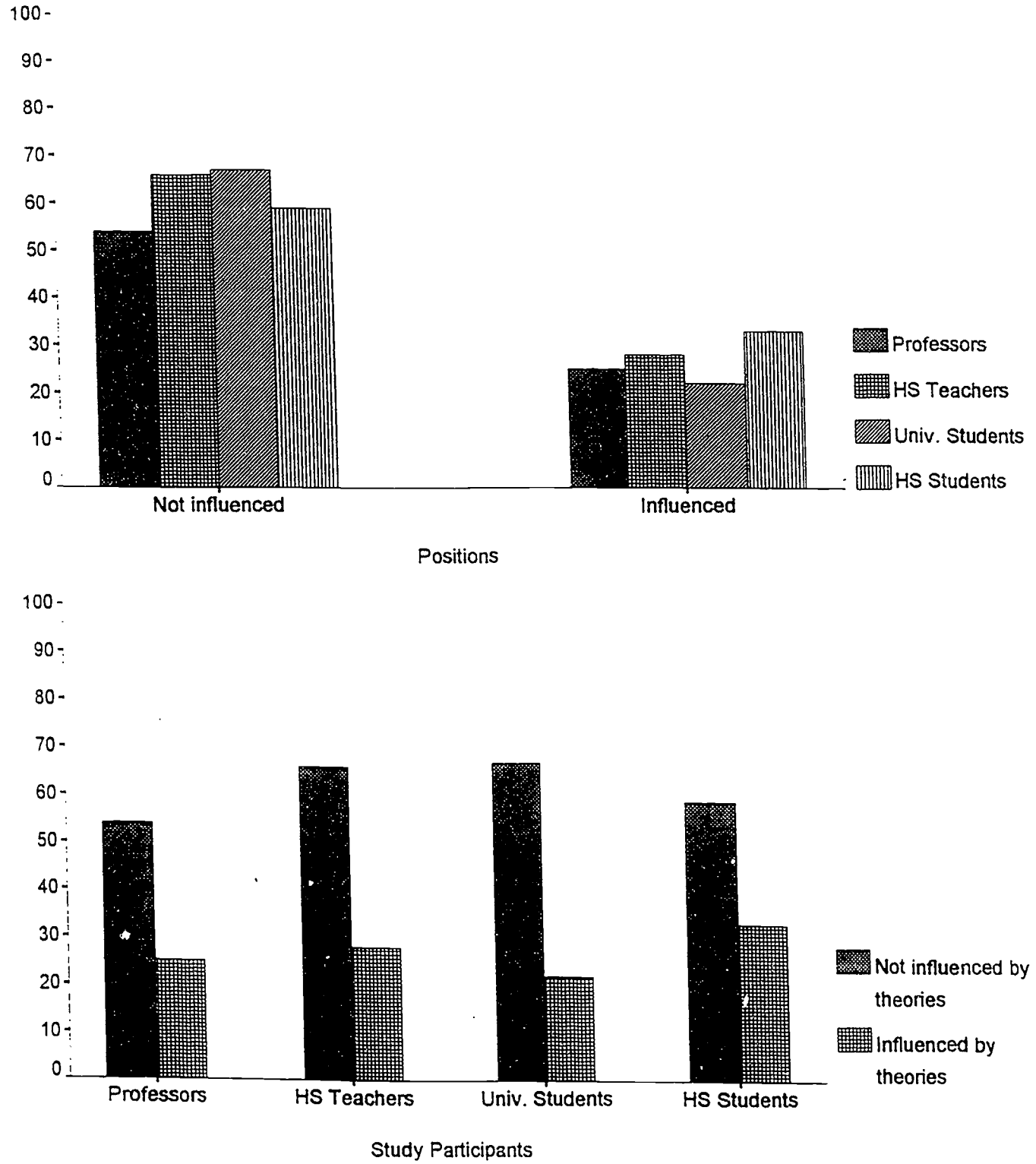
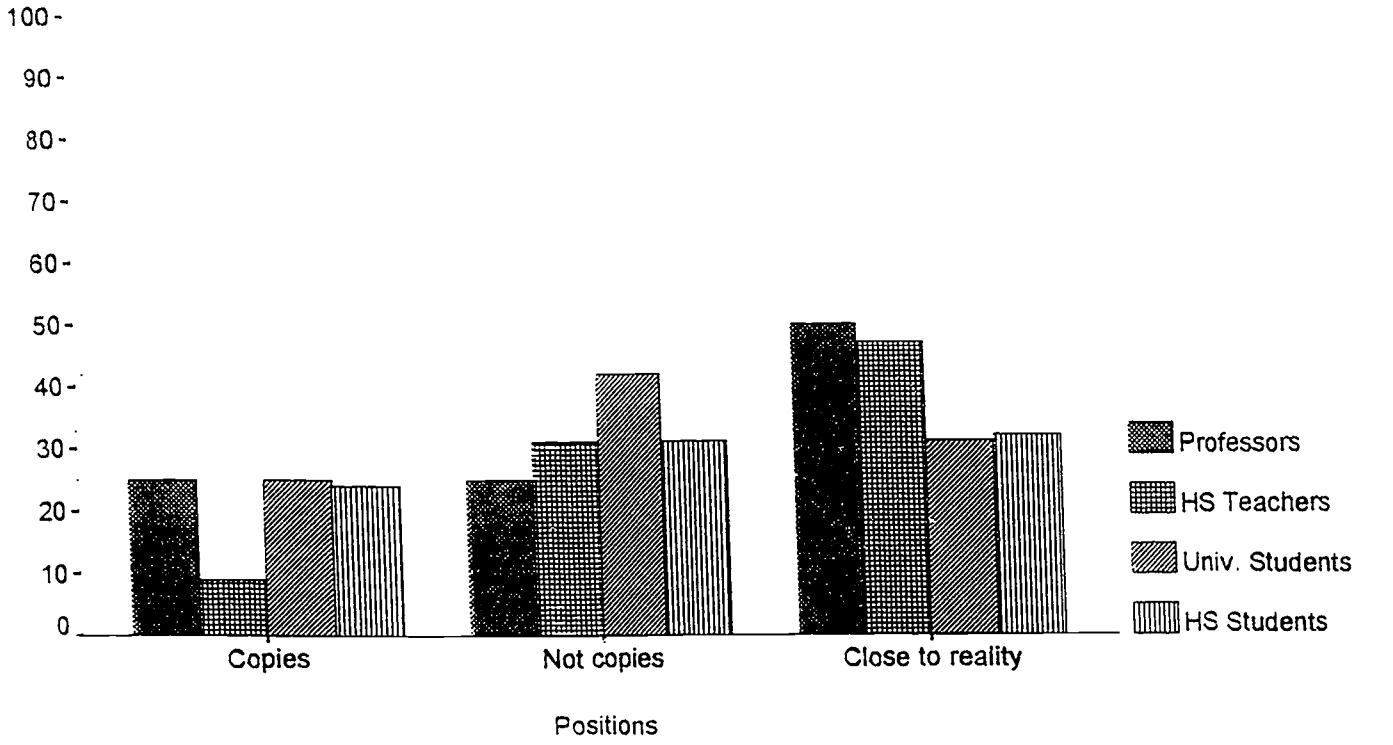


Figure 3. Are scientific models copies of reality?



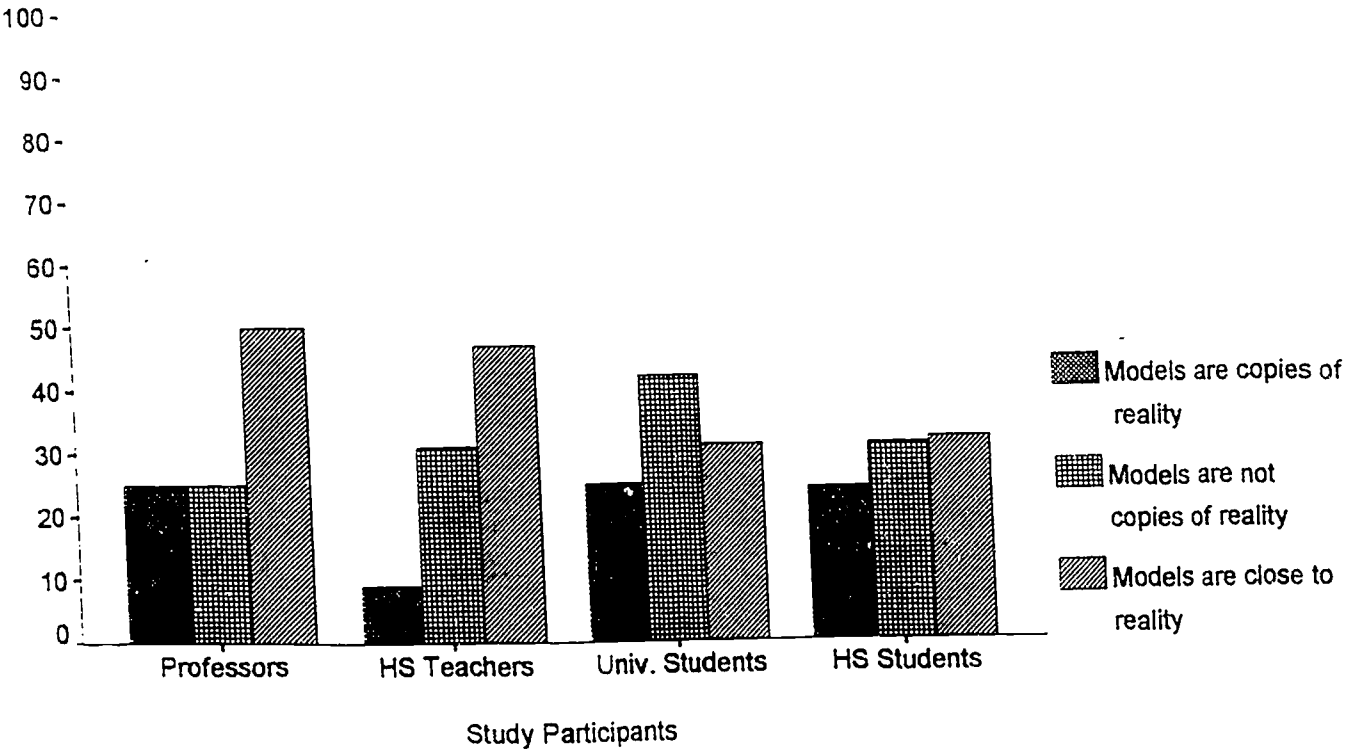
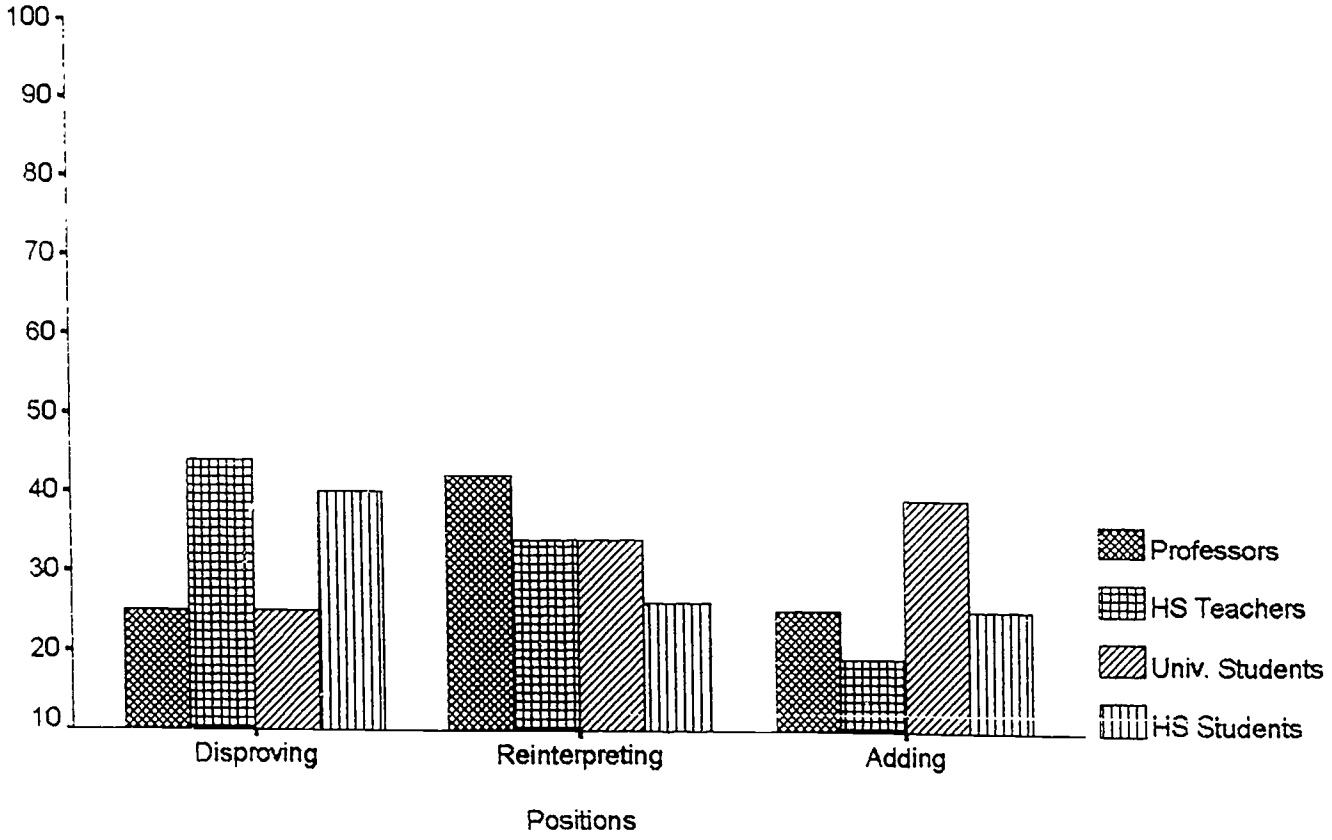


Figure 4. How does scientific knowledge change?



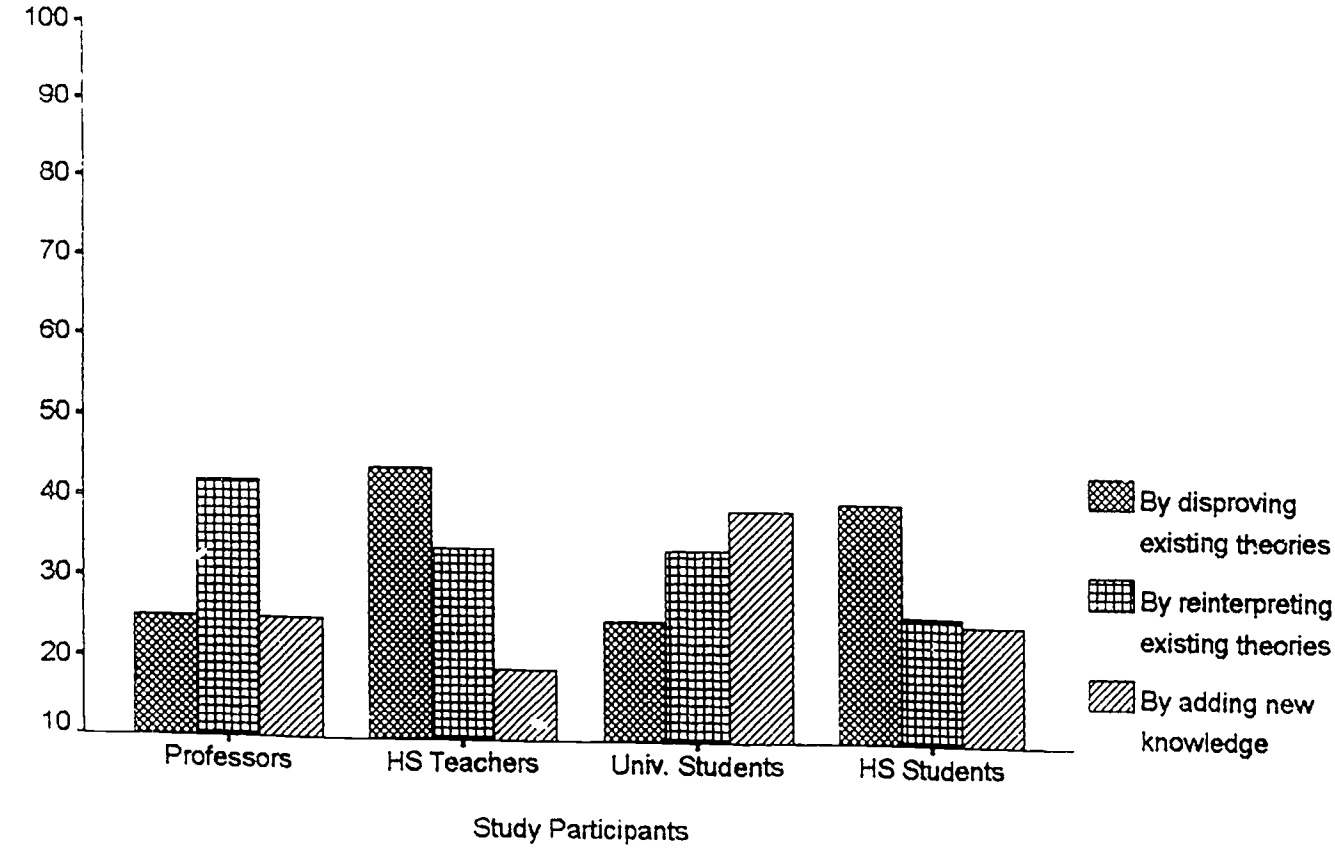
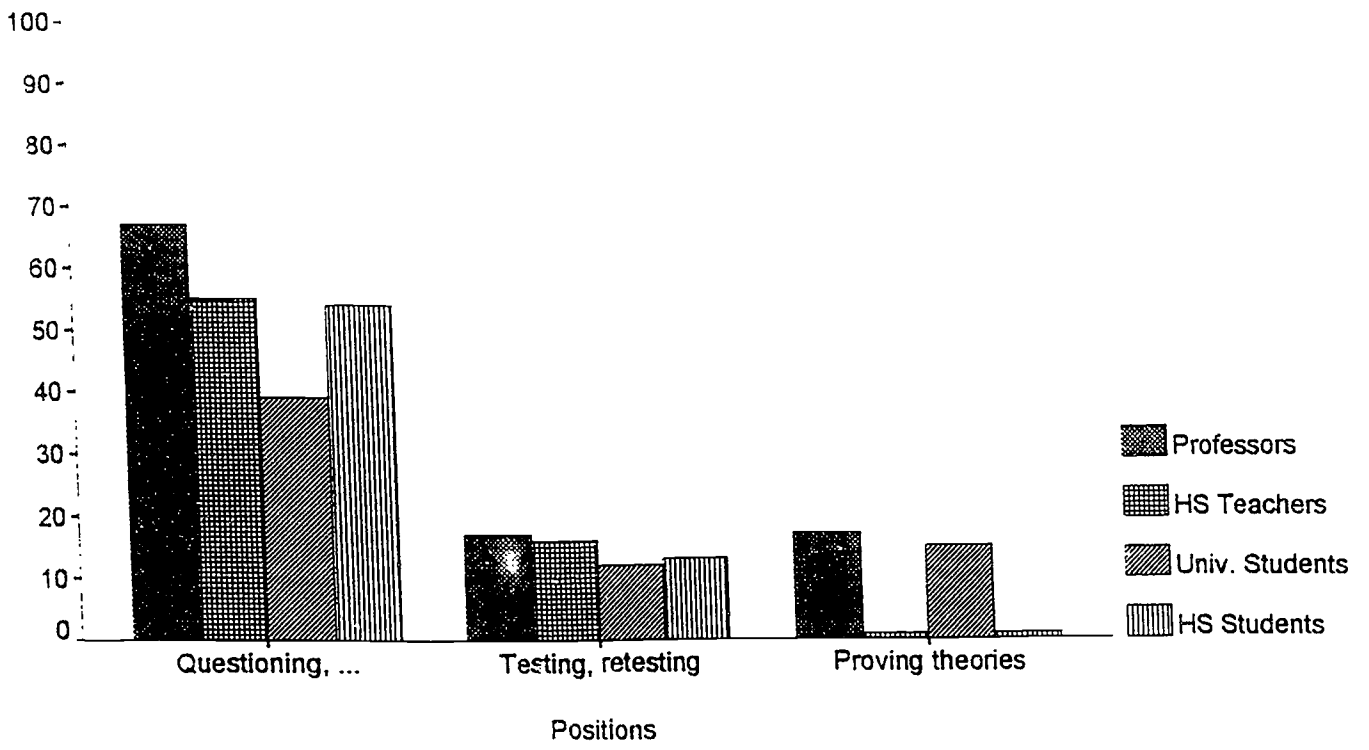


Figure 5. Definitions of the scientific method.



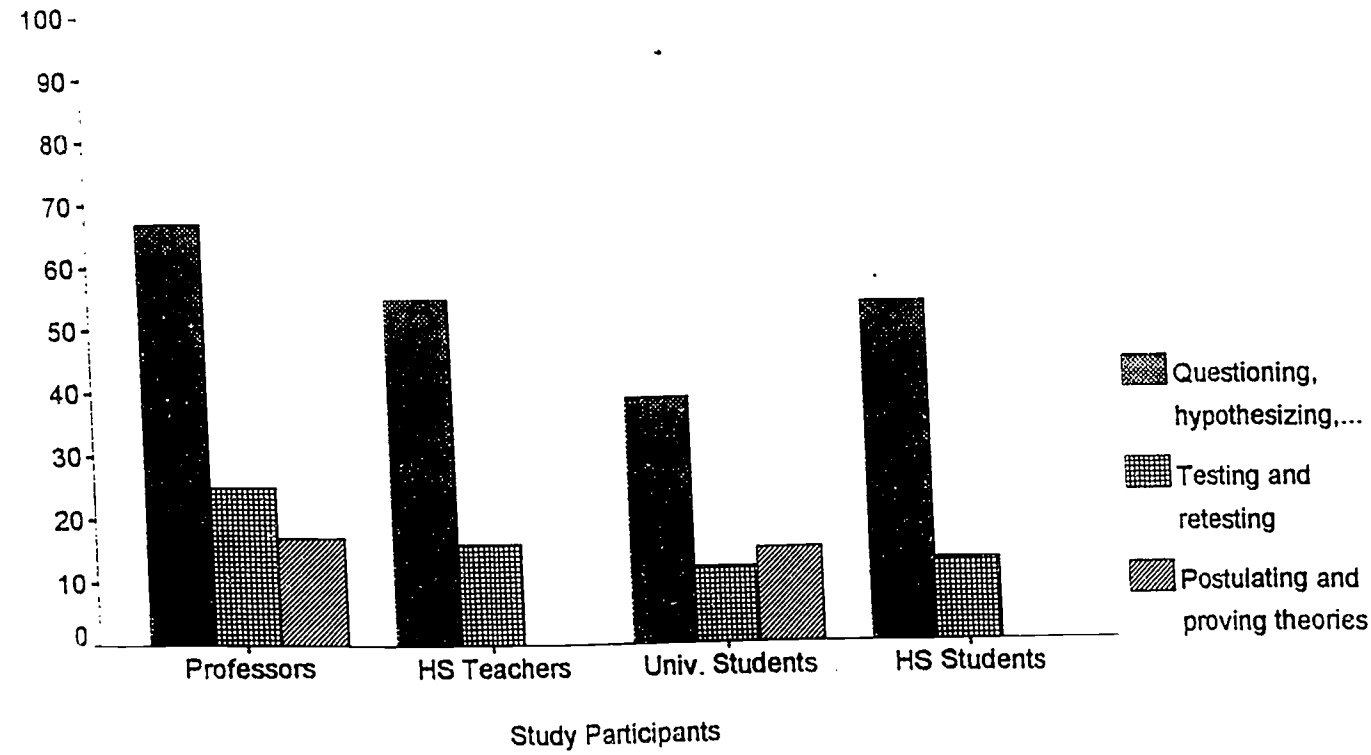
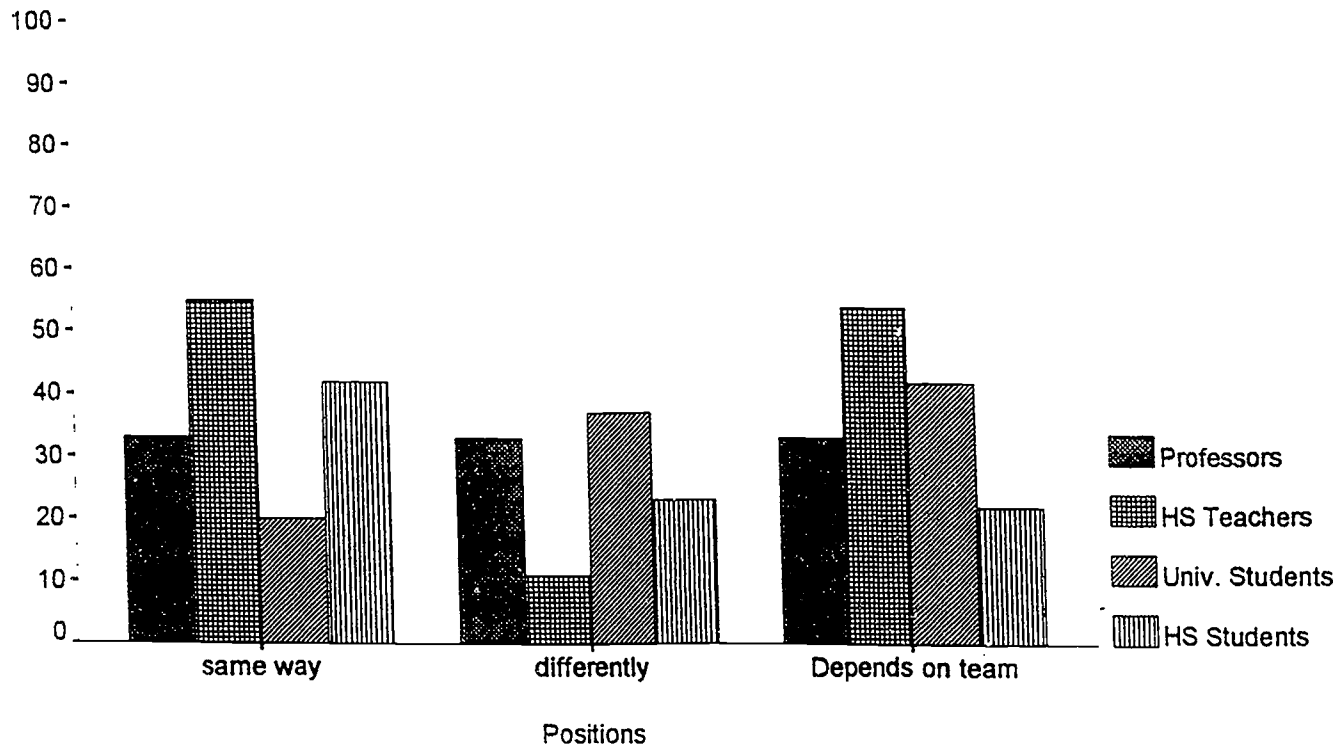


Figure 6. How is science conducted worldwide?



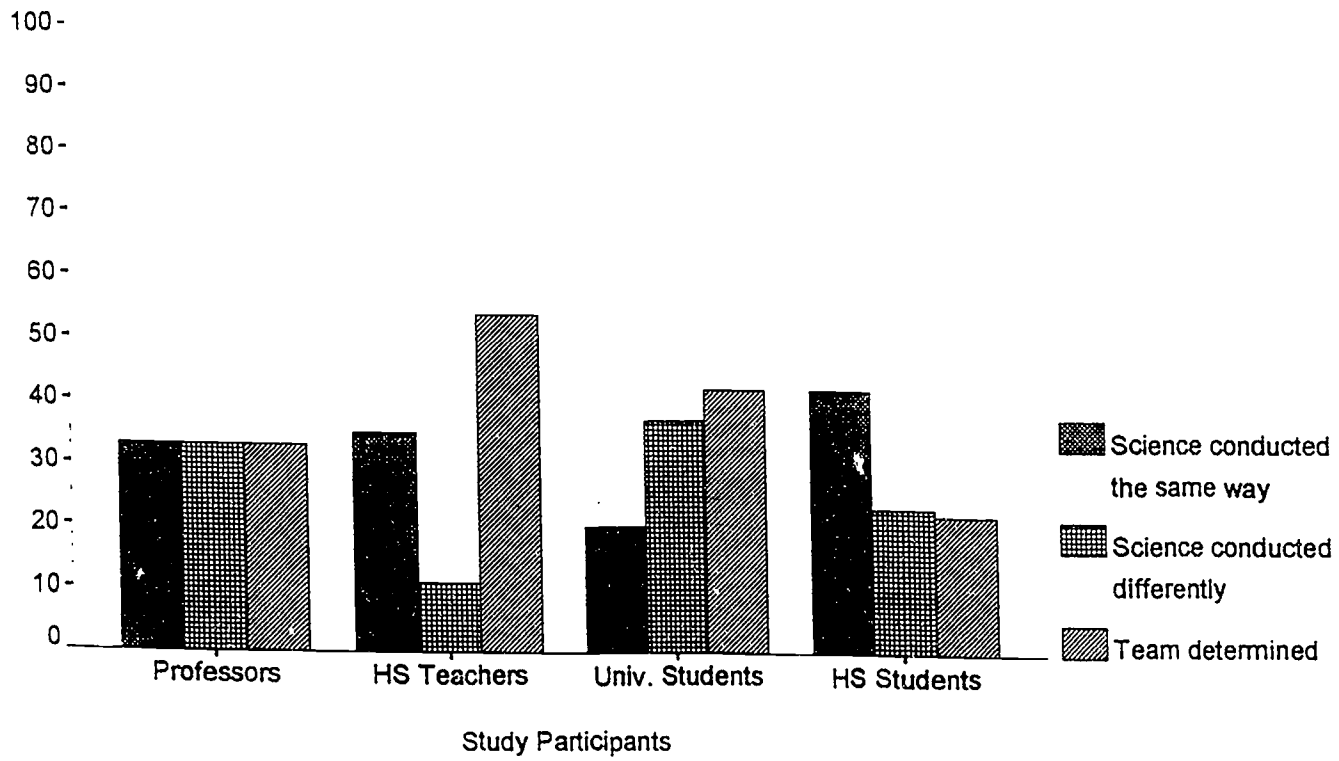


Figure 7. Effect of a country's educational system on scientists' work.