CONTRASTING CHRISTIAN APPROACHES TO TEACHING THE SCIENCES

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Editorial introduction

In January, 1970, Calvin College was host to a group of Christian educators participating in a Colloquium on a Christian Approach to Curriculum. A number of curriculum areas, science studies being one of them, were selected for extended discussion in this three-day conference of educators from various segments of the Reformed academic community. A major paper was presented in each area with each one having two respondent papers. Each formal presentation was followed by a panel discussion. Both at this Colloquium and since then there have been requests to capture the best of that dialogue in more permanent form so as to make it available to a wider audience.

This monograph has arisen out of that dialogue, both written and oral, both at the Colloquium and since then. Two writers of papers, representing divergent views within the Reformed academic community, were given opportunity to revise and adapt their papers in the light of not only the Colloquium discussion but of a further exchange of communication between them. They were asked to address themselves to the same educational questions and to so arrange their essays that the reader might easily sense the differences in approach of each.

The Table of Contents will reveal to the interested reader the degree of parallel structure in the two following essays. The text itself will reveal the degree to which the writers have provided contrasting answers to the same scientific and educational questions. The editor wishes to express his thanks to the writers, Professor Russell Maatman of Dordt College and Professor Gerald Bakker of Earlham College for their cooperation and for allowing him to provide the editorial comments on their essays.

I am sure that the writers join me in assuring the reader that these two alternatives set forth here by no means exhaust the Christian approaches to science or the general theoretical frameworks within which one may teach Christianly. They would be the first to express appreciation for each other's viewpoint, however contrasting they have made them for the benefit of the reader. Teaching, being the art that it is, proceeds not only out of a relatively conscious theory of the role that scientific thinking should play in the life of a Christian but also out of the total personality of the teacher. Thus, the writers and editor would agree that the actual classroom teaching act does not usually exhibit unambiguously any stated ideology concerning the best way to teach Christianly. The writers have here exercised discipline in exhibiting in their respective curricular implications not the richness in method of which they are capable but merely selections that clearly and consistently represent their priorities in objectives. They both would readily admit, I believe, to some eclecticism in classroom method, but would wish to demonstrate here that different emphases tend to flow from different primary objectives in teaching science. The careful reader will observe the degree to which they have demonstrated the relationship between objectives and teaching strategies. I believe that careful analyses and comparisons of the two major approaches will enable many teachers to identify more closely with one, while benefiting from the insights of the other.

The views expressed in these essays represent those of the writers and not necessarily those of either Calvin College or their respective colleges. They are being published as part of the Calvin College Monograph Series so that a wider audience, both of those within Reformed educational circles and those in evangelical Christianity generally, may benefit from this clarification of the creative tensions over education which exist among practicing Christian educators. It is offered in the hope that it may stimulate Christian teachers of science at all levels to rededicate themselves to teaching with more deliberately Christian goals and practices in mind. May it provoke many a faculty room discussion, many a department meeting resolution, and many a curriculum committee recommendation concerning teaching more Christianly.

Donald Oppewal
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Christian education through science studies

RUSSELL MAATMAN

What we see in our world today causes us to doubt that modern science is serving us well, What went wrong? Once God told us to subdue and replenish the earth and to have dominion over it. Subduing, replenishing, and having dominion today mean that scientific activity is to be included in man's activities. In telling us to do these things, God was also saying that man has the ability or the potential to carry out the command. In spite of all this, Christians have always known that the presence of sin in the world means that man's science would be a perversion of the subdue/replenish/have-dominion command. It could not be otherwise. Man has used science, certainly; but it has been *fallen* man who has used science.

Our theology teaches that sinful man will not use science correctly; our theology also teaches us what science *should* be. This is where Christian education enters. Our educational process is not merely transmission of parts of our culture from the adults to the young; a *Christian* education is to be instruction in what the culture-in this case, the scientific culture -- *should* be.

Teaching God as creator and guide

To understand Christian education in natural science we need to understand first the existence of a very important parallel. On the one hand, natural science is man's study of physical creation.[1] On the other hand, our students are also men. As we teach them science, we *relate* them to creation. With this parallel in mind, it will be possible, by understanding why man is able to carry out scientific work, to understand what science to teach and how to teach it.

The key idea I want to present is that man can carry out scientific work because man and creation are in harmony. (Man's *body is* of course a part of physical creation, but I speak here of the harmony between the *investigating man* and creation.) Man is able to observe and he does observe creation; he is able to correlate what he sees and he does correlate; and finally he calls these correlations "natural laws." The laws of thermodynamics and of motion are examples of natural laws. These man-made laws have a certain predictive ability in the sense that they correctly describe situations or processes similar to those already observed. Thus, the motion of as-yet-unobserved double stars is known. These laws also correctly predict discoveries to be made in the future. For example, the discovery of some fundamental particles of matter, such as the positron and some mesons, was correctly predicted by certain natural laws. To the extent that man's natural science can make correct predictions, man is in harmony with creation.

It is in this context that we should examine what is meant by "order" in creation. "Order" means that man and creation are in harmony, that man and creation are "on the same wave length." To explain this the scientist usually claims that an evidence of order is the beautiful simplicity of the fundamental natural laws; a forest of seemingly unrelated facts can be explained

by a small number of simple laws. Christians realize that creation fits together and they know that God created and now upholds a coherent universe. We can, however, conceive of God creating and caring for a universe in which none of his creatures could discern the pattern, *i.e.*, perceive that order exists. When we say that we see order in creation, we are making a statement more about ourselves than about creation. In the sense that "order" is used here the Christian cannot conceive of a creation actually containing that which is the opposite of order, *i.e.*, disorder.

When we translate this idea into action in our educational process, there is something we should *not* do and there is something we *should* do. What we should *not* do is to acknowledge that God created and takes care of everything we study, while we teach the subject matter itself as if the question of God's creating and taking care of it is immaterial. What we *should* do is to teach so that the concept of creation and providential guidance is a *necessary* part of everything we teach.

An analogy may help us understand that the idea of creation and providence is "necessary." The day-to-day activities of the human family depend very much upon the length of time required for the infant to become an adult. As it is, children remain with the parents for about twenty years. The family would be quite different if only two years were required for the infant to mature. Almost none of the institutions and the customs associated with family life would be recognizable. Thus, as the sociologist teaches a course on the human family, the question of whether the maturation process requires twenty years or two years is of vital importance. If his students did not know how long the period is, it would be absolutely necessary to tell them; otherwise, they would not make much sense of what he teaches.

In a similar manner, our science students should be taught so as to make it impossible for them to grasp what is being taught unless they make the assumption that God created and guides everything they study. I shall presently give some examples showing what this principle means for a Christian scientific education. But first I shall describe the difference between Christian and non-Christian scientific education which there would be if the approach I suggest is adopted.

The Christian understands the universe to be created and guided by God. The *consistent* non-Christian (*consistent* because he is not like the non-Christian who mixes in elements of Christian teaching in his position) believes in principle that the only things which exist are those which he observes or which he could observe. Therefore, non-Christian scientific education, to the extent that it is consistent, is education in what man has achieved and will achieve, while Christian scientific education should be education in what God has done and is doing. As the non-Christian explores and teaches, he supposes that he removes "superstition", which to him is the same as "religion." As the Christian teaches, his students learn more of the creating, providential God and their Christian faith is strengthened. When the non-Christian encounters limitations in science, he is frustrated. The Christian knows that *he* is limited, but that God is not limited; for the Christian there is no frustration.

Furthermore, one particular wrong attitude which sometimes creeps into the classroom of the Christian educator can be eradicated if the suggested approach is adopted. I refer to the

all-too-common tendency to debunk science. To be sure, what is usually attacked are improper motivations and conclusions of specific scientists. Yet, it is implied repeatedly (an example is the struggle over water fluoridation) that some non-scientists know as much or more about science than scientists. If, however, students are taught that man's investigation of creation has significance because of the nature of man and of creation, then scientific investigations will not lightly be cast aside. A truly Christian approach to science teaching will help remove from the minds of non-scientific Christians the widely-held idea that "science is bunk."

Curriculum application

In what follows, the emphasis is on the heart of the question, on the harmony between man and the creation he studies. Such an emphasis must not be taken to indicate that the Christian teacher may ignore the applications of science and the ethical questions which arise in connection with those applications. What could be shown in a longer article is that one is in great danger of giving wrong answers to these ethical questions if he misunderstands the nature of science. An attempt will be made to show that the principles of science are no more "neutral" in a religious sense than are the applications of science.

To show more clearly what is meant by the principles which have been given, some classroom applications are provided. Although the applications are grouped according to scientific discipline, it is understood that some physics, chemistry, etc., is taught in several courses at many grade levels and not merely in senior high school courses bearing those names.

A. PHYSICS

Classical mechanics is a traditional subdivision of physics. To the student, this subject often seems to be uninteresting and complicated. I wonder if classical mechanics would have that image if the student actually realized what he is doing. Classical mechanics is an excellent example of what man can do with "common sense knowledge" (the *basic assumptions* with which he begins his work) to produce a satisfying, important, and many faceted branch of science.

Because I shall refer to these basic assumptions throughout the rest of this paper, a clear idea of what I mean must be given. These basic assumptions are the set of ideas which one uses as his starting point as he begins his work in science. These basic assumptions change. As each generation does its scientific work, the basic assumptions of future generations are affected. For example, once all men thought that the shortest distance between two points is always a straight line; many scientists now understand that in some contexts the shortest distance is *not* a straight line. In a few generations this new fact may be so generally known that it will be taken as a basic assumption. What is extremely important for our discussion is that we need not limit ourselves to the best modern knowledge as we use basic assumptions in the classroom. For example, with classical mechanics, which was developed before the present century, it is quite satisfactory to assume that the shortest distance between two points is a straight line. We can look back and see that many such basic assumptions were good approximations in the context in which they were used. The youngest students can use the basic assumptions of an earlier day to develop some of

the still-usable scientific knowledge of an earlier day; as the students proceed through the grade levels and through college they can use better and better basic assumptions to develop additional scientific knowledge.[2]

To understand how magnificent is the classical mechanics we teach at the high school level, we must know what the physicist has started with in developing this field. He uses Euclidean geometry, algebra, the idea that energy is conserved, Newton's Second Law of Motion (Newton's First and the Third laws can be derived from the Second), and the Law of Gravitation. Each of these tools or ideas depends upon some of our basic assumptions. I shall explain. It is well known that geometry and algebra rest upon cornmonly accepted basic assumptions. We can make the same claim for the physical laws I mentioned. Can we conceive of a universe in which energy (on a higher educational level, mass-energy) is *not* conserved? When we consider what we mean by "force" and "mass" in the classical sense, how could we arrive at anything *but* Newton's Second Law? Considering the force and mass concepts of the Second Law, and adding the classical idea of rectilinear space, a basic assumption, we know what form the Law of Gravitation must take if we can but assume (relying upon our general experience) that there is indeed an attraction between massive bodies. We conclude that classical mechanics rests on a foundation of commonly accepted basic assumptions.[3]

I said before that the approach I am suggesting uses the fact that man and creation are in harmony. I want to show what this concept of harmony means for one of these basic assumptions in order that you can see how I relate the concept of harmony to *all* basic assumptions. Consider the idea of the conservation of energy which I just mentioned. With respect to the conservation of energy, God could have created a universe in which energy is not conserved, and in this universe he could have put beings who could learn that energy is not conserved. He could also have put in such a universe only beings who could *not* learn whether or not energy is conserved. A third way he could have created was to create a universe in which energy is conserved and in which some beings could learn that it is conserved. Finally, he could have created a universe in which energy is conserved but in which no creatures could learn whether or not it is conserved. He actually created in the third way mentioned. We could go through each of the basic ideas of science and make a similar observation: in each case, God chose to create so that some beings could learn that particular idea. This is what I mean by my claim that man is in harmony with creation. Only because of this harmony is science possible. Since the science we teach rests upon just such principles as the conservation of energy, I suggest that our science teaching is to rest on the man-creation harmony.

What is built upon this small number of basic assumptions in classical mechanics? With these ideas and *nothing more* you can explain to the high school physics student why a baseball curves, why it is that wings give an airplane "lift," how a gyroscope works, how it is possible for a sailboat to sail into the wind, why a rocket engine forces the rocket ahead, why a rocket can function in a vacuum, why an artificial satellite or the moon does not fall to the earth, why an outfielder throws a ball at 45° to the horizontal to achieve the greatest distance, how a highway engineer calculates the angle at which a curve must be banked, how a hydraulic jack works, why the period of a clock pendulum does not vary as the clock runs down, why Archimedes' principle is true -- and much more. I regret that textbooks are very weak in emphasizing this relationship.

Man and creation are indeed in harmony. With the use of these simple basic assumptions, all these diverse aspects of classical mechanics have been developed by scientists, who are men, and by the same token they can be explained at the appropriate grade level to students, who are also men. Furthermore, the student should be told that he is able to understand all this *because* man and creation are in harmony.

But if we teach the student about a *created* harmony, *are we not missing the whole point of education if we do not tell him of the Creator who also upholds that which he creates?* As we enable the student to perceive that many diverse facts are explained by a few basic ideas, we must go one step further; we would be remiss if we would stop at that point. Our investigation of creation should, if we have been taught by the Holy Spirit, enable us to encounter the basic fact of the universe, the fact of God's creation. I am not talking about the ancient but discredited teleological "proof" for the existence of God. In objecting to this "proof," some persons have unfortunately gone so far as to say that science should not be taught in the manner that I indicate because such teaching does not lead the student to the God who saves through Christ. But it is the duty of the Christian to describe the *work* of the *Triune* God and as the Christian studies science he studies the *creative and providential* work of the Triune God. The Christian educator should describe things as they are; he should "tell it like it is." A correct description is not possible if it does not recognize that God created and cares for the universe. All men are to understand that God created and now cares for creation, and that when we examine the universe we are looking at the evidence for creation and providence. This is what Paul meant when he said, "For the invisible things of him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead . . ." (Romans 1:20). To study physics correctly is to praise God.

Explaining the complex in terms of the simple is also possible in other branches of physics. We cannot always explain to the student the details of how one proceeds from the simple to the complex; the path might be too difficult for the grade level in question. But we ought to have no trouble in convincing him that the connection between the simple and the complex can be made. Consider, for example, the modern story of fundamental particles, a story which can be given in outline form to high school students. For several decades more and more fundamental particles of matter, i.e., the particles of which matter is composed, have been discovered. This development was a surprise to physicists because they expected, as men always expect, a basic simplicity in creation. Now, however, it is becoming apparent that their expectations were correct. It has been possible to predict *mathematically* which particles exist. The simplicity which was expected lies in this instance in the *mathematics* which man has developed, illustrating very well what man-creation harmony means.

We often speak glibly of the ordered motion of the planets and stars; the physicist knows that it is literally true that their motion is ordered. Once again it is possible to account for much that is observed using only a few fundamental ideas. The student who is willing to begin with the assumption that mass-energy is conserved (a step higher than the basic assumption concerning the conservation of energy), Newton's Second Law, the Law of Gravitation, algebra, geometry, and some of the simplest ideas concerning the nature of light, can be taught in a general way that

these ideas, when suitably combined, explain planetary motion, galactic motion, the aging of stars, and much more. With a few more intuitive ideas it is possible to explain the existence of variable stars, nova, and supernova. The teacher should show that behind the observations are a few laws and that behind those few laws is the ultimate in unity, the one true God, the Creator and Upholder. Understanding the fundamentals which lie behind that most majestic subject, astronomy, teaches our students that the heavens declare the glory of God.

Meteorology is sometimes included in physics. Initially, the student is likely to be both interested in meteorology and quite convinced that it is a fantastically complicated subject. The teacher can explain that meteorology is not as complicated as one might think. Without elucidating the procedure which can be used in high school science courses, I shall indicate what one can start with and the kind of conclusion which can be made. We must assume that the earth: (1) is spherical (2) is heated by the sun (3) rotates on its (tilted) axis, and (4) revolves around the sun. We must also assume that the earth has the geography it does have and the simplest laws of gases and evaporation and the Law of the Conservation of Energy. With this information, we can show why the United States rainfall pattern is what it is; why the seasonal temperature fluctuation is so large in the Central Plains States; why there are hurricanes; and we can explain much else. The Bible states many times that God controls the weather. In a Christian approach to the study of weather, we can explain *how* God controls weather.

B. CHEMISTRY

Chemistry is also an orderly science. We can describe to students the modern understanding of the structure of the atom even though we will not be able to explain the rather sophisticated experiments which reveal that structure to us. This description of the structure of the atom will serve as a kind of starting point, an idea which is equivalent to the basic assumptions referred to earlier. (It is certainly not possible to show how this description of the atom actually rests on higher-level basic assumptions, one of which is the wave-particle nature of matter. There could be merit in indicating that the connection does in fact exist.)

Using only this description of atomic structure and whatever basic assumptions are involved in simple reasoning, it can be shown how the periodic classification of the elements is constructed. The periodic classification is an excellent example of man's attempt to simplify and to explain seemingly isolated facts in a systematic way, to put all facts under one logical roof. Thus, in the approach I suggest, we are to teach history backwards: we start with the modern picture and we show how, given such a picture, the periodic classification is the only one possible; whereas in actuality men very slowly first discovered the periodic relationship and then after many efforts, some in a wrong direction, developed the modern description of the atom.

In addition to the description of the atom and the periodic classification, the student needs some of the simpler ideas already discussed, such as the Law of the Conservation of Energy and a few ideas on the nature of light, to understand many of the elementary facts of chemistry. Even though at first glance chemistry may seem to consist of a large mass of unrelated facts, it is possible, using no more than what I have indicated, to achieve a fairly good understanding of the chemistry of the elements. The student can understand, for example, how a water softener

functions, why certain compounds are bleaching agents, why substances like rusted iron and the copper compounds on weather-beaten statues are colored, how a battery produces electricity, how strontium salts and certain other salts produce the color of fireworks displays, how an electric eye functions, how a whole branch of chemistry can be based on the element carbon, why certain metals are found "free" in their natural state-and much more. The connection between the fundamental principles and the seemingly isolated facts is not as clear here as, for example, in classical mechanics. But all students, regardless of level, should be made aware that the connection does exist even if they cannot comprehend it. The student should always have held before him in science courses the idea that behind the observations are unifying laws, and that ultimately there is God himself, a consistent God, the author of unity.

C. OTHER SCIENCES

I shall refer only briefly to other sciences.

At the elementary and secondary levels we teach aspects of one other fundamental science, biology. We might expect that non-Christians would attempt to find unifying laws which are by their very nature God-denying. The theory of biological evolution is a unifying attempt which denies parts of God's special revelation. This attempt has been responsible for the wide acceptance of the idea that life evolved spontaneously from non-living matter and the idea that non-living matter is itself eternal. The theory of biological evolution has in this way become intimately associated with a kind of blasphemy, the denial of creation itself. I suggest that the unification idea in scientific studies will mean more to our students if we show them how unbelief can fashion a wrong, a God-denying, kind of unification.

We also have courses such as geology or earth science, courses which depend upon the fundamental sciences. It is in these sciences which are not themselves fundamental that we are most likely to err in this matter of teaching unification. We are prone to treat, for example, the facts of geology as isolated facts, especially as we teach them at the elementary level. As we now teach we might, for example, show the relation between volcanoes and earthquakes, but we do not go beyond such a relation to emphasize the basic unity which would take us through the laws of chemistry and physics back to creation itself. Naturally, we could not show the student the details of such a chain of reasoning; but our fault lies in not teaching him in a forceful manner that such a chain does exist.

I have given some principles and applications of the principles of Christian education through science studies. Do these principles and their applications represent the only Christian approach to the teaching of science? To answer this question, I shall review the argument. What has been done is to apply our Christian faith in a creating, providential God to science as we know it. Scientific activity has indeed been an activity in which man has made observations, formulated laws, and found that many of these laws give him deep insight into the nature of creation. In other words, scientists have (sometimes in spite of themselves) used the idea that there is a basic unity in creation. Their work is testimony to the harmony between man and the rest of creation. What is being maintained here, then, is that a Christian approach to the science *which we know,* and not to a hypothetical science which man has not engaged in, must take into

account this man-creation harmony. This harmony is the heart of the matter, and an approach to science which attempts to be Christian, but which does not recognize and depend upon this harmony, can have at best only some of the superficial aspects of a thoroughly Christian approach.

Guidelines for method of teaching science

What I have said up to now amounts to this: The content and structure of our science courses must be determined by our Christian faith. What has been proposed might sound too idealistic. You might object that grade and high school students cannot grasp these ideas. Science is difficult enough, you might say, without *emphasizing* the theoretical or the abstract. Yet it must be true that if *what* we teach is properly based on the nature of man and creation, then *how* we teach ought to be based on the nature of man and creation. Using this principle, I shall make only four comments on the method of teaching science. 1 do not enter into most of the methodological questions (e.g., the role of the laboratory).

A. THE GENERAL APPROACH

Our entire approach should be based on the principle of a unifying law already outlined. The student should see that behind the observations are simple laws and that behind these laws is God, a God of unity and not of chaos. By these means we do not prove to the student that God exists; rather, we teach in the context of Christian faith, and we assume throughout that he exists and that he has created and that he upholds that which he has created. We who teach should not doubt that any scientific fact can ultimately be traced through fundamental laws to God the Creator. But, some facts are more obviously related to fundamental laws than others. Thus, for a scientific fact to be included in our curriculum we should usually be able to show to the student its relationship to fundamental law. Then, the higher the grade level, the more sophisticated will be the relationship between fundamental law and observed fact. At any grade level the usual criterion for choosing facts that are to be taught should be our ability to show relationship to fundamental law. We ought not to carry this so far that the more difficult sciences are completely omitted at the lower grade levels.

B. BASIC ASSUMPTIONS

To use the unifying-law approach, the student is always required to begin with certain basic assumptions. No doubt in my earlier discussion one might wonder if these ideas are indeed so self evident to students. Unfortunately, they often are not. I propose that we anticipate this problem in the earlier grades. What is being done in the early grades in the new mathematics is a step in the right direction. As a result, the high school student just beginning physics is now better able to understand that algebra and geometry are not mysterious; he can see that they rest on a small number of readily-perceived postulates. Perhaps we could use the same approach in the early grades for other fundamental principles the science student needs. For example, it might not be obvious to the present day beginning physics student that energy is conserved; is it not possible that he will accept this without question if he is taught, starting in the early grades, that

the various forms of energy are interconvertible? Other basic assumptions needed in the later grades could be treated similarly.

C. USE OF THE STUDENT'S ENVIRONMENT

If our task is to relate the student to the physical universe which God created, then we should emphasize what the student encounters in his own environment. We sometimes say that it is logical to teach by starting with that which the student himself observes. I would like to add that it is logical to teach in this way because God has created us in the way he has. Man is in harmony with creation, and God has put in us a desire to find out about creation. It is therefore quite *natural,* in the sense that creation is *natural,* for the student to be curious about the factors which lie behind, for example, the weather that affects his daily life.

D. LIMITING SUBJECT MATTER

The natural sciences have the reputation of being difficult, regardless of the grade level. Hopefully, they will not be as difficult if they are taught in the kind of framework which I have described. It will be helpful if two additional ideas are considered as subject matter is chosen.

First, much of the student's difficulty exists because he is taught too many facts. We tend to tell the students too much. I have indicated that at any grade level much of what we teach can be related to fundamental laws and that we can show that these laws come from the hand of the Creator. But if we can in this way relate fifty facts to the Creator, is it necessary to relate one hundred? It is necessary to relate the one hundred facts in the last stages of the student's training, perhaps at the college level, when he is preparing for his vocation. Surely it is not necessary to give such extensive instruction before that time.

Chemistry was once taught just the way a science should not be taught. We taught hundreds of chemical facts and we related them to each other very poorly. Many teachers in high school and college chemistry courses used the Bohr model of the atom in their modest attempt to relate seemingly isolated chemical facts decades after chemists discarded (in the 1920's) the model as unusable. The reason these teachers were able to use this extremely poor model of the atom in their attempts to relate chemical facts was that they attempted to relate so little. Most chemistry students of that period did not notice, for example, that according to the Bohr model of the atom, water would be a gas, not a liquid, at ordinary temperatures. This shortcoming, as well as a very large number of others, was not noticed because our emphasis was on teaching a large number of facts. I suggest that even though we *can* do well in relating all these facts to theory, that we make science palatable by reducing the number of facts we include in our courses. The direction which has been taken in recent years in the teaching of high school chemistry, as well as some of the other sciences, is in this respect the right direction. We may want to go even farther in the reduction of the number of facts taught in order that we can make clear to the student our ultimate purpose, relating the student to creation and the Creator.

A second source of difficulty in studying science is our inclusion of much material which is theoretical or abstract but which does not contribute (at the grade level at which it is introduced)

to the unification concept. I shall take an example from chemistry here, also, although the problem is general in the sciences.

For many beginning chemistry students, the "mole concept" is hopelessly difficult. This concept prevents the student from understanding much of what the teacher tries to impart. The student acquires mental blocks for everything stoichiometric. As a result his ideas about chemical formulas and equations are vague. Above all, he has difficulty with the concept of the concentration of a solution; many beginning students cannot understand "molarity" and practically all stumble over "normality." I wonder if the existence of these difficulties ought not to teach us that we are to relate the beginning chemistry student to the Creator of the chemical facts by bypassing the mole concept. Of course, the student cannot go very far in chemistry without learning the mole concept and related ideas. But it seems that we make an error when we insert these admittedly man-made tools, tools which are arbitrary, between the student and fundamental laws.

Even though we need mathematics for certain purposes, as I have indicated earlier, we probably use far too much mathematics, including arithmetic, in teaching the introduction to the various sciences. Is it important to teach the beginning student of chemistry how to calculate the percentage of oxygen in water or the beginning student of physics how to calculate where two boys of different weight must sit to balance a teeter-totter? When we give students such problems, they tend to spend a disproportionate amount of their time on them. If quantitative problems are introduced at the wrong time, the student's attention is diverted from that which he should learn. But if we take the student to fundamental law and to the Creator by the shortest route, we will be doing what is "natural", i.e., we will be taking into account the relation between the student and creation which actually exists. When a knowledge of the quantitative is *needed* to enable the student to advance in his understanding of the fundamental laws which show him God's creative and providential hand, the student will be ready for such quantitative knowledge. For these reasons, some mathematics might be taught more effectively than at present, if in teaching it we would show how it aids us in understanding creation.

Conclusion

The program which has been outlined is a radical departure from the usual approach, including the approach used in Christian schools. It is radical because a single framework for all of natural science education is proposed; subject matter, especially theory, is added to what we presently teach, so that the framework can be better perceived by the student; certain subject matter we presently teach is to be taught at a higher grade level so that it can more easily be seen to fit into the framework, while other subject matter is to be taught at a lower level to enable the student better to develop the framework as he grows. Finally, the program is radical because it assumes there is only one way to teach science correctly, namely, the way which teaches that God is the Creator and Upholder of the universe and which shows the relationship between his creative and Providential acts and our observations.

On placing limits on Christian education

GERALD BAKKER

There was a time when St. Paul's speech on the Areopagus used to disturb me. When I was a child I had the very uncomfortable feeling that Paul had in some way betrayed his Christian message by addressing his audience as a religious people, equating the 'real God' with their 'Unknown God', and including references to heathen poets. Since then I have come to know that Paul was neither deceiving his listeners nor debasing the Gospel. He was properly and carefully using ideas consistent with the Christian message. But the real source of my previous discomfort still exists; the idea lives on that we must somehow be pure and unique in our thinking if it is to be Christian. There are still those who would argue that there must be a radical disjunction at all times apparent between the Christian approach to science education, or the Christian approach to whatever is being discussed, and the approach taken by a non-Christian.

There are a number of ways to counter this kind of argumentation, which is basically *ad hominem* in its style, but I should like to focus attention on the variety of points of view which may be assumed by a Christian in analyzing his subject. I wish to argue that a uniformity in our thinking on the subject at hand, science education, is not necessary and that within the group of Christian science teachers there may be many differing ideas on what should be taught and how it should be taught. Demanding one identifiable, defensible approach to science education places unnecessary limits on Christian science teachers.

Using multiple approaches to science

In this paper I will try to show how a Christian can teach science in a variety of ways based on different philosophical presuppositions. I will then offer a set of objectives for science education and, finally, raise some of the ethical questions facing scientists, science teachers, and anyone acquiring scientific and technological knowledge.

In the writings of philosophers of science there are three major approaches to the treatment of scientific law. These have been well delineated by the philosopher Marx Wartofsky of Boston University. The first approach, called the Realist approach, is based on the idea that what is real in this world is not the set of objects we perceive, for these pass away, but the relations between objects and the ideals behind the objects themselves. That which is permanent is real. Universals are real. Among other things which can be called 'real', natural laws are an important class and the task of the scientist is to *discover* these natural laws or make his scientific laws approximate natural laws ever more closely. Scientific explanation from this point of view consists of finding the scientific laws which cover the particular phenomenon in question. A teacher of science holding this view would naturally place greater emphasis on teaching the fundamental laws and less emphasis on the specific instances where the law can be applied. And if this teacher were a Christian, he would likely speak of the relationship between natural law and God the Creator and Sustainer. Such a teacher would spend more or less time on this religious question depending on

how he viewed the demands of the subject matter and the classroom situation in which he found himself.

In the strongest contrast to the Realist there is the Nominalist who denies there is anything beyond the particulars themselves. Instead of seeing universals as real, he considers universals to be only names. He places his greatest emphasis on that which he can perceive and not on some presumed ideals behind the particulars. There is not some 'ideal' table which is exemplified in passing fashion by the tables we see, but only this table, that table, and the other, etc. A teacher holding this view would consider scientific facts to be important. Scientific laws would not hold as much importance for him, for laws to the Nominalist are only summaries of facts and are instruments to be used and then judged by their usefulness. For such a teacher, scientific laws would not be held to be true or false, only more or less useful. If this teacher were a Christian he would have to have a place for God in his scheme of what is real. But in teaching science, he would speak of the scientist, his facts, and his summary laws, and to him the world of created objects would be as beautiful and as descriptive of God as to the man who would replace the objects with their universal forms.

Between the Realist and the Nominalist can be placed most scientists and philosophers of science. These positions can be described as Conceptualist, for universals here are considered to be neither real nor only names, but in some way they are the product of the mind and senses of the observer. Thus the world is not considered to be filled only with the shadow forms of the Realist nor with simply a set of unrelated particulars as for the Nominalist. There is a reality to both the particular instances and to the humanly produced relationships. There is something about our minds which either organizes the world or forms the very way we can even think about and perceive the world. A Conceptualist teacher sees significance in both the scientific laws devised and the particular phenomena studied. He is likely to see more of the cultural, historical, and personal influences on the development of science and he will keep his students aware of these influences. Such a teacher, were he a Christian, would show his awareness of the human involvement in scientific development and would probably have a real appreciation for man as the "crown of creation."

On this line, ranging from Realist through Conceptualist to Nominalist, Christian teachers can be found at each point. Probably the majority of scientists will assume a position close to that of the Realist and many Christian science teachers have taught their subject based on these philosophical presuppositions. But if they assume that this position is the only proper position for a Christian, I would argue they are making a faulty assumption. The Christian has a whole range of metaphysical and epistemological positions he may take. None of the treatments of scientific law is inherently any more Christian than the others. For example, to hold that a Christian's purpose in teaching science must be to show God through fundamental natural laws is to ignore a whole range of points of view which may as legitimately be labeled Christian and to restrict unnecessarily the choices of a Christian teacher. When looking for the philosophical basis of science and science education, we may do as Paul did on Mars Hill, use the ideas we find, bending them to our purpose. All of this is not to say that I do not myself find one of the positions more convincing, but I do not find one more Christian than the others and I would not try to use one in an exclusive fashion to define a science education which is Christian.

There is a difficulty even more troublesome which faces those who wish to define Christian science education primarily in terms of philosophical and religious commitments. There are few guidelines as to what the limits should be on how much theology, how much worship, and how much science there should be in a K-12 science program. The following questions are examples of a kind of question not easily answered. How many years of science teaching are necessary to get across the idea: observations -- laws -- a God of unity and order? Or if, in a given year, 50 phenomena can be studied and found to show the beauty of God's creation, may not only 20 or 10 do just as well? And should we require physics of all graduates of a Christian school because in a physics course we can show most convincingly how man the scientist can operate on God's created world? Proponents of Christian education will often at this point assume a hortatory stance and simply call for more references to God and His creation in the classroom. And a teacher never really knows if he has mentioned the creating and sustaining Hand often enough for his efforts to be called Christian.

Guidelines for science education

How then should we in the Christian schools[4] organize science education from kindergarten through the twelfth grade? I would argue that as to content and approach we have remained, and probably will always remain, within the relatively narrow range permitted a science teacher for his own individuality through professional courtesy. Some examples of what I mean are in order. As science moves into the lower grades on the American scene, our Christian schools will not be far behind. When Jerold Zacharias and the PSSC team changed the subject matter and approach to the teaching of physics, this shift gradually came into the Christian high schools, too. When the confidence in Newton's Laws as eternal verities was shattered in the early 1900's, it was shattered in the Christian schools too. When chemistry teaching shifted from the recital of dreary, unrelated facts to the development in the classroom and laboratory of the powerful laws of chemistry, it happened in Christian and public schools alike. And whether we like it or no, some developments in American science education are carefully planned and justified and others are fashions. Our Christian schools will likely share them all. There are some exceptions to this which cannot be ignored, such as the treatment given evolution in some schools, but the main point still stands. The major outlines of what is done in the Christian schools and most of the particulars follow closely what is done on the overall American scene.

Objectives in science teaching

What should the objectives be in science education? Let me propose a set which is similar to that which has been written by the Science Division at Earlham College. Beginning with kindergarteners, the teacher of science should work toward enabling his students to:

1. Think like a scientist and be capable of demonstrating an ability to design, execute, and report on experiments.
2. Compare and contrast the methodology of science to that employed in other areas of human knowledge.

3. Demonstrate competence in the process of acquiring knowledge in the sciences, including use of the laboratory and the library.
4. Demonstrate a working knowledge of science as shown in oral and written communication.
5. Demonstrate an understanding of the role of science in society.
6. See science in operation and meet practicing scientists.
7. Enter a science-related vocation or educational program where these goals are appropriate.

Implicit in my statement of the objectives of science education is the assumption that science education must be defined in terms of itself and what is being done generally in science education. Then the limits placed on science education will at least provide a working basis for organizing a science program, even if fads and fashions may be more important than we scientists would generally like to admit.

The value dimension

What then does the Christian teacher do in organizing and teaching science which may be traced more directly to his faith in God the Saviour and Creator? There are: (1) moral judgments necessary in the doing and teaching of science and (2) questions about the ultimate use to which science should be put. In both of these areas the Christian teacher finds it necessary to apply his own religious principles.

Let me describe briefly some of the value questions.

1. The development of science has not had a smooth course. Sometimes little progress is made for years and then a new idea or two may revolutionize the research in a given area. These revolutionary times have generally been accompanied by very vigorous arguments belying the usual notions about scientific objectivity. Given this messiness in the development of science, is it honest to present science to students in neat packages with all questions easily answered? The state of the body of scientific knowledge changes with time. The science of the 70's will be different from that of the 60's. Laws are changed, the importance of certain experimental evidence varies, and research directions shift radically. In all honesty we must not present science as if it has once and for all been codified.

2. The importance of the data of science and the particular methods used to obtain the data need not be argued, for scientific laws stand or fall on the quality of the experimentation and the data produced. In the presentation of an honest picture of science should there not be some emphasis on the laboratory evidence? For didactic purposes a currently accepted theory may sometimes be presented first, but the basis of the theory in experimentation should also then be included.

3. In a growing number of research areas, experimentation on human beings is becoming more necessary. What are the moral questions and how should they be answered for

heart transplant research, the testing of contraceptive devices, the testing of supposed cancer cures such as krebiozen, the psychological or sociological manipulation of human subjects in social science research, etc.?

4. In the 1940's and at other times in man's recent history, science has been presumed to have the answers to all human questions. Where problems still existed, the application of scientific methodology was presumed to be the key to obtaining the necessary answers. The debate among the physicists over the development of the H-bomb and the current concern over misuse of science and technology (regarding DDT, waste, etc.) has pretty well laid to rest the more grandiose beliefs in the super-relevance of the scientific method. But it is still incumbent on a science teacher to say something about the limits on the applicability of the scientific method. The scientific mode of explanation needs to be placed alongside the legal, political, philosophical and religious modes.

Finally, no scientist or science teacher can afford to ignore questions as to the ultimate use and value of science, and especially not the Christian. Science may well be used to point to the beauty and order of God. Compared to other human disciplines such as literature, law, philosophy, and art, science can serve this purpose well. But there are other more important questions about the use and value of science. What is the responsibility of a scientist for the use of knowledge he sought for "pure science" reasons? New answers are now being formulated to this question; Christians must contribute to the debate. The belief that any research may be done without regard for its consequences is being extensively debated. It is important, I believe, for science teachers to challenge the assumption that the direction science takes is not a moral decision made by individual scientists. Certainly it is not possible to foresee all the evil uses of a particular piece of scientific knowledge, but it is just as certain that in some cases one can foresee it. Chemical and biological instruments of war are not being made simply as curiosities. The scientist is morally responsible for the consequences of his work; the Christian should be telling the scientist what these consequences are.

There are also the priority questions to answer and value judgments are involved here. In these days, when a major portion of the research in this country is sponsored by the government, what should be the position of the scientist when faced with the alternatives of more money for NASA or more money for our urban centers? Can he simply say that more knowledge is always the higher good? Is research for its own sake justifiable when the world is crying for solutions to problems that should be technologically solvable? Would it not be better to save our environment from some element of pollution than to devise new laws of doubtful use? The alternatives are never so neatly framed but may the Christian shrink from a moral question because it is complicated?

Science education is in a vigorous, changing state today. We can, as Christians, contribute to the changes occurring or we can rigidity our own science education with artificial limits. I urge us to participate in the development. Where moral judgments are needed and ultimate goals must be defined, let us be ready to speak from our Christian conviction.

[1] In the remainder of this discussion, I shall for the sake of convenience use "science" instead of "natural science" and "creation" instead of "physical creation."

[2] Naturally, those older ideas which we now realize were dead-end ideas, such as the phlogiston idea in chemistry, should be avoided at all levels.
[3] At a higher level of education the student will, of course, learn that several of these assumptions are replaced by better assumptions.
[4] By Christian schools I mean those private elementary and secondary schools which have Christian dogma written into their organizational rules and which call their efforts Christian education.