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ABSTRACT

This investigation was guided by the following research questions: (1) how do teachers' understandings of the nature of science influence classroom practice?; and (2) what factors facilitate or impede the influence of teachers' understandings on classroom practice? An in-depth, year long assessment of the classroom practices and goals of five biology teachers (three males, two females), with a wide range of experience was conducted. A combination of semi-structured interviews, open-ended questionnaires, classroom observations, collected lesson plans and instructional materials, periodic informal interviews/discussions, and student interviews are used to investigate the relationship between teachers' conceptions of the nature of science and classroom practices and to elucidate those factors that impede or enhance the relationship. The sample teachers all possessed views consistent with those advocated by current reforms in science education. The teachers' conceptual frameworks of biology and pedagogy were assessed and it was found that consistent with previous research, the teachers' conceptions of the nature of science did not necessarily influence classroom practice. Implications for science teacher education and reform implementation are discussed. Contains 20 references. (LZ)

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Translation and Transformation of Teachers' Understanding of the Nature of Science into Classroom Practice

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Translation and Transformation of Teachers' Understanding of the Nature of Science into Classroom Practice

The efforts to reform science education are being significantly informed by NSTA's Scope, Sequence, and Coordination project (NSTA, 1993), the Benchmarks for Science Literacy (A.A.A.S., 1993), and the National Science Education Standards (National Research Council, 1994). Although the perspectives of each of these specific recommendations for reform differ to some degree, a strong emphasis on the nature of science is clearly a common theme. This should not be surprising since students' understanding of the nature of science, as an educational outcome, has been a concern since 1907 (Lederman, 1992).

Although there appears to be a perennial concern about students' conceptions of science, little progress has been made toward the achievement of this instructional goal. Indeed, there is presently much dissatisfaction with the levels of both teachers' and students' understandings of the nature of science (Duschl, 1990, Lederman, 1992). In addition, disagreement continues over the nature and extent of the relationship between a teacher's understanding and classroom practice (Brickhouse, 1989, 1990; Duschl & Wright, 1989; Gallagher, 1991; Lederman & Zeidler, 1987). Whether a teacher's understanding of the nature of science is necessarily reflected in planning for instruction and/or classroom practice is largely an academic question. Of more practical importance is the relative lack of knowledge concerning how teachers who do understand the nature of science transform or translate their understandings into classroom practices that impact students. Consequently, this investigation was guided by the following research questions: 1. How do teachers' understandings of the nature of science influence classroom practice? 2. What factors facilitate or impede the influence of teachers' understandings on classroom practice?

Sample

Five biology teachers (three males, two females) constituted the sample for this investigation. These teachers possessed a wide range in experience (the two beginning teachers had two and four years while the experienced teachers had 9, 14, and 15 years) and taught in separate schools representing four school districts and both urban and rural locales. Gender was balanced among the five teachers with one female and one male constituting the beginning teachers, and with two of the three experienced teachers being male. Selection of these teachers was based upon the researcher's close working and personal relationship with each teacher and their possession of a view of the nature of science consistent with that advocated in the current reforms (A.A.A.S., 1993). It is important to note that although each of the teachers was aware of an existing science curriculum (only two actually had a copy of the document) within the school district, each teacher was free to follow a curriculum of his/her own choosing.

Analysis of the district curricula clearly indicated that "students' understanding of the nature and limitations of science" was a stated goal/objective. None of the four districts imposed formal or informal assessment approaches (as derived from teacher interviews) to insure that the stated curriculum had been followed.

Method

This investigation involved an in-depth, year long assessment of the classroom practices and goals of five biology teachers. A combination of semi-structured interviews (one at the beginning and one at the end of the investigation), open-ended questionnaires, classroom observations, collected lesson plans and instructional materials, periodic informal interviews/discussions, and student interviews was used to investigate the relationship between teachers' conceptions of the nature of science and classroom practices and to elucidate those factors that impede or enhance the relationship.

One biology class (tenth grade) for each of the teachers was randomly selected for investigation. Teachers were interviewed one week prior to the beginning of the school year. These interviews were semi-structured and designed to collect data on each teacher's academic background, teaching experience, significant aspects of the school context, general student body characteristics, specific characteristics of the students enrolled in the selected biology class, and the goals and objectives for the biology class. In addition, each teacher was asked to complete two open-ended questionnaires designed to assess their overall conceptual frameworks of biology and pedagogy, and a third questionnaire which focused on teachers' understandings of the nature of science.

Teachers' conceptual frameworks of biology and pedagogy were assessed by two open-ended questionnaires, validated and used in previous investigations (Gess-Nesome & Lederman, 1993; Lederman, Gess-Newsome & Latz, 1994; Lederman & Latz, in press). Conceptual frameworks for biology were assessed with the following questions:

1. What topics make up biology?
2. If you were to use these topics to diagram biology, what would it look like?

Conceptual frameworks for pedagogy were assessed with the following questions:

1. What are the important elements/concerns of teaching?
2. If you were to use the elements/concerns to diagram teaching, what would it look like?

Teachers were assured that there were no right or wrong answers to the questions and that they were free to represent or format their conceptions of biology and teaching in any manner desired. In addition, the teachers were told not to take the terms "topics" or "elements/concerns" literally. That is, they were free to use themes, processes, concepts, etc. to represent either biology or pedagogy.

The questionnaire related to teachers' conceptions of the nature of science has been used and validated elsewhere (Lederman & O'Malley, 1990) and primarily focuses on the concept of tentativeness. In particular, teachers were asked to respond to the following open-ended questions:

1. After scientists have developed a theory (e.g., atomic theory), does the theory ever change? If you believe that theories change, explain why we bother to teach students theories. Defend your answer with examples.

2. What does an atom look like? How do scientists know that an atom looks like what you have described or drawn?

3. Is there a difference between a scientific theory and a scientific law? Give an example to illustrate your answer.

4. How are science and art similar? How are they different?

5. Scientists perform scientific experiments and investigations when trying to solve problems. Do scientists use their creativity and imagination when doing these experiments and investigations?

6. Is there a difference between scientific knowledge and opinion? Give an example to illustrate your answer.

7. Some astrophysicists believe that the universe is expanding while others believe that it is shrinking; still others believe that the universe is in a static state without any expansion or shrinkage. How are these different conclusions possible if all of these scientists are looking at the same experiments and data?

It is important to note that all three open-ended questionnaires were reviewed and discussed during the latter stages of the second (and final) semi-structured interview in an effort to insure that the questions were understood and that answers were correctly interpreted by the researcher. The three completed questionnaires were placed in a sealed envelope and not viewed by the researcher until just prior to the second semi-structured interview in an effort to avoid the biasing of classroom observations or subsequent informal interviews/discussions.

The selected biology classes were directly observed once per week without teachers' knowledge of the exact day of observation. In addition to the field notes taken during observations, all lesson plans and copies of instructional materials (for all of each teacher's biology classes) were collected each week. Consequently, although observations were made in only one class, complete records of planned instructional occurrences in the teachers' other biology classes were collected. Following each of the classroom observations, an informal interview/discussion was conducted to collect data related to the teacher's intentions and reasons for organizing and implementing the observed lesson. Additional data was collected concerning the overall organization for the week's instruction and the teacher's reasons for proceeding as planned. If time was not available immediately following the observed lesson, this information was collected by telephone the same evening. As a consequence of the researcher's close working and personal relationship with the teachers, there were weekly opportunities for informal discussions with these individuals in social settings each Friday after school. At the end of the investigation, each teacher participated in a one hour semi-structured interview during which the three completed open-ended questionnaires were discussed in detail.

Finally, upon completion of data collection for the teachers (i.e., following the second semi-structured interview), a random sample of 10 students (class sizes ranged from 19-32 with a mean size of 24) in each teacher's observed class was selected for interviews related to students' understandings of the nature of science. The specific focus of the interviews was on tentativeness of scientific knowledge and the role of subjectivity, creativity, empirical evidence, inference, and observation in the development of scientific knowledge. The interview questions directly followed those used on the questionnaire administered to the teachers as well as those posed in teacher interviews. The interviews were conducted in an effort to gather direct evidence of the possible influence of the teachers' classroom practices on students' understandings of the nature of science.

Results

All data sources were analyzed individually using a model of analytical induction (Bogdan & Biklen, 1992; Miles & Huberman, 1984) and then together in an effort to "challenge" developing assertions and conceptualizations. The numerous sources and types of data (e.g., interviews, observations, instructional materials) allowed for triangulation of data and the construction of highly valid profiles of each teacher's beliefs and classroom practices. Following the construction of profiles, each teacher was allowed to read and critique how he/she had been described. Without exception, the teachers' corroborated the accuracy of the profiles that had been constructed, lending further credence to profile validity. It is important to note that the results reported are the outcome of systematic analyses and contrasting of all data sources. Furthermore, the reader is reminded that the researcher conducted classroom observations and subsequent interviews without knowledge of the content of the two completed questionnaires related to the teachers' conceptual frameworks of biology and pedagogy and the questionnaire related to understandings of the nature of science.

Conceptions of Biology and Pedagogy

Analysis of interview data and subsequent analysis of the completed questionnaires clearly indicated that each of the teachers possessed a highly integrated and "rich" conceptual understanding of biology, with the nature of science, history of science, and S-T-S serving as unifying themes. Furthermore, all of the teachers appeared to possess highly integrated conceptions of pedagogy, with students' needs and concerns serving as a focal point. In addition, the representations of pedagogy often included various aspects of biology/science subject matter indicating that the teachers did not clearly distinguish between subject matter and the teaching of the subject matter. This finding is in stark contrast to previous research using the same questionnaires (Lederman, Gess-Newsome, & Latz, 1994; Lederman & Latz, in press). Although these previous investigations indicated teachers' preference for conceptualizing subject matter and pedagogy as distinct, the samples used were restricted to preservice science teachers as opposed to the inservice teachers used in the present investigation. Figures 1 and 2 are representative of the manner in which the teachers chose to represent their conceptions of biology and conceptions of pedagogy.

Insert Figures 1 & 2 Here

Conceptions of the Nature of Science

Analysis of teachers' interviews, and subsequent analysis of their completed questionnaires, indicated that each teacher exhibited views of the nature of science consistent with those identified in the various reforms (e.g., tentativeness, creativity, objectivity as an ideal as opposed to a reality, construction of knowledge, etc.). In addition to the teachers' universal agreement that scientific knowledge is tentative and that many of the ideas in science are constructed explanations for observable phenomena (as derived from the completed questionnaires), the following representative comments were made during the interviews spanning the entirety of the investigation. When asked to define science, the teachers typically replied:

> "False knowledge."
>
> "Our best attempt to make sense of our surroundings, our universe. Of course, we never really know if our 'sense' is correct."

As a follow-up probe to the teachers' clearly articulated beliefs in the tentativeness of science, they were asked why it should be studied and learned by students. Comments similar to the following were typical.

> "It's a funny thing about science. We never know if any of it's true and yet we base our whole lives on it. But, you need to have some frame of reference."
>
> "The kids ask me that whenever I say that we don't know anything for sure. I just tell them we need a starting point to make sense of anything, but we have to keep in mind that starting point is just a starting point."

The data from the teachers' questionnaire responses and interviews clearly corroborated the researcher's a priori perceptions of these teachers' understandings of the nature of science and support the initial reason for selection of these particular teachers.

Instructional Practices and Teachers' Conceptions

Classroom observations, inspection of lesson plans, and interviews indicated clear differences between the classroom practices of the beginning teachers (less than five years of experience) and those of the experienced teachers. The two most experienced teachers (14 and 15 years experience) exhibited classroom practices consistent with their professed views about the nature of science, a finding generally consistent with Brickhouse (1989, 1990). That is, these teachers included many inquiry oriented activities (i.e., demonstrations and laboratories) that required students to collect data and infer explanations for the data that had been collected. These inferences were often subsequently tested and revised accordingly. However, interviews (formal and informal) and analysis of lesson plans clearly indicated that neither of these two teachers was intentionally attempting to teach in a manner consistent with their perceptions of the nature of science. Indeed, neither teacher had students' understandings of the nature of science as an instructional objective or specified it as a goal. When asked about the purpose/goal of activities seemingly oriented toward the nature of science, the teachers explained their lessons as follows:

> "My main purpose for this demonstration is that the students really enjoy it and it is a good way for me to get them to see that science is fun and that they can do it. How the students feel about themselves is a big thing for me."

> "I want students to consistently see things that help them develop process skills. At the same time, I want them to develop thinking skills that they can use outside of science class."

This finding is also consistent with prior research (Duschl & Wright, 1989; Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome, & Latz, 1994) indicating that teachers rarely consider the nature of science when planning for instruction or making instructional decisions. When specifically questioned about the importance of the nature of science in the seemingly appropriate activities or its emphasis in overall instruction, the teachers consistently responded with comments such as:

> "Sure, I want to model science as it done and I do think students should see this. But, I think the most important thing for these kids at this point in their lives is to feel good about science and their ability to do science."

The two beginning teachers (less than five years of experience) were still struggling to develop an overall organizational plan for their biology courses and were each a bit frustrated by the discrepancy between what they wanted to accomplish versus what they were capable of accomplishing with their students.

> "I want students to have a global view of science as a way of knowing in addition to the factual stuff I need to teach. I just can't deal with that right now with all the management concerns I have."

> "I want to teach more process and nature of science, but I need to feel that I have things under control first."

Management, of course, appears to be a primary and persistent concern of both beginning teachers. And, although each clearly expressed an interest in addressing the nature of science in their classes, each felt that they were not ready to take on the challenge. The multitude of factors that mediate beginning teachers' classroom practice have previously been documented by Gess-Newsome and Lederman (1993) and Hollingsworth (1989) and corroborate the findings in this investigation.

One of the experienced teachers (nine years of experience) did not teach in a manner consistent with her view of science). She was overly concerned with students getting the basic foundational knowledge of biology and she felt that the substantive aspects of the nature of science were too abstract for tenth grade students to "effectively and functionally" learn.

> "I have always felt that there has been much too much concern for process skills. It's not that process is not important, but you can't process in a vacuum. Students need to have some basic knowledge to use with their process skills."

> "Nature of science has always been interesting to me, but I also know how complex and abstract it is. I remember how difficult it was for me to learn let alone my tenth graders."

At first glance, it becomes clear that a teacher's conceptions of the nature of science do not necessarily influence his/her classroom practice. At the most superficial level, it appears that teaching experience mediates the relationship between a teacher's beliefs about science and classroom practice, as indicated by the consistency between views of the nature of science and the classroom practice of only the two most experienced teachers. It also appears that teachers' intentions, goals, and perceptions of students are critical factors which influence teachers' instructional attention to the nature of science. The two experienced teachers who did teach in a manner consistent with their views of science are quite intriguing. After all, neither reported attempting to teach the nature of science. One is compelled to ask if these individuals provide evidence for the necessary influence of one's beliefs on classroom practice and counter-evidence for the idea that teachers' intentions are critical.

These two experienced teachers consistently professed the importance of students "feeling successful" in science, developing "positive attitudes" toward science, "feeling good about themselves," and seeing the relationship of science to their daily lives. These reasons were consistently used to support the teachers' use of the various projects, discrepant events, and inquiry activities noted in their classes. It is evidently clear that there are some classroom practices and instructional approaches which can be used for a variety of instructional outcomes. In short, although the aforementioned instructional approaches could be used to teach the nature of science in a manner consistent with the reforms and the views of the teachers in this investigation, the same activities could also be used to promote success, positive attitudes, and relevancy in science. Consequently, the two experienced teachers actually lend further support for the idea that teachers' intentions are of paramount importance when trying to ascertain the relationship between teachers' beliefs about science and classroom practice. This finding is clearly consistent with the empirical research on teachers' thinking and decision-making (Clark & Peterson, 1986). Previous research concerning the relationship between teachers' conceptions of science and classroom practice have consistently alluded to the curriculum as a factor that significantly inhibits teachers' attention to the nature of science (Brickhouse, 1990; Duschl and Wright, 1989; Lederman & Zeidler, 1987). The reader is reminded, however, that each of the teachers in this investigation was free to follow a curriculum emphasis of his/her own choosing and was, consequently, not significantly influenced by the stated science curriculum.

<u>Students' Understanding of the Nature of Science</u>

There are many who would claim that teachers' modeling of the nature of science is the most effective approach to promoting students' understanding (Duschl, 1990; Lederman, 1986, 1992; among others). However, contrary to this belief, the overwhelming majority of the students interviewed across all five teachers (46 of the 50) did not exhibit an understanding of the nature of science consistent with current wisdom and science education reforms. Comments such as the following were the norm:

> "Theories change all the time, but laws come out the same way all time and so we know they are right."
>
> "Scientists need to be creative in developing experiments, but the results should be seen the same way regardless of the scientist. This is why scientists do the same experiment many times."
>
> "Scientists have their own opinions about things, but the strength of science is that, in the end, it is objective."

In general, the students believed that only certain types of scientific knowledge were tentative (i.e., theories) and that creativity, imagination, and subjectivity had limited, if any, place in the development of scientific knowledge. This was as true for the classes of the two teachers that modeled the nature of science as it was for the classes of the other teachers. The data appear to indicate that unless a teacher clearly intends to address the nature of science, and follows through with explicit emphasis during instruction (as opposed to simple modeling), students will not develop an understanding of the nature of science that happens to be consistent with the organization of a particular lesson or activity.

Implications for Science Teacher Education

Consistent with previous research it seems clear that teachers' conceptions of the nature of science do not necessarily influence classroom practice (Brickhouse, 1990; Lederman, 1992; Lederman & Zeidler, 1987). Indeed, this was the case for this sample of five teachers who all possessed views consistent with those advocated by current reforms in science education. Consequently, it is critical that science teacher education programs (preservice and inservice) continue their efforts well beyond the often advocated development of teachers' conceptions of the nature of science (Duschl, 1990; Gallagher, 1991) and directly address teachers' abilities to translate such understandings into classroom practice (Lederman, 1986). A systematic and concerted effort to help teachers develop those attitudes and classroom skills and abilities which will enable them to transform their understandings of science into classroom practice must be pursued.

The initial focus of these efforts must be on promoting the internalization of the view that the nature of science is an important instructional objective which must be considered during the development and implementation of every instructional unit, lesson, and activity. As indicated in the current investigation, and in prior research on teachers' instructional decisions (Clark & Peterson, 1986), even though the teachers possessed what would be considered to be desired views of the nature of science, it was the teachers' instructional intentions that significantly impacted what occurred in classroom practice. Helping teachers to internalize the instructional importance of the nature of science will help to avoid the lack of attention to the nature of science evidenced in teachers' instructional decisions (Duschl & Wright, 1989; Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome, & Latz, 1994; Lederman & Latz, in press) and insure that teachers' intentions are focused on trying to promote students' understandings of the nature of science. Once teachers have internalized the importance of the nature of science and their intentions to address the topic are firmly in place, both beginning and experienced teachers will need to develop the instructional skills and abilities necessary to transform their knowledge into classroom practice (Lederman, 1986; Lederman, 1992; Lederman & Zeidler, 1987).

Given the significant concern for classroom management evidenced by the beginning teachers in this investigation and in other investigations (Hollingsworth, 1989; Gess-Newsome & Lederman, 1993, Lederman, Gess-Newsome, & Latz, 1994), the development of a wide variety of instructional routines and schemes which allow beginning teachers to feel comfortable with the organization and management of instruction appears to be a critical prerequisite for any efforts to assist such teachers' efforts to promote students' understandings of the nature of science. For experienced teachers, the focus should be upon those specific instructional approaches identified in prior research (Lederman, 1986, 1992) that can be used to influence students' conceptions of science. Naturally, it will be critical for teachers to explicitly address the nature of science instead of assuming that its mere modeling will accomplish the desired outcomes.

The implications of the present findings are critical for the successful implementation of the reforms advocated by the Benchmarks for Science Literacy (A.A.A.S., 1993), National Science Education Standards (National Research Council, 1994), and the Scope, Sequence, and Coordination of Secondary School Science project (NSTA, 1993). These reforms place a significant emphasis on students' understandings of the nature of science. And, as with any curriculum reform, success will be contingent upon teachers internalizing the importance of the stated goals (Clark & Peterson, 1986) and their ability to transform these goals into classroom practice.

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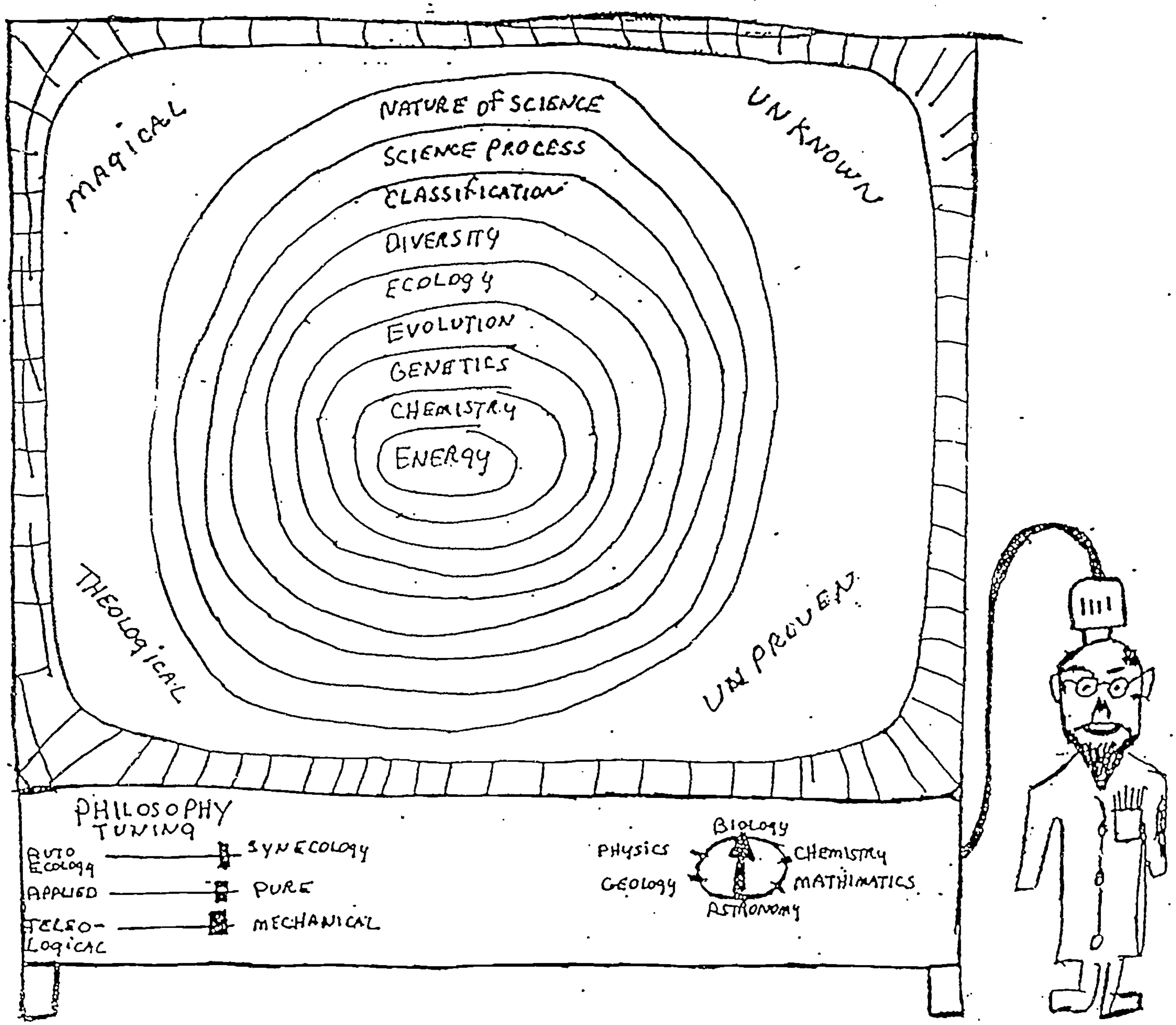

Figure 1. Integrated and "rich" conception of biology

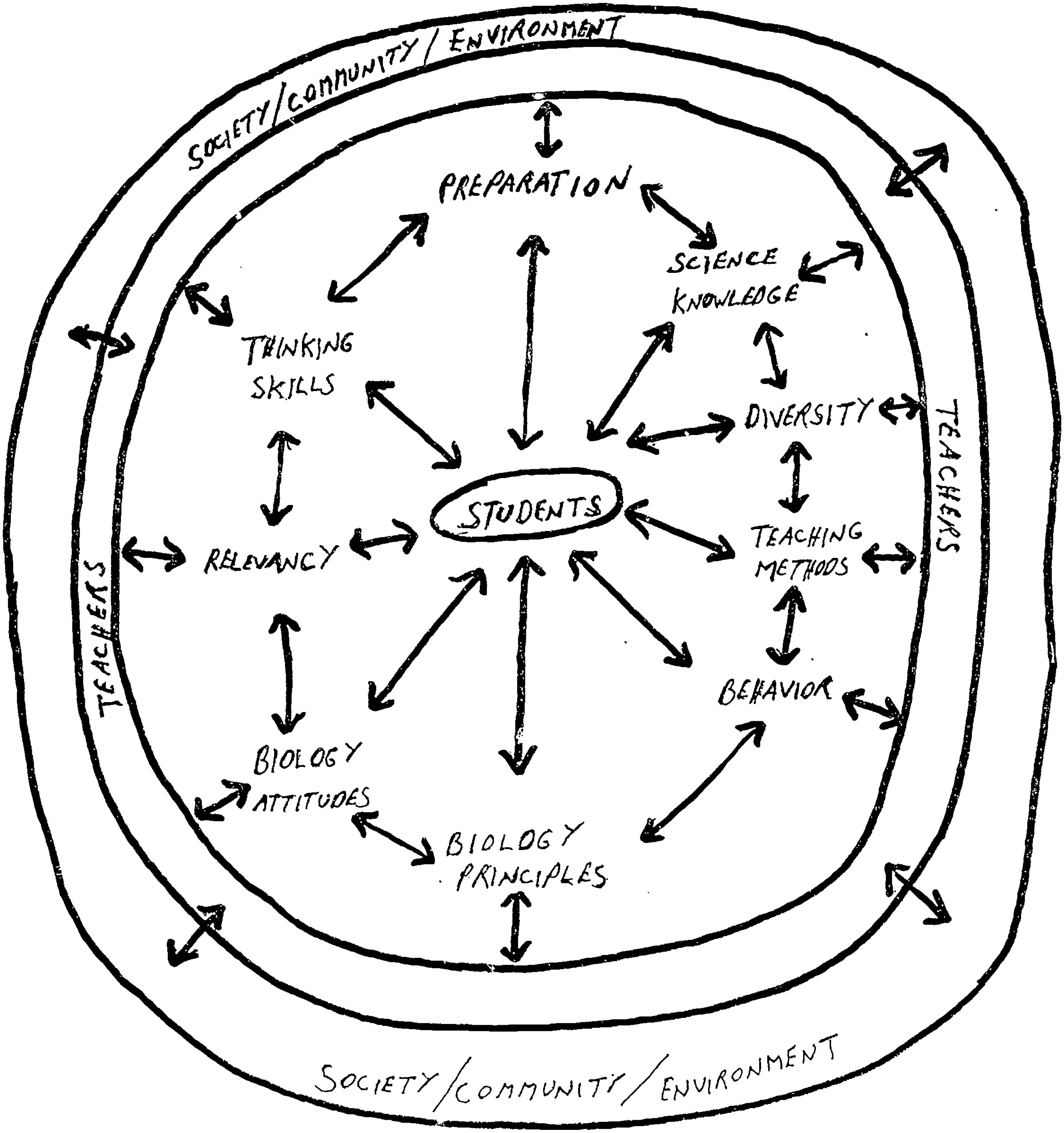

Figure 2. Student-centered and integrated conception of pedagogy