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ABSTRACT

Ten preservice biology teachers were followed through the final year of their preservice education to assess the content and stability of their knowledge structures of biology. A questionnaire asking the subjects to list the topics which make up biology and to diagram these topics in relation to one another was completed three times during the Fall Term. The questionnaire was completed again in the Spring Term during student teaching and was followed by an interview. Qualitative analysis of the data attempted t derive any evident patterns among and within the preservice teachers' stated subject matter structures. The data suggest that preservice teachers' knowledge structures of biology are extremely fragile and are influenced by the opportunity to think about teaching subject matter. Teaching, and courses specifically related to science teaching, provided integrating themes for the perception of isolated biology topics created by college science coursework. These results suggest that courses in science education may be the natural and most effective location for initial reflection on the integrating themes of science, but that the translation of such understandings may not be realistic for the novice teacher who gives priority to planning and classroom management. Since many of the new reforms in science education depend on the incorporation of integrating themes, inservice programs may be critical to foster teachers' reflections on subject matter structure and its translation to science instruction. (Author)

Preservice Biology Teachers' Subject Matter Structures and their Relationship to the Act of Teaching

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Abstract

Ten preservice biology teachers were followed through the final year of their preservice education to assess the content and stability of their knowledge structures of biology. A questionnaire asking the subjects to list the topics which make up biology and to diagram these topics in relation to one another was completed three times during the Fall Term. The questionnaire was completed again in the Spring Term during student teaching and was followed by a 30-minute interview. Qualitative analysis of the data attempted to derive any evident patterns among, and within, the preservice teachers' stated subject matter structures.

The data suggest that preservice teachers' knowledge structures of biology are extremely fragile and are influenced by the opportunity to think about teaching subject matter. Teaching, and courses specifically related to science teaching, provided integrating themes for the perception of isolated biology topics created by college science coursework. These results suggest that courses in science education may be the natural and most effective location for initial reflection on the integrating themes of science, but that the translation of such understandings may not be realistic for the novice teacher who gives priority to planning and classroom management. Since many of the new reforms in science education depend on the incorporation of integrating themes, inservice programs may be critical to foster teachers' reflections on subject matter structure and its translation to science instruction.

Introduction

Interest in teachers' knowledge of subject matter has gained renewed emphasis with current attempts to increase the quality of teacher education programs (Carnegie Forum, 1986; Holmes Group, 1986; Kennedy, 1990). In many states, these reforms have featured increased entry requirements for teacher candidates. In particular, many programs now require all aspiring teachers to have a degree in a specific content area prior to entry into teacher certification programs. Interestingly, prior attempts at correlating quantitative measures of what teachers know (e.g., GPA's and number of courses taken) with measures of effective teaching have rarely produced strong relationships of practical significance (Brophy & Good, 1986).

More recently, biology teachers' understanding of their content has become a specific focus of concern. A report prepared by the National Research Council's Committee on High-School Biology Education (1990) has cited the importance of biology teachers not only having a firm grasp of biology content, but also possessing a conceptual framework of this knowledge. Such a framework is expected to translate into a more coherent view of biology for students, and to aid the teacher in the selection of the most appropriate topics to be included in the curriculum. Unfortunately, little research is available to validate this intuitive notion concerning the importance of conceptual frameworks to teaching or to aid in our understanding of what is actually learned in university science classes and how this may translate into effective classroom practice (Guyton & Farokhi, 1987; National Center for Research on Teacher Eduation, 1988). Past paradigms of research on teachers' knowledge and effectiveness have provided us with correlational data on quantitative measures of teachers' knowledge. This research appears inadequate in providing the information necessary to answer current questions and concerns. More in depth qualitative measures of teachers' conceptual frameworks of subject matter are necessary to enlighten the discussion of teachers' subject matter knowledge, its formation, and its potential impact on educational practice.

Rencent attempts to specifically explore teachers' subject matter knowledge in a more qualitative manner have been characterized by card sort tasks in which subjects are asked to organize and/or categorize topics provided by the researcher in order to unveil underlying subject matter structures (Baxter, Richert, & Saylor, 1985; Hashweh, 1986; Hauslein & Good, 1989; Wilson, 1989). Unfortunately, methodological flaws call into question the results of these studies. First, each of these studies assumed that coherent subject matter structures were already in place when the individuals were first interviewed. No attempt was made to assess whether the outcomes of the card sort tasks were actual measures of "cognitive models" of subject matter thinking, or simply created by the completion of the required task. Secondly, in each case, subjects were limited to the topics suggested by the researcher. This methodology has its origin in early attempts to define cognitive structures for quantitative modeling purposes (Shavelson, 1974). Though the importance of defining terms a priori makes sense in a quantitative context (Shavelson, 1974), it may place artificial constraints on the cognitive structures produced, calling into question the validity of the assessments of knowledge structures in qualitative studies of this type. Finally, all previous studies of biology teachers' conceptions of subject matter knowledge have been short in duration. To date, almost no studies have attempted to assess the development and stability of such subject matter structures over time. One rare exception is a study by Morine-Dershimer (1989) which looked at preservice teachers' conceptions of lesson planing and subject matter structures during a microteaching course. Over the duration of the course these teachers, of various subject matter areas, adjusted their subject matter structures to be more consistent with what and how they taught.

The purpose of this investigation was to answer the following questions: 1. Do preservice biology teachers possess a subject matter structure? 2. What do these subject matter structures look like? 3. What is the source of one's subject matter structure? 4. Is the subject matter structure stable during the final year of teacher preparation? and 5. Does the act of teaching influence one's subject matter structure?

Design

Subjects

Ten preservice biology teachers, five male and five female, were selected as the subjects for this study. This sample consisted of all the preservice biology teachers enrolled in one or more of the three science specific teacher certification courses offered during the Fall Term (Secondary Science Methods and Strategies, Microteaching, and Science Practicum). Each of the subjects was in the final year of coursework leading to initial teacher certification in secondary level biology. Eight were completing the requirements for a BS in Science Education, one subject had previously attained a BS in Fisheries and Wildlife, and the other a BS in Elementary Education. All subjects were Caucasian and ranged in age from 22 to 45 (median=26). Though data was collected on all preservice teachers enrolled in the courses mentioned (i.e., chemistry, physics, and integrated science preservice teachers), only the data from the biology teachers were analyzed in this study. This is important from the perspective that both researchers possess extensive academic backgrounds in biology and public school experience as biology teachers, providing them with the necessary knowledge to assess the subject matter structures of the preservice teachers.

Given the nature of this research, it is important to set the context of the coursework which the students were completing. During this final year of teacher preparation the preservice teachers were involved in a field-based practicum (traditionally taken during the Fall Term), three campus-based university classes which directly related to the teaching of science (previously mentioned), and student teaching (traditionally taken during the Spring Term). All of the students took Methods during the Fall Term, Microteaching during either the Fall (i.e., six) or Winter (i.e., four) Terms, and Science Practicum during the Winter Term. Though there was some deviation from the "traditional" course sequence by some students, this variation did not seem to affect the results of this study (as determined by systematic comparisons of data collected from the various groups of preservice teachers). In addition, most students were involved in completing one or more of their upper division biology courses during the Fall and Winter Terms. The number and types of content courses taken during this time depended on the program of the individual student.

The Secondary Science Methods and Strategies course included instruction on the nature of science, the writing of lesson plans and objectives, classroom questioning, teaching methods and strategies, science curriculum, science, technology and society interactions (STS), evaluation and classroom management. The Microteaching course served as an opportunity for the application and refinement of the methods and strategies discussed in the methods class. Each student was asked to plan and teach four 20-minute lessons using the following methods/strategies: lecture/recitation, general inductive model, general deductive model, and "laboratory." Lesson topics, selected from those that are typically taught in the public schools, were randomly assigned for the lecture/recitation and deductive presentations. Due to the nature of the teaching strategies and time constraints, students were allowed to select their own topics for the inductive and "laboratory" presentations. Lessons were videotaped and critiqued verbally by instructors and peers. Written critiques were provided by course instructors and a self critique was completed by the presenter. Finally, the Science Practicum course focused specifically on laboratory and demonstration techniques and laboratory safety. In addition, students were involved in the development of a resource file, collection of teaching ideas, and were given practice in completing budgets and laboratory inventories. All three courses were taught by one or both of the researchers. These classes are required of all science education majors, therefore, the content was not geared specifically to biology majors (though examples from all science content areas were used as appropriate within the teaching context). No special attempts were made to influence students' conceptions of science content beyond the normal scope of the courses as described.

Data Collection and Analysis

Given the exploratory nature of this study, a qualitative approach was deemed most appropriate. In particular, the case study design, as specified by Bogdan and Biklen (1982) was used. The use of a qualitative approach allowed for a more open-ended investigation of students' conceptions of subject matter structures and eliminated many of the biases introduced by assessment instruments in previous studies of this nature. Specific details of the case study methodology will follow.

Data was collected and analyzed in two phases. Of initial interest was whether preservice biology teachers possessed a structure for their understanding of biology and what these structures looked like. These questions were primarily addressed in Phase I. The additional questions proposed by this study were addressed in Phase II.

Phase I. The first phase of this investigation consisted of the exploration of preservice teachers' subject matter structures. Each subject was given approximately 15 minutes, at the end of the first day of the Methods course, to answer the following questions:

1. What topics make up your primary teaching content area? If you were to use these topics to diagram your content area, what would it look like?
2. Have you ever thought about your content area in the way you have been asked to do so above?

The questions were typed on a single sheet of paper. Upon distribution, the questions were read to the students and clarifications concerning the primary teaching content area (i.e., biology, chemistry, physics, integrated science) were made. Students were assured that there were no right or wrong answers to these questions and that their answers would in no way affect their grade in the course. It should be noted that no specific methods of formatting the diagram were suggested or taught to the students. For instance, students were not asked to diagram their topics in terms of a concept map, hierarchical structure, etc. The final representation was left up to the individual.

Students were asked to answer Question #1 again at midterm (i.e., week five of the ten week term) and at the end of the course using the same procedures. For the second and third administrations, the following questions replaced question #2:

Have your views changed? If so, how and why?

Following the third administration, the subjects were asked to list the content courses which they had taken during the current term and the topics taught during their microteaching lessons (if this course was taken concurrently) on the back of their paper.

It was felt that this methodology was superior to past attempts to assess subject matter understanding because it gave the subjects the freedom to select their own topics (as opposed to card sorts) and organize the topics in any manner with which they felt most comfortable (as opposed to artificially forcing topics into categories or formats). It was hoped that this approach would provide a clearer portrait of the student's conception of biology, its component parts, and the relationships (if any) among topics.

Qualitative analysis of data collected in Phase I attempted to derive any evident patterns among, and within, the preservice teachers' stated subject matter structures. More specifically, each student was viewed as an individual case study. Upon completion of data collection, the answers to the questionnaires for each student were analyzed in terms of overall structural format (e.g., linear arrangement, web-like, etc.), indications of a subject matter structure existing prior to initial questionnaire administration, the general number and type of topics mentioned, main categories versus subordinate topics, the presence or absence of integrating themes, and global changes over the course of the three administrations. In addition, any patterns which may be related to the content courses currently being taken or the microteaching lessons taught were noted. Trends found for individuals were then compared across case studies to assess the generalizability of the findings. This initial analysis served to formulate tentative hypotheses and helped guide additional data collection during Phase II.

Phase II. The second phase, conducted midway through the student teaching experience during Spring Term, assessed changes in the preservice teachers' subject matter structures and helped to clarify patterns elucidated in Phase I. Each preservice teacher was asked to complete the questionnaire again and participate in a 30 minute videotaped interview conducted by one of the researchers. Students were again reminded that there were no right or wrong answers to the questions asked and were assured that answers were expected to vary greatly among individual students. The interviews were guided by the following general questions (which varied slightly depending on the students' written responses):

1. Describe what you have written down on your paper.
2. Why did you select these topics?
3. What specifically did you mean by the term (botany/plants; zoology/animals; taxonomy/classification; genetics/heredity)? For instance, If I were to substitute Botany for plants, would it still have the same meaning? Why or why not?
4. What do your "lines/arrows" between topics represent?
5. Have your views changed? Why or why not?

Students were then provided with their first three questionnaires (completed during the Fall Term), the list of content courses they had previously taken, and the list of topics which they had taught during Microteaching. Using this material as a stimulus and source of reflection, the subjects were asked the following questions:

6. Are the questionnaires you filled out previously the same or different?
7. (If different) If you could group the questionnaires, how would that be done? What characterizes each group?
8. How did completing this questionnaire make you feel?
9. Were these structures (from past questionnaires) reflected in your microteaching lessons? How (if appropriate)? Why or why not?
10. Is this structure reflected in your student teaching? If yes, how? If no, why not?

All interviews were transcribed for analysis. Data were again compared within each subject to check for internal consistency in specified structures and across subjects in order to derive any evident patterns for this particular group of preservice teachers. In particular, patterns which emerged during the initial analysis were used. In addition, evidence concerning the source of subject matter structures, their stability, and the influence of and on the act of teaching one's content were sought. Both phases of data analysis were conducted by one of the researchers and later corroborated by the other researcher in a blind review of both written and videotaped data.

Results and Discussion

Although a chronology of the working hypotheses generated during data analysis could be presented, it would do little to impart the strength of the final results. For this reason, the results reported represent the culmination of total data analysis and will be organized in terms of the initial questions guiding this investigation.

It is interesting to note that the blind review by the second researcher resulted in complete agreement (i.e., 100%) concerning the key elements of this data set and the views held by the preservice teachers in this study. Though this seems somewhat unusual, the data collected for this study was extremely clear and consistent across subjects. Additionally, corroborating support for the findings of this investigation have recently been reported by Borko and Livingston (1989) and Morine-Dershimer (1989). The specifics of this corroboration will be presented within the context of the following discussion.

Do preser e biology teachers possess a subject matter structure?

When students were asked if they had ever thought about biology in terms of its constituent topics and the possible relationships between these topics (Questionnaire #1), the overwhelming answer was "no." Nine of the ten subjects responded with a simple "no" to the question: "Have you ever thought about your content area in the way you have been asked to do so above?" One student indicated that he had thought about it "somewhat." During the interview, when asked to elaborate on this answer and the feelings they had when initially completing the questionnaire, comments such as the following were representative:

> It kind of made me feel, I don't know if ignorant is a good word. I put biology down (on the paper) first, and from there I didn't know where to go.

> I never tried to just sit down and tried to think of all the things I might be teaching. In fact, your class where we were supposed to come up with our resource file (of major content topics), that was the first time I really thought about what biology was all about.

Contrary to the findings of previous research, which used card sort tasks to determine a subject's science subject matter structure (Baxter, et al., 1985; Hashweh, 1986; Hauslein & Good, 1989), the preservice teachers in this study, completing their final year of coursework, had no coherent structure of subject matter. The absence of such a structure or conception of subject matter in preservice teachers is disconcerting but has been supported by other recent studies. Borko and Livingston (1990) found that student teachers lacked the "connectedness" in explanations that more experienced teachers possessed, often due to the inability to plan more than a day or two in advance. This supports the contention that a well defined subject matter structure may not have been in place prior to student teaching. Morine-Dershimer (1989) asked students to construct a concept map of the subject m tter that they would be teaching to peers in a "microteaching" course. All students in the study found it necessary to reorganize their concept maps after teaching to make them more logically consistent and address the conceptual framework the subject matter was based upon. The emphasis on conceptual orientation and organization was fostered by the format of the course and was not spontaneously recognized by the subjects. Despite consulting multiple textbooks for the content of their subject matter structures, these students (Morine-Dershimer's) did not seem to be able to address the types of topics they might teach and the logical relationships among them in an adequate manner.

In each of the above studies, including the one presently being reported, students' conceptions of subject matter structures were determined through open-ended questionnaires and/or interviews. In each of these cases, it appears that students do not possess a coherent subject matter structure as a result of their university content courses. This has not been the finding of studies utilizing card sort techniques. Perhaps, the more directed card sort tasks used in previous investigations actually served to create the subject matter structures reported as opposed to providing an objective assessment of cognitive frameworks possessed by preservice/inservice teachers. This possibility may limit the generalizability and validity of such studies.

What do these subject matter structures look like?

The reader is reminded that the overall approach of this study was qualitative in nature. Of primary interest were the general formats or orientations of the subject matter structures students' possessed and the global changes which took place over the course of the final year of teacher preparation. Hence, an in-depth analysis of the specific topics included in the diagrams was not pursued.

Interview responses indicated that preservice teachers felt very inadequate while completing the initial two administrations of the questionnaire. Many felt confused, uncertain of what to put down, and leery that this was a test of their content understanding. The following comment illustrates the feelings of many of the subjects while they compared the four sets of answers to the questionnaires:

> As I went along it got better because it seemed more logical to me. Because, here [pointing at questionnaires 1 and 2] it is obvious that I didn't know what the heck I was doing. Things just didn't flow together very well. There were like little groups of things that I was taking [in college]...

In general, if any response is accepted as a structure, as was the case in this investigation, the structures students provided were primarily listings of discrete biology courses taken at the university (see Figure 1).

Insert Figure 1 about here

In particular, main categories such as Anatomy & Physiology, Botany, Cell Biology, Classification, Ecology, Genetics, Evolution and Zoology were common. Though the formats that the students used varied [e.g., linear (Figure 2), hierarchical indication of members of a set (Figure 3), web-like (Figure 4), discrete topics (Figure 1)], few connections or themes were evident between or within the listed topics.

Insert Figure 2 about here
Insert Figures 3 and 4 about here (side by side?)

Organizational patterns, if they existed at all, resembled a linear approach to biology, starting with cell biology, moving through genetics, plants and animals, and ending with ecology. It should be noted that these categories and arrangements are similar to those found in the required content courses for biology certification and resemble the organizational structure of many popular high school level textbooks.

It is also interesting to note the discrepancy between the subject matter structures derived from this study and those reported by Baxter, et al., (1985), who provided students with thematic topics (e.g., science as inquiry, diversity of type and unity of pattern, complementarity of organism and environment) as part of a card sort exercise. Thematic topics rarely occurred in the subject matter structures of the students in the current investigation, supporting the possibility of a testing effect in earlier studies which employed card sort techniques.

What is the source of one's subject matter structure?

As mentioned above, and as might be expected, the topics which students selected for inclusion in their subject matter structures came directly from biology programs to which they had been exposed. When questioned directly about the source of the structures that had been recorded, the students comments were as follows:

> I took biology in ninth grade and it was so bad. I remember about two things from the whole class. One was we had to memorize the formula for photosynthesis, and we all cheated, and we dissected frogs, and that's all I remember.

> I've been so used to, in college, you take plant physiology and it's just plant physiology. You take invertebrate zoology and it's just invertebrate zoology.

> I guess I've been biased being here at the university for so long. These are the courses I've taken to get knowledge in these areas so that's why I feel that they will become what I teach in the future.

> My basic idea hasn't changed, but basically when I started out with this [questionnaire] I was viewing this as what college biology was like, because I really can't remember high school that well. I can remember a few isolated things that we did, but I don't remember what order they did them in.

Despite references to the fact that of college and high school biology courses and programs had an influence on subject matter structures, little pride in the science teaching profession can be derived from comments such as these. These students had only isolated memories of the content which they learned in high school biology, and only a topical list of courses which might fall under biology as a result of their college coursework. When integrating topics were recognized because of their presence in a number of classes (e.g., genetics, DNA, evolution), little appreciation or understanding of the value of this integration existed. These comments should cause the science teaching community, both at the public school and university levels, to take a serious look at the types of knowledge and understanding which are communicated to students.

The preservice teachers also admitted that their structures were only tentatively delineated without any apparent rationale. The realization that maybe there should be an organizing framework from which to view biology (fostered unintentionally by the administration of the questionnaire) seemed to bother many of these students. The following quote illustrates this point:

> I feel like the only pattern I had when I made that [subject matter structure] was the pattern I've been fed. And because I've been channeled through [the content] one way. And so I'm afraid I'm going to spit it out the same way it was fed to me without actually thinking about it, why things should be organized in a certain way.

These findings suggest that college biology students are not being provided with an explicit or implicit structure of biology as part of their content preparation. This is not surprising considering the manner in which college science courses are taught and presented as topics and courses disconnected from the knowledge potentially gained from total programs (Cheney, 1990; Kennedy, 1990). Unfortunately, this fragmented and discrete style of content presentation may be passed on, intact, as these preservice teachers attempt to teach courses at the secondary level. This is of particular concern since an integrated understanding of subject matter is considered to be of vital importance for both teacher and students by the current reform movements in science education (National Research Council, 1990).

Is the subject matter structure stable during the final year of teacher preparation?

Changes in responses in the questionnaires were evident by the third and fourth administrations, suggesting that students' conceptions of subject matter are not stable during the final year of teacher preparation. In fact, these structures were quite malleable and easily influenced by reflection on subject matter knowledge, coursework in content specific education courses, and the act of teaching. This flexibility is encouraging in light of the initial structures recorded by the students and the misalignment of these structures with many of the conceptions which we would hope new biology teachers would bring to the classroom (as specified by the National Research Council, 1990). The specifics of the influence of reflection and content specific education classes on subject matter structures will be addressed below. The influence of teaching will be discussed in the following section.

It is interesting to note that the original format selected by individuals in designing the diagram of biology (e.g., hierarchical, linear, etc.) remained relatively constant throughout all attempts at this task. Many students seemed to use the initial format as a point of departure for their thinking and expanded upon it with additional reflection, as the following comment suggests:

> I'd say the last two times [I filled out the questionnaire] I felt a lot better about it because I felt like I knew what was going on. Because I had a graphic in mind and I could stretch it. And a graphic shows a lot

> more than a laundry list. An umbrella or concentric circles have certain meanings. Maybe not to the reader, but they certainly had meaning to me.

This "stretching" process emphasizes the usefulness and importance of allowing students multiple opportunities to reflect on their subject matter. This form of reflection does not seem to occur spontaneously or in the process of science content courses, but may be a natural addition to science education classes. Without an opportunity for such reflection, students' beliefs about their content and how they will teach it may go largely unrecognized. Articulation of these beliefs in some manner may increase the likelihood that they will have a positive and conscious affect on teaching practice (Cornett, Yeotis & Terwilliger, 1990). As one student explains:

> Just making someone reflect upon themselves like that has to help somehow. And I look at it [filling out the questionnaires] now and I think that it helped me a lot because I had to write it down. You can have these abstract ideas and, well, for me personally, until I write them down they don't mean anything. So I wouldn't say it [my diagram] was great, but it's been a good tool after all.

Possibly as a result of this reflection, and possibly as a consequence of education courses they were taking, changes occurred in the conceptions students had of the meaning of the subject matter structures they had designed. In response to the question "Have your views changed? How?," students wrote:

> Maybe they haven't changed as to what I put down on paper, but I have realized that a science classroom isn't just for dissections, lectures, and questions, but so many other things can be discussed as well.

> Yes, but it is not reflected above. Biology and teaching is more complex than I "imagined" - "knew" - The more I know; I know! I know less and less! About biology and all related subjects and teaching!

By the third administration (which occurred at the end of the Science Methods course Fall Term), the students felt that their subject matter structures were essentially the same in terms of content, but were now taking on new meanings in terms of how they viewed the subject matter in relation to teaching. This change was difficult for students to express in their actual subject matter diagrams, but represents a growth in their conceptions of biology for teaching. Growth such as this has often been delineated as a form of pedagogical content knowledge (Grossman, 1989) and represents a step in the developmental process of gaining expertise in teaching one's area of subject matter expertise (Gudmundsdottir, 1990). The diagram depicted in Figure 5 is taken from the fourth questionnaire of the same individual who diagrammed Figure 2. The changes exhibited by comparing this individual's first and fourth questionnaires clearly illustrate the aforementioned conceptual changes.

Insert Figure 5 about here

In addition to the conceptual changes mentioned above, other changes included an increased number of terms in the subject matter structures and a greater appearance of integration among the topics. In particular, many students added components dealing with the importance of issues related to the nature of science, relevancy of science to students' lives, and S-T-S interactions, as the following quotes portray:

> I had previously centered my teaching ideas on content - not excluding the "nature of science" and STS, but my focus is probably a more balanced approach now.

> I've added "why is biology important?" and "biology as a science" [to my diagram]. I'm thinking that there is more than content to teach and more of who I'm teaching and why they should want to learn it... I want to be able to show connection, how each step relates to previous steps and makes it relevant to everyday life.

> All sciences are connected and one cannot stand without the others. No matter who you are or where you are, you need science.

These topics were overtly taught or discussed in the Methods and Strategies course and were consistently reinforced in the other two science specific education courses. It is encouraging to see that such exposure can influence the integration of the themes considered important to biology instruction. Perhaps more importantly, students acknowledged that these additions were influenced by science related education courses. There is a general tendency for students to feel that little value has been gained from their time spent in education classes (Lanier & Little, 1986). This tendency changes when the courses pointedly address the teaching of specific subject matter (Grossman, 1987). These preservice teachers were no exception in that they considered their science education courses to be the most relevant and beneficial classes taken during teacher preparation, as the following representative quotes will attest:

> Again, I think the very first time [I filled out this form] it was more of a topical laundry list. If we go back to some of our discussions from methods and microteaching, we got more into the processes [of science]... I think then I saw things more from a teaching side, the teacher to the student. What am I trying to get them to do? And, I think, that brings in the processes....These last three classes really had a major impact on me. Tying things together, where we are going, and what the kids need.

> Student: I think before it was just bam, bam, bam, bam, bam. No interrelationships between topics, kind of a text book kind of thing. Whereas in this one [questionnaire 3] I have more of an interrelationship and stuff going on between topics.
> Interviewer: Is there anything that you can think of that may have caused these changes?
> Student: Maybe because I've had more education when it comes to sciences and stuff like that. Before I would be in biology classes and stuff and they would just cram it all down your throat. I think this more, this way I have a different outlook on science. Not just purely scientific but sort of an emphasis on other things.

> Interviewer: Why do you think your ideas changed?
> Student: I was taking methods and microteaching at the same time and I think as I got more into writing lesson plans and into thinking more of what I was going to teach, that's what changed it. Because, here [questionnaires 1 & 2] I was thinking about this as a university student and the classes I was taking.

The viewpoints expressed here resemble the science teaching orientations (Smith & Neale, 1989), orientations to the curriculum (Gudmundsdottir, 1990), or goals for teaching (Grossman, 1989) described in several recent studies on teachers' knowledge. As the students were provided with the the opportunity to reflect on their subject matter they clarified their ideas and related them increasingly more closely with general teaching approaches which might be applied in the classroom.

As previously mentioned, the fact that this reflection occurred in science specific education classes may not only be natural, but also the logical placement for such reflection. Current theories concerning knowledge specificity or generality across various domains have generally proposed that knowledge is learned in context-specific situations and then, through reflection, can be decontextualized for use in a broader range of experiences (Alexander & Judy, 1988; Brown, Collins & Duguid, 1989; Perkins & Salomon, 1989). These theories, applied to the context of this investigation, enhance our understanding of the generally poor opinions students have of generic education courses and the overall positive response they have to content specific education courses. Generic education courses, which tend to emphasize global educational theories, cannot be related to specific teaching situations by students without experience in the classroom. For the novice, only content and context specific information seems to have any relevance (see Gess-Newsome, 1991 for additional discussion on this issue). Thus, it is within content specific education courses that the greatest gains in subject matter reflection may be achieved.

It is also important to note that the researchers who conducted this investigation were directly involved with instruction in the science specific education courses. Whether the noted changes toward teaching oriented strucutres of biology would have been provided to a science professor as opposed to a science educator is a question which needs to be answered in future research. In short, questions concerning the possibility of an interviewer effect are perennial problems for research of this type (Borg & Gall, 1989).

Does the act of teaching influence one's subject matter structure?

As previously mentioned, during student teaching the preservice teachers began to structure their subject matter in terms of how they thought it should be taught. This finding supports suggestions made by Hauslein and Good (1989) that it may be impossible to view subject matter as separate from the manner in which it is, or will be, used. The act of teaching and/or thinking about how one will teach biology had a significant influence on the way that biology was perceived. The following quotes illustrate the influence of thinking about content in terms of teaching it:

> I think the first one [questionnaire] I did was like [had the categories] plants, animals and genetics. And now, well you think of it in a different way when you think about how you're going to teach it to people. I've been so used to, in college, you take plant physiology and it's just plant physiology. You take invertebrate zoology and it's just invertebrate zoology. But when you're teaching, especially younger [students], you have to show how everything is interconnected. And so that's one way my views have changed. It's not just these separate things anymore. It goes back to everything going kind of circular (see Figure 6).

> And now that I'm getting into teaching, it changed it. Yeah, now that I look at it and think about it, it really has been helpful to see how everything relates together. But, I didn't really know what I was doing back then [before I started teaching and thinking about my content area].

Insert Figure 6 about here

These preservice teachers' subject matter structures were obviously impacted by the act of teaching, or formulating ideas about how they would go about teaching. But teaching per se was not the only critical classroom variable which affected these views. As numerous other studies have shown (e.g., Duschl & Wright, 1989; Grossman, 1987; Hollingsworth, 1989; Lantz & Kass, 1987; Lederman & Gess-Newsome, in press), students' needs and abilities and time constraints also exert a significant influence on what occurs in the classroom. The following quotes illustrate the fact that these preservice teachers were no different than similar groups described in prior research:

> I changed. Primarily because, maybe, because of this particular class [a low level biology class]. I changed more toward the process orientation... Again, this group, what did they need [to know in order] to function?

> Student: But I changed it [my subject matter structure] now that I'm doing my student teaching. And as I'm teaching to the kids I'm realizing that you can't just have a group of plants and say "these are plants." You have to break it down into smaller groups and give them a little bit at a time. The main thing is that my other ones [structures] weren't broken down into smaller categories. And I realize now that they [the students] can only handle a little bit at a time. And breaking it up into smaller categories is easier for my organization as well as for them to understand how everything really fits together.
> Interviewer: So now you're looking at it from the student's viewpoint?
> Student: Right, and before I was looking at it from my own and how the other classes I have taken here [at the university viewed it]. And now that I'm actually out there and working with it [the content], it [my subject matter structure] has changed a lot.

Students in this study were seen to increase their verbal commitments to the importance of relevance and process skills to science instruction. In addition, topics were broken down and reorganized into smaller pieces to more accurately reflect what occurs in the classroom, a finding similar to those of Morine-Dershimer (1989). So, it does appear that how one uses his/her subject matter exerts a strong influence upon how one structures or perceives subject matter. But, what about the often advocated alternative relationship (Shulman, 1987)? Does the presence of a subject matter structure influence the manner in which subject matter is taught? When specifically asked whether the stated subject matter structure was evidenced in their teaching, either in practice microteaching sessions at the university or during student teaching, these preservice teachers denied such an effect.

[My subject matter structure] probably subconsciously [affected my teaching], but not directly. I think maybe I was probably concentrating too much on the content, getting the procedures down, and following the requirements of the particular lesson. I would like to think that maybe I did make a transition that way [as I taught].

Typically. the subjects talked about the importance of showing the interrelationships of concepts to their students. This often showed up in the form of using examples to tie together topics (for instance, one student discussed the importance of beach grass to prevent erosion when discussing fibrous roots in a plant unit), or in relating topics to STS and current issues in order to make topics relevant to students. But, many lamented at the difficulty of this task within the context of classroom practice. The following comments are illustrative:

Interviewer: Does your conception of biology affect what you do in student teaching?
Student: Well, it does in that I have to try to, as I'm teaching, keep these things in mind. But it's very difficult. I think student teaching right now is less a concentration on content area and more a concentr on on classroom management. That's what I'm learning out of student te.ching. And so, it is difficult, especially with the ninth graders, to even have a lecture without having it so jerky, with "you sit down" and that kind of stuff, to even try and get some kind of unifying theme in a lecture. It is almost impossible. It's more like trying to get the information out as fast as you can so you can move them on to something else where the students are not a problem.

Student: Ideally, I would like to tie in, you know, bringing in the purpose, "what is science?," and at least have that in the back of my mind as I'm presenting it [the content] and try and make it more obvious and that. But during student teaching, I just don't have the time to get everything in. I can barely managed to be planned each day the way it is.
Interviewer: So you are usually only planned one day ahead?
Student: Yeah. That's all the farther I can take it. Maybe tomorrow. Tomorrow I can handle. Two days from now, maybe if my cooperating teacher sat down with me and said "this is what we are going to do..."

Though many felt that they were moving toward a more integrated view of biology and had a new appreciation for themes which were important to its understanding, the classroom, actual or campus-based, was considered too complex a forum in which to focus on the portrayal of these beliefs. Classroom management, the mastery of lesson dynamics, and day-to-day planning overwhelmed the preservice teachers to the point that planned or spontaneous incorporation of perceived themes and topic integration became virtually impossible. This view has been supported by Hollingsworth (1989) who contends that classroom management must be mastered and routinized before teachers can attend to subject-specific pedagogy.

Implications for Science Teacher Education

It does not appear that preservice biology teachers have well formed or stable subject matter structures. The structures which do exist (if any student conception is accepted to be a structure) are largely the result of college science coursework and are often vague and ephemeral with little evidence of coherent themes. Clearly, the perennially popular policy of requiring increased subject matter backgrounds for preservice teachers may not be an effective approach for the improvement of K-12 science instruction. Paradoxically, such an approach may only serve to create preservice teachers who are even more strongly wedded to conceptions/structures typified by linear relationships among fragmented and isolated concepts. Since any significant reform in the instructional approach which typifies college science teaching seems unlikely, the responsibility of stimulating students to reflect on their subject matter seems to be most appropriately placed within the domain of the science educator. It is possible that repeated opportunities to reflect on one's subject matter structure (during coursework and field experiences) may be sufficient to provide preservice teachers with a coherent schema for their subject matter and allow them to integrate more of the information presented in their science content preparation. Since the results of this investigation elucidated the significant influence of how one uses his/her subject matter upon its structure or how it is conceived, science education courses again appear to be the logical arena for the development and reorganization of preservice science teachers' subject matter structures.

Despite the apparent ability of subject specific education courses to develop coherent knowledge structures, these structures do not appear to immediately transfer into classroom practice. It is possible that classroom complexity (as viewed by the novice or preservice teacher) alone is responsible for this lack of transfer, and that several years of experience will allow for the mastery of initial skills and permit the later emergence of integrated content presentations in the schools (Doyle, 1977; Gudmunsdottiir & Shulman, 1987). Consequently, further research is needed to determine the stability of a teacher's subject matter structure and its relationship to teaching experience as well as its eventual translation into classroom practice. It is almost certain that this transfer is not automatic and inservice programs need to act as vehicles to foster teachers' reflections on subject matter structure and its incorporation into science instruction. This is especially critical since many important characteristics of the new reforms in science education depend on the incorporation of themes such as the nature of science and S-T-S interactions. It may be that realization of advocated reforms in science education depend upon subject matter structure reflection fostered by science educators who are content specialists as well as experts in pedagogy.

Finally, the basic expectations held for the preservice and/or beginning teachers may need to be reassessed. As noted by Hollingsworth (1989) and Doyle (1977), until classroom management is routinized, few other concerns can be addressed by the classroom teacher. Thus, until a teacher has gained experience and mastered basic classroom skills, it may be unrealistic to expect coherent subject matter structures to exist and/or to be translated into classroom practice.

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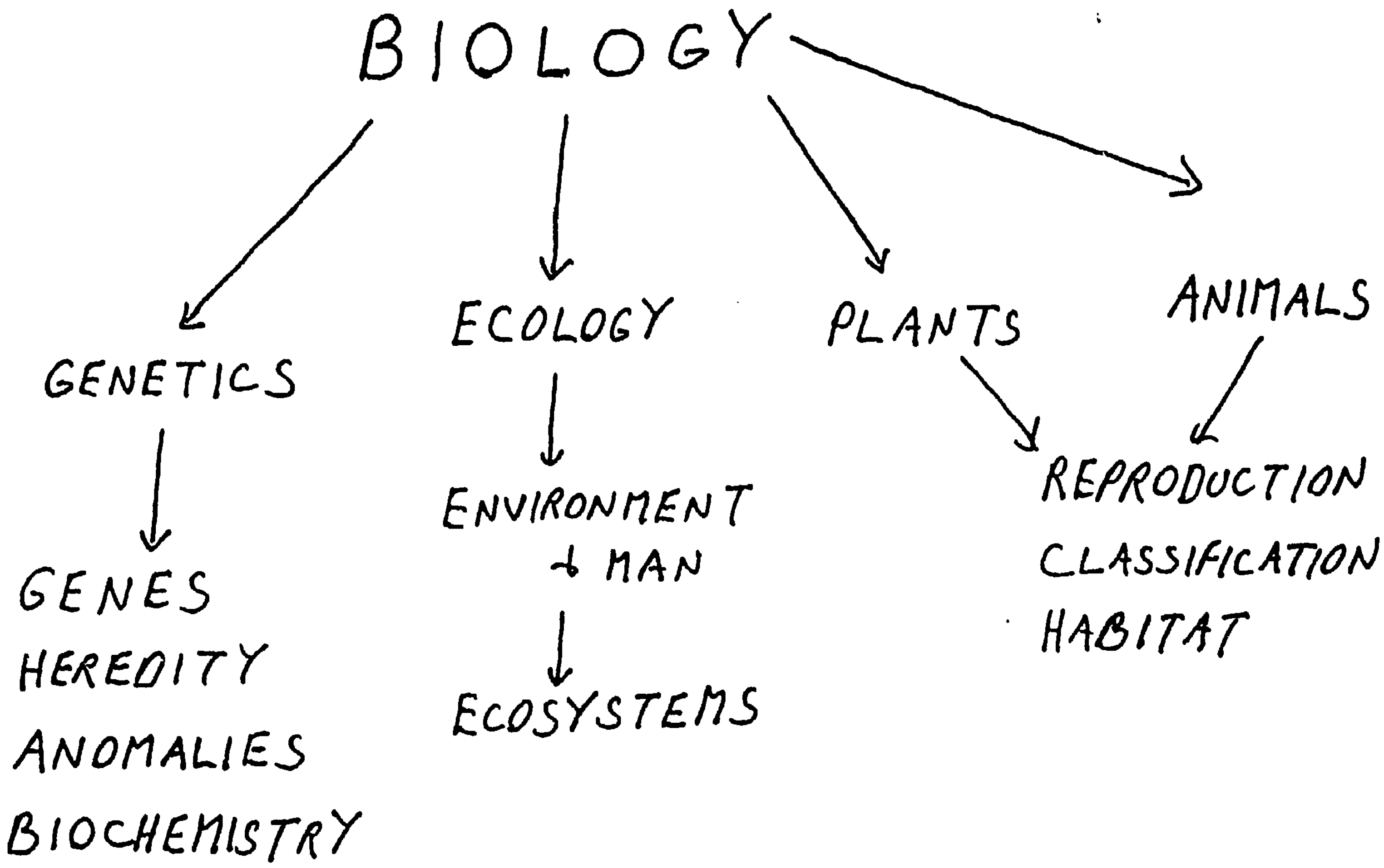

Figure 1. Representative diagram of structure composed of discrete topics/course.

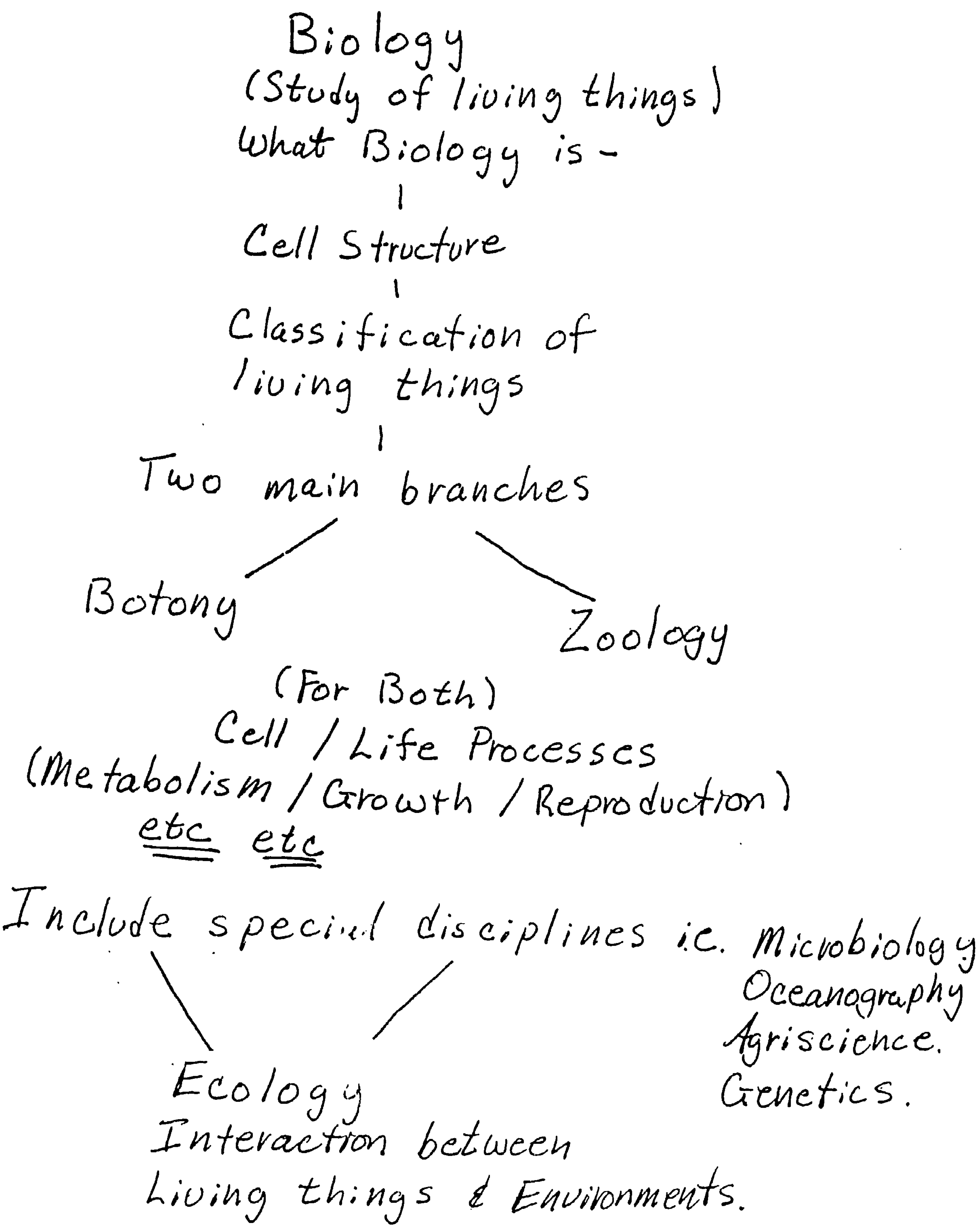

Figure 2. Linear format for subject matter structure.

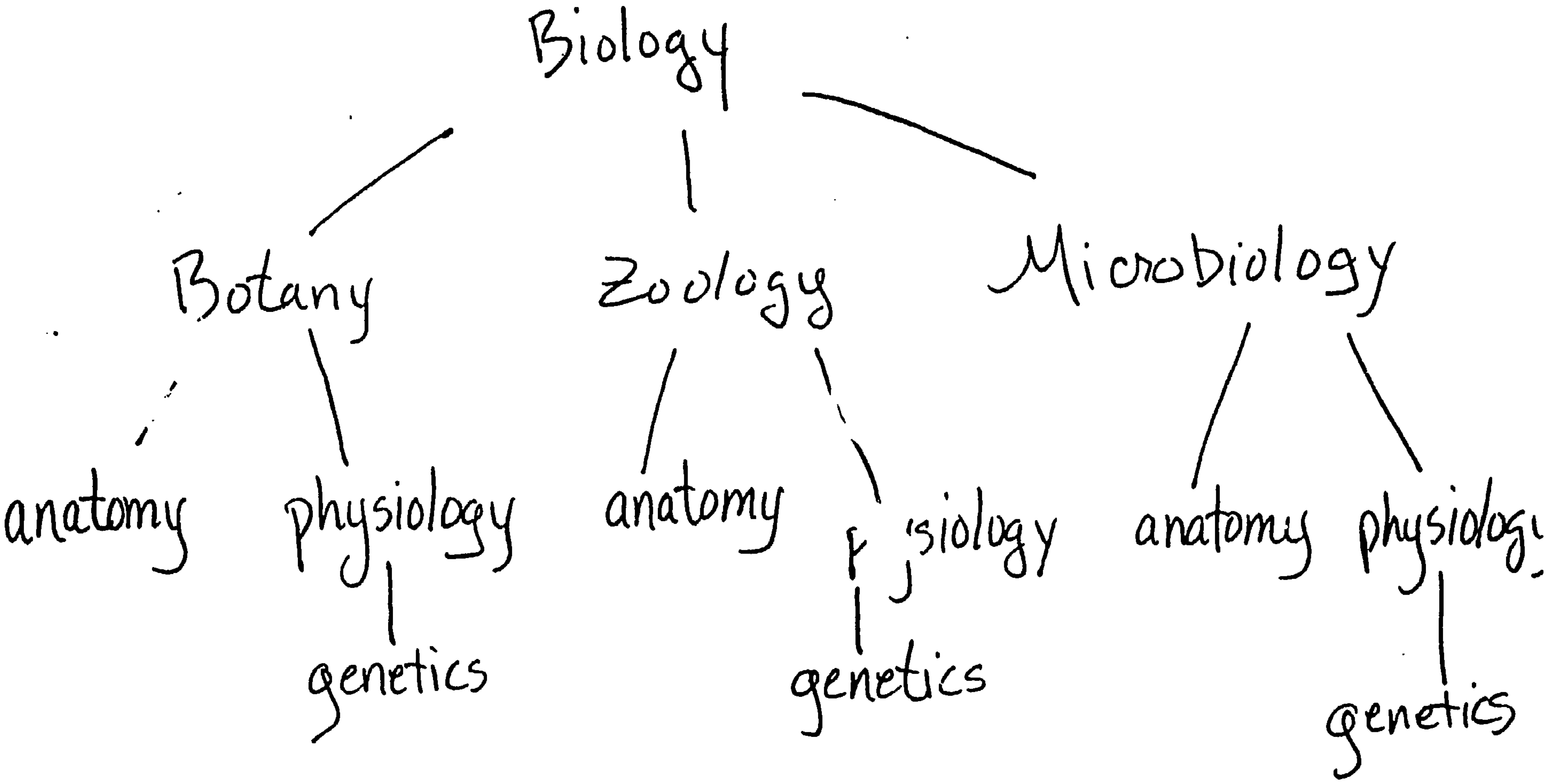

Figure 3. Simple hierarchical format for subject matter structure.

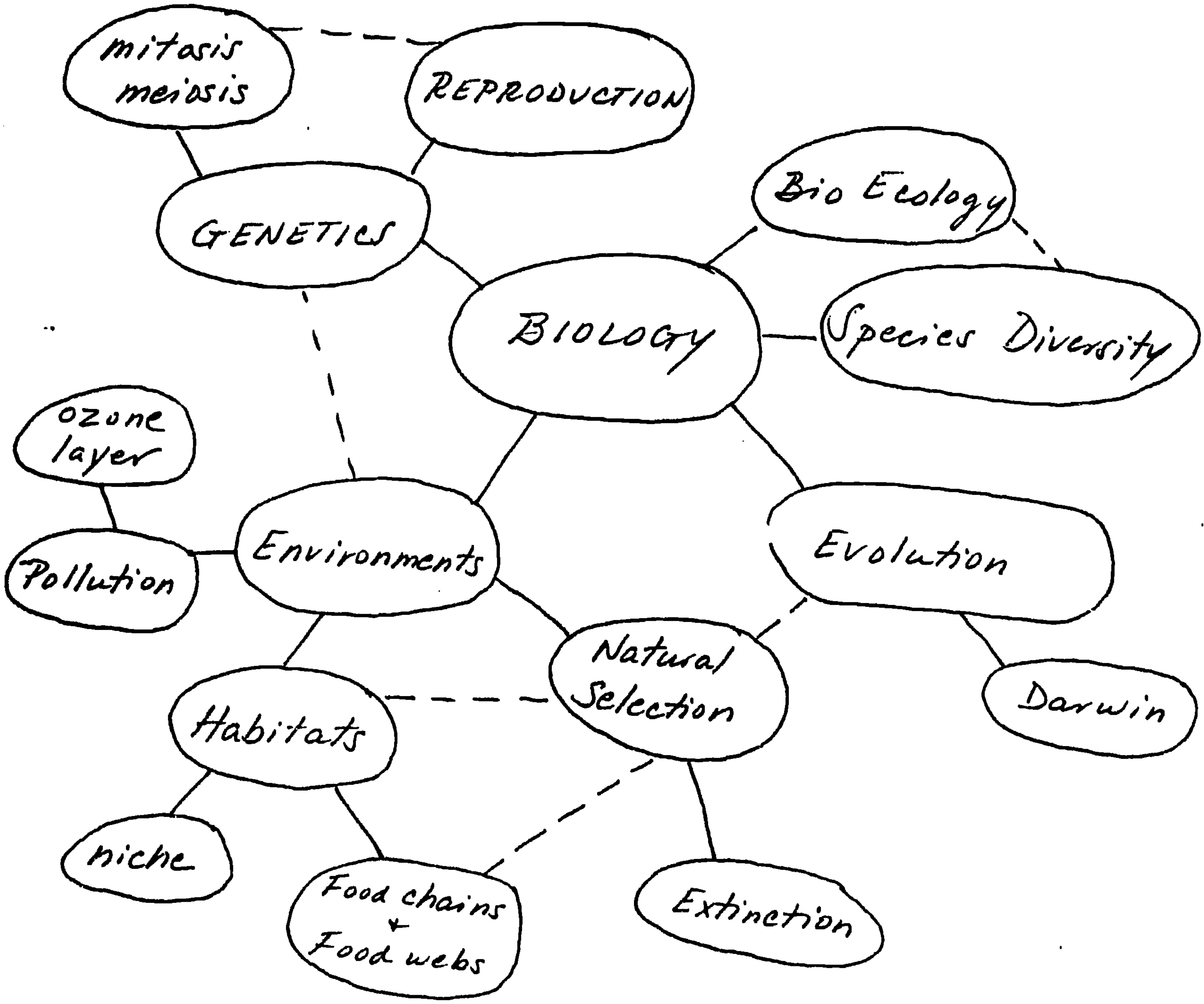

Figure 4. Web-like format for subject matter structure.

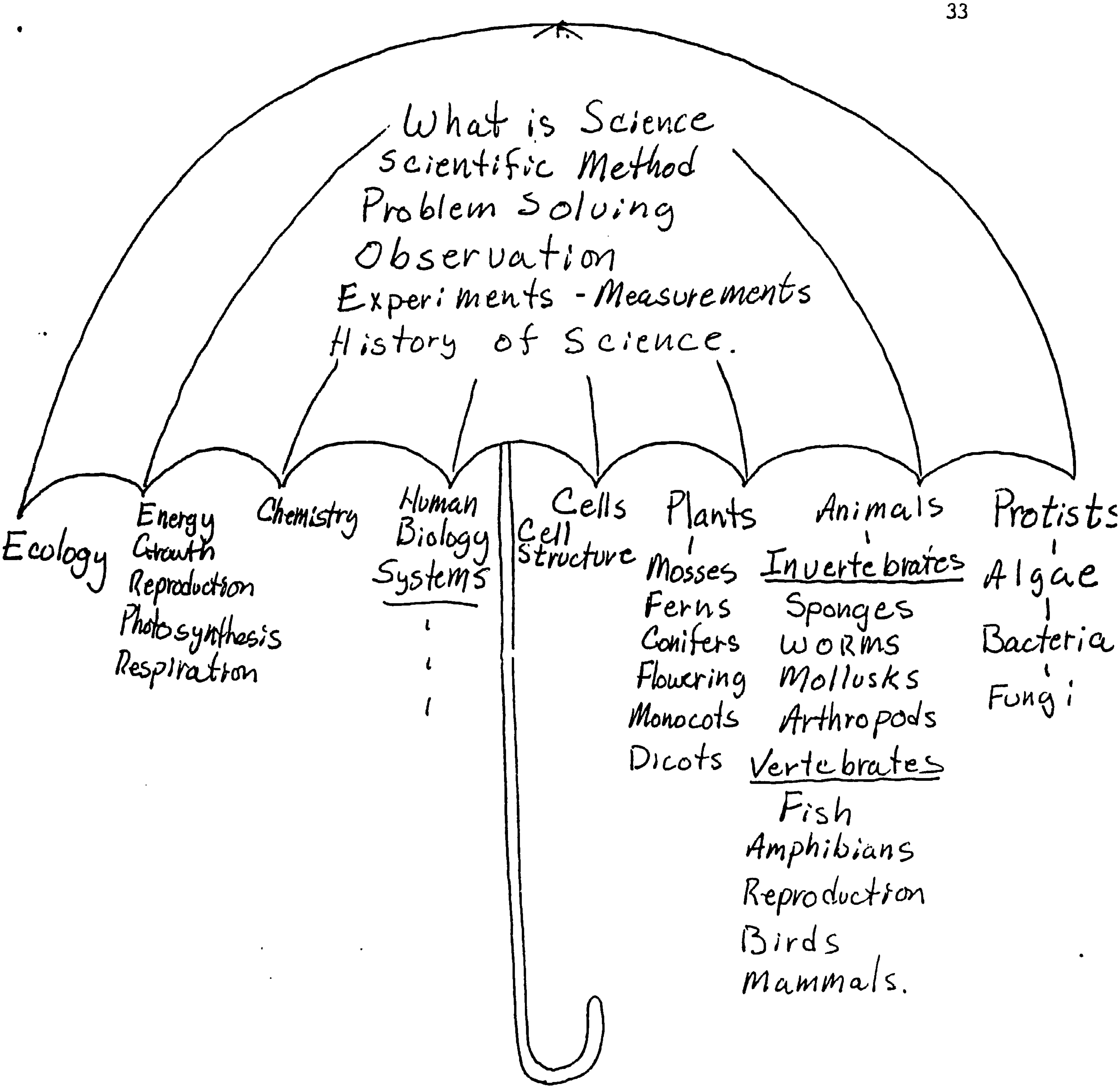

Figure 5. Diagram created during student teaching by individual who created Figure 2.

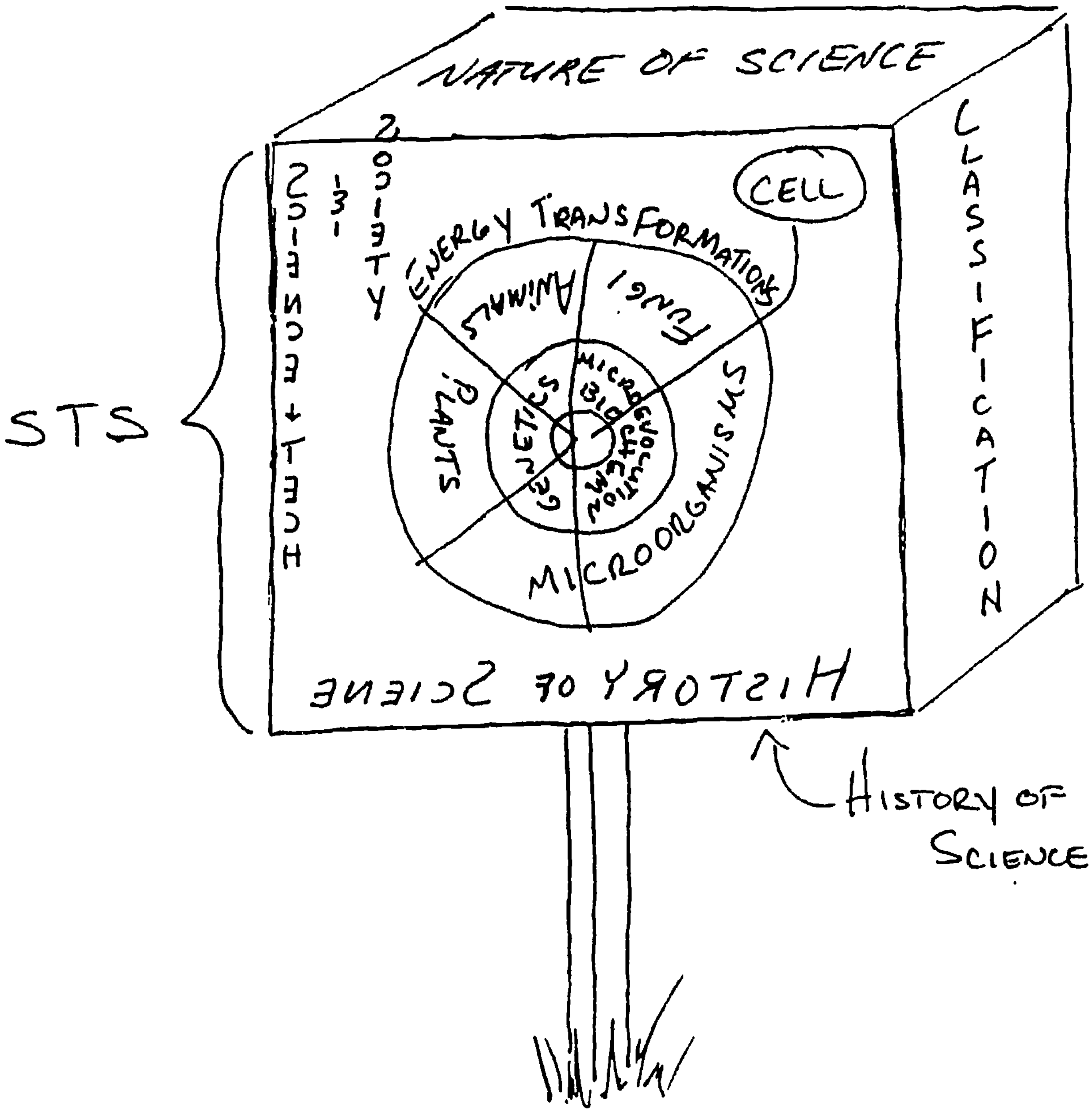

Figure 6. Integrated conception of subject matter as a reflection of having to teach biology.