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ABSTRACT

Current reform efforts in the teaching of high school biology demonstrate the need for a synthetic treatment of prominent concepts. There exists insufficient research that delineates the global content understandings--in this paper designated subject matter structures (SMS)--of biology teachers; or that assesses whether these SMS do, in fact, translate themselves into classroom practices. The purpose of this investigation was to determine the nature of biology teachers' SMS and the relationship of these structures to classroom procedures. Case studies of five biology teachers from five different high schools in a small region of a western rural state were conducted utilizing interviews, classroom observations, anecdotal data, and analyses of instructional materials. In phase 1 of the study, initial interviews were held in order to construct an academic and professional profile of each teacher. In phase 2, each teacher was observed during 15 periods within the same semester. The data were analyzed qualitatively to determine which SMS the teachers demonstrated within the classroom teaching context. These observed-SMS were compared to the SMS provided by the teachers in post-observation interviews and to the SMS encouraged by the text. In general, teachers' SMS tended to be fragmented, indicating the absence of coherence necessary to the integration of biological concepts within classroom instruction. Mediating variables between teachers' SMS and their classroom techniques included teachers' intentions, knowledge of textbook content, pedagogical knowledge, student curiosity and level of interest, teacher autonomy, and time constraints. (40 references) (JJK)

Biology Teachers' Perceptions of Subject Matter Structure and Its Relationship to Classroom Practice

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Introduction

The manner in which science is taught and the degree to which it is learned continues to be a focal point in the criticism of American schools. The academic community has responded by creating a multitude of panels who have written and promoted new directives and goals for science education. These directives commonly admonish the current tendency to teach "science as a foreign language," steeped in the memorization of static ideas and vocabulary, and advocate science instruction which capitalizes on a broad, integrative understanding of a few underlying concepts. In particular, the National Research Council (NRC, 1990) argues that "the high school biology course should be a synthetic treatment of important concepts and of how these concepts can shape our understanding of ourselves and our planet" (pg. 6).

Implicit in such a recommendation is the notion that science teachers already possess an integrated conceptualization of important biological concepts and, given the appropriate resources, will use this understanding to provide "a conceptual framework to bind the course together" (NRC, pg. 34). Research in a wide range of fields (Berliner, 1987) has revealed that teachers with "expert" knowledge have well developed schema or structures on which to build knowledge, making knowledge acquisition more efficient. Furthermore, there is some indication (Carter & Doyle, 1987) that teachers who have well developed subject matter structures will be more efficient at learning and presenting subject matter to students. For the purposes of this study, **subject matter structure** (SMS) will refer to any conceptual framework or schema which teachers have for their knowledge of the content they teach.

In many of the studies which serve as the foundation for understanding the subject matter knowledge and structures held by biology teachers (Baxter, Richert, & Saylor, 1985; Carlsen, 1989; Hashweh, 1986; Hauslein & Good, 1989), subject matter knowledge was visualized as the structure given to the content and often resembled a cognitive map. To assess such understandings, subjects were typically given cards upon which subject matter topics, determined in advance by the researcher, were written. The subjects were then requested to sort or arrange the cards in a manner which reflected the subject's content understandings. The richness of a teacher's subject matter knowledge was, thus, determined through the relationships expressed among various content topics/concepts. Translation of this knowledge into activities designed to simulate classroom interactions and/or planning activities were often conducted, establishing the potential influence of subject matter knowledge and structure on the act of teaching.

Though such approaches to studying subject matter knowledge and structure have offered new insights, many of the past methods employed may contain serious flaws. First, all of the studies which have sought to determine a teacher's subject matter structure have assumed that equally coherent structures exist at all levels of expertise. It is intuitively accepted that expert teachers develop coherent

cognitive structures in their areas of expertise, however, there is much less agreement for the belief that all teachers at all levels of experience possess such coherent and well defined structures. Despite some indication that novices also have coherent subject matter structures (Baxter, et al., 1985), it is necessary to determine if these structures were formed as a consequence of learning subject matter or as an artifact of research methods which required subjects to reflect on the structure of their specific subject matter.

Second, nearly all studies of subject matter structure and knowledge (with the exception of Gess-Newsome & Lederman, 1991; Lederman, Gess-Newsome & Latz, 1992) have provided teachers with a set of items which were to be included in content maps, or SMSs, which they were asked to create. Such restrictions may dramatically influence the outcome of an investigation. For example, teachers may be presented with terms or ideas which they would not have generated if asked to identify the key themes, ideas, or topics of their subject matter. Providing such terms may actually create knowledge by acting as a stimulus for the formation of relationships among topics which had not been previously considered or may simply lead to a misrepresentation of one's knowledge structure.

Finally, research which has attempted to explore the relationship of teachers' subject matter knowledge with teaching practice have often been limited to laboratory based activities which simulated the classroom situation (e.g., Clermont & Krajcik, 1989; Hashweh, 1986; Krajcik & Layman, 1989; Marks, 1989). Although these activities control for many variables, they provide limited understanding about the ramifications of SMS on teacher performance in an actual classroom. The exploration of the translation of subject matter knowledge within the context of an actual classroom situation is critical when one considers the conflicting information which currently exists. Some researchers (Carlsen, 1989; Dobey & Schafer, 1984; Leinhardt & Smith, 1985; Wineburg & Wilson, 1991) contend that they have found direct influences of SMSs and knowledge on classroom practice. Other researchers feel that such interactions are much more complex than initially envisioned. Many factors exist which appear to interfere with the direct translation of teachers' views to students. These factors include the teaching context (Brickhouse, 1989; Duschl & Wright, 1989), the curriculum (Lantz & Kass, 1987), and the students themselves (Beyerbach, Smith, & Swift, 1989; Brown, 1989; Housner & Griffey, 1985; Lederman & Gess-Newsome, 1991). Perhaps more importantly, attempts to relate teachers' views of the nature of science to classroom practice (Duschl & Wright, 1989; Lederman & Zeidler, 1987) have found no evidence to support the direct transfer of beliefs to the classroom situation.

The literature which deals with the SMSs of teachers has many limitations in methodology and has left many questions unanswered. If teachers have SMSs which they use to guide instruction, the elucidation of these structures may clearly have significant implications for the preparation and evaluation of teachers. Unfortunately, direct ties between possible SMSs and classroom practice have rarely been investigated. The purposes of this investigation were to determine the nature of experienced biology teachers' SMSs for biology, the source and formation of the SMS currently held, and the relationship of teachers' SMSs to classroom practice.

Method

Since this investigation was exploratory in nature, an inductive, qualitative method of data collection and analysis, as described by Bogdan and Biklen (1982), was used. Generally speaking, this means that the data generated in each phase of the study was looked at holistically in order to derive any evident patterns or categories of information. These patterns and categories were then "tested" against data from subsequent phases with patterns and categories being added or deleted. It was hoped that this method of data analysis would remove potential bias which may be introduced by the use of a priori patterns or categories.

Each phase of data collection and each type of data was analyzed separately through a constant comparative format. The details of this method will be described within the phases of data collection and analysis which follow. Triangulation among data types and phases was sought in order to confirm or question the patterns of evidence found among the various phases and types of data collected.

Sample

Five male teachers from five different high schools in four school districts agreed to participate in this study. This was a sample of convenience from a small region of a rural western state. Though this sample included all male teachers, this sample was representative of the biology teaching population in this area. The sample of teachers who volunteered for this study had a range of 7 to 26 years experience in the teaching of high school biology ($\overline{X}$ = 12.2 years). Pseudonyms (Alex, Ben, Carl, Don and Ed) were randomly assigned to assure the anonymity of the teachers.

Three of the teachers, Alex, Don and Ed, taught in a large school district which served a population of approximately 45,000. Alex and Ed taught in the two high schools located in a town of approximately 40,000. Don taught in a rural high school in a nearby town of approximately 5,000. The final two teachers, Ben and Carl, taught in rural school districts with town populations of approximately 5,000.

Though some of the schools used in this study were quite small, all of the schools had at least one other faculty member who had teaching responsibilities in biology or life science. In addition, none of the teachers selected taught biology exclusively, having either two or three class preparations during the semester of observation. Interestingly, all five teachers were using the same biology textbook (Biology: The Living World, Prentice Hall, 1989), and taught multiple sections of biology. The fact that the same textbook was used by all teachers acted as a "natural control." Specifically, variations in the order of curricular topics and manner of presentation could be attributed to decisions made by the teachers rather than as a function of the textbook.

Phase I: Pre-Observation Interviews

The initial data collection phase of this investigation focused on the development of a profile for each teacher. A semi-structured interview was conducted prior to the start of the school year. To avoid sensitizing the subjects to the focus of the investigation, each teacher was told that he would be

observed as part of a study to determine the various techniques used to teach high school biology. Since many acceptable variations of the teaching of biology exist, it was hoped that such an explanation would help reduce teachers' concerns about critical evaluation and minimize the impact the observations on the classroom structure.

The initial interview followed a protocol which focused on the following categories of information: general academic and professional background of the teacher, the specific climate for teaching biology, and teacher intentions in terms of teaching biology. The interview was followed by a request for a written list of subject matter and education courses taken as part of preservice or inservice teacher preparation. Finally, a copy of the textbook and curriculum guidelines (if they existed) for the biology course were requested. The pre-observation interviews, which lasted between 45-90 minutes, were audiotaped and transcribed.

Past studies (Gess-Newsome & Lederman, 1991) have demonstrated the potential testing effect which can exist from asking teachers about their SMS. In an attempt to control for such effects, two of the five teachers were randomly selected and asked to complete the SMS questionnaire listed in Figure 1 prior to the first classroom observation. The teachers were informed that the questionnaire was intentionally vague and that there were no wrong or right answers. The results of the questionnaire were requested in writing and remained unknown to the researcher until the conclusion of data analysis in Phase II. This process avoided potentially biasing the researcher's subsequent classroom observations and derivation of apparent subject matter structures as they appeared in classroom instruction.

Insert Figure 1 about here

The methodology described was considered superior to those used in previous investigations for three reasons. First, the topics which could be included in the schematic of biology remained open-ended, removing possible sources of bias imposed by the researcher. Second, less than half of the subjects were asked to complete the SMS questionnaire prior to the investigation. It was hoped that this approach would help determine the potential testing effect of the questionnaire. Testing effects could occur through the "creation" of a subject matter structure where one did not previously exist or through the sensitization of a teacher to a SMS, potentially increasing the possibly of translation of the SMS into classroom practice. Third, by not allowing the researcher to see this information, the classroom observations had the potential to act as objective measures of the impact of a teacher's subject matter structure on classroom practice as opposed to verification of a belief held by the researcher.

The information collected from the initial interview and the list of education and subject matter courses provided by the teacher was used to construct an academic and professional profile for each teacher (e.g., educational background, coursework, philosophy of science teaching, and personal perceptions of teacher preparation, the community, and the school situation). Additional information, offered by the teachers throughout the investigation and during the final interview, was used to enhance or modify this profile.

Phase II: Classroom Observations

The second phase of the investigation consisted of extensive classroom observations and the collection of classroom documents and anecdotal data. The primary purpose of this phase was to attempt to inductively generate the SMS of each teacher as evidenced by patterns in classroom teaching. This methodology was considered superior to previously used techniques because it removed researcher bias introduced by prior information concerning teachers' knowledge structures and acted to closely link evidence of potential SMSs to classroom practice.

Three types of data were collected and analyzed: classroom observations, classroom documents, and anecdotal data. Classroom observations were prearranged with the teachers and occurred within a single Biology class of the teacher's choosing. Attempts were made to observe the class once each week and to see as wide a range of classroom situations as possible. Classroom observations focused on the general presentation of biology content. All verbal transactions between the teacher and the students were audiotaped and supplemented by extensive field notes recorded by the researcher. The field notes specifically recorded information concerning the teacher's movements and apparent enthusiasm, student interest, general classroom tone, teacher and student actions, student behavior, conversations not directed to the teacher, observer impressions of the overall class proceedings, board and overhead work, and the sequence of any written materials used during the class period. Data from the field notes were merged with those from the audiotapes by the researcher in order to provide the most extensive record of the class period as possible.

Documents used in the normal course of teaching were collected as a second form of data in this phase of the investigation. Each teacher was asked to save all written materials provided to students (worksheets, textbooks, laboratory activities, homework assignments, tests, quizzes, and final exams, etc.) as well as copies of lesson plans. There were three primary purposes for the collection of the stated documents. The first was to provide information on the classes which were not actually observed by the researcher. It was hoped that the comparison of classroom observations and lesson plans would aid in the interpretation and portrayal of all lessons taught. Secondly, the materials collected were analyzed in order to make inferences about the nature of the teacher's SMS. Finally, the analysis of documents provided general descriptive data concerning the overall classroom routines and activities as well as a check for the consistency of teacher stated philosophies into practice.

Anecdotal data, often in the form of conversations which occurred prior to or following a lesson or during phone conversations, were also documented for later analysis. Such conversations often provided information on a teacher's general classroom philosophies and perceptions. For this reason, anecdotal data was often used to enhance the information gleaned from the pre- and post-observation interviews and contributed to the philosophy statements derived for each teacher.

Data analysis during this phase of the investigation was continuous and was used in two ways. First, a classroom profile portraying a generalized class period and a description of general classroom routines was constructed by the researcher in order to provide the context of the teaching situation. Second, an extensive analysis of the data was conducted in order to extract any potential indicators of

the nature of a teacher's SMS was used to generate a graphical representation of each teacher's SMS of biology as evidenced in classroom presentations. In addition to the generation of a SMS for each teacher, a SMS was derived for the textbook, Biology: The Living World (Prentice Hall, 1989), following the same procedures. The SMS of the text was compared to the SMSs derived from classroom instruction in order to determine any possible relationship.

The process of generating a classroom (and textbook) SMS was derived through initial analyses of the classroom data as it was collected. Though the specific procedures are too complex to fully describe in this article, an overview of the procedures may help the reader interpret the researcher-derived SMSs. Since the procedures for generating the textbook and classroom SMSs were essentially the same, Figure 2 will act as a model and referent for the following explanation of procedures. First, the classroom transcripts were read each week to develop a general "picture" of the content being taught by each teacher. This description consisted of a series of informal notes related to the sequence of instructional units (creating a linear "content map" and represented by the numbers preceding the unit names, as can be seen in Figure 2) and their content. Units which would be potentially taught during the second semester were not numbered (since their actual sequence was not observed). Units were titled and graphically represented with a box.

Insert Figure 2 about here

Secondly, potential indicators of the nature of the SMSs of the teachers were sought. Such indicators, derived from classroom transcripts and materials, were defined as instances of connections or themes. These categories were qualitatively determined through several initial analyses of the data and were determined to be the most descriptive of the conceptual framework potentially held by the teachers. Connections were defined as instances in which the teacher specifically or inferentially related one content topic to another. Such connections were required to include more than just the use of previously defined vocabulary. For a portion of the text or a transcript to be considered a connection, content outside the specific unit of instruction was introduced in such a way as to build on previous content (a back-reaching reference) or allude to upcoming content in a way which states a relationship between current and upcoming content (a forward-reaching reference). For example, simply using the term "enzymes" in a chapter on digestion (i.e., "enzymes are found in the stomach") would not be sufficient to constitute a connection. However, a reminder that "enzymes can only operate on a single substrate so that there must be a wide variety of enzymes in the digestive tract," or, "enzymes can be denatured by changes in pH such as those that exist in the various portions of the digestive tract" would be considered examples of back-reaching references. Connections of this nature were identified in the transcripts, paraphrases and noted in such a way as to facilitate the documentation of connections on the previously created linear framework (i.e., Human Biology -> Cell Energy: Enzymes can only work on one substrate, thus many types of enzymes are needed in the digestive tract). Connections were graphically represented by arrows indicating the source of the connection and its referent. Units which

had multiple referents between them (forward- and back-reaching connections) were represented by overlapping unit boxes.

The second type of evidence which was used as a potential indicator of the nature of a teacher's SMS involved the presence of themes. Themes were considered to be rationales, concepts, or goals which were "laid over" the content being taught and occurred on several nonconsecutive days. For instance, in the analysis of the textbook (Figure 2), evidence for two themes emerged: History of Science (HofS), and Science-Technology-Society Interactions (STS). The HofS theme was evidenced by the inclusion of the historical development of a scientific concept. Such passages often included the scientists involved and the theories which they influenced. STS interactions included situations in which science was applied to develop technological solutions to a problem, where technology furthered the development of science, or where society affected or was affected by either science or technology. Themes were noted by name or graphically represented as ideas (boxes) overlapping multiple units (where applicable).

The procedures just described were formulated during the initial readings of the transcripts and classroom data. Each data type was analyzed separately and then across data types to assess congruence and to generate a comprehensive profile of the classroom situation. Informal analysis, or data analysis which occurred weekly during the classroom observations, was used to ascertain patterns, develop working hypotheses, and direct future data collection. Hypotheses formed each week for individual teachers were tested through subsequent analysis of additional data. Patterns supported through a number of sources were recognized as more consistent. Patterns supported through single and multiple data sources acted as foci for questioning during the final interviews. The end product of this analysis was a rough draft of a SMS for each teacher and the textbook.

Classroom transcripts and instructional materials were analyzed a second time in order to find evidence of direct of implied connections and themes. From this analysis, a SMS was created for each teacher to provide a visual representation of the SMS as inferred through the mediums of classroom discourse and materials. Once the SMSs were completed, a third reading of the set of transcripts for each teacher was conducted in order to verify the patterns derived in the SMSs. Narratives were developed describing the meaning of the SMSs, the major types of connections found, and the factors which influenced the SMSs interpretation. All analyses described to this point occurred prior to the final interviews which took place in Phase III of the investigation.

Phase III: Post-Observation Interviews

The final phase of data collection consisted of an audiotaped, semi-structured interview conducted within six weeks of the semester of observation. The final interview focused specifically on the teachers' perceived structure of biology and was audiotaped and transcribed for later analysis. Actual interviews lasted from one to three hours.

Prior to the start of the interview the teachers were again reminded of the general "purpose" of the investigation and told that the focus of the interview was on understanding what the teachers

thought, the reasons behind their actions in the classroom, and the factors which affected these thoughts and actions. The first portion of the interview focused on general questions of clarification. These questions were specific for each teacher, and generally dealt with global issues which arose as a function of the classroom observations, such as school responsibilities, etc. Following this opening series of questions, the teachers were asked about their current teaching situation (Spring semester versus Fall semester) and to discuss any changes which might have occurred.

These questions acted as a prelude to the discussion of information specific to the Fall semester. These questions included issues related to the content that they taught and the teacher's perception of his own subject matter knowledge gained in school. Specific information concerning a teacher's philosophy of teaching and sources of teaching ideas were collected in order to increase the understanding of the selection of classroom activities. This information also contributed to the understanding of the potential sources of the SMS observed and inferred from classroom observations. Finally, the teachers were asked specific questions which related to the rationale (intentions versus reality) behind what actually occurred in their classrooms and the perceived situational constraints, if any, that existed.

Following this line of questioning, all teachers were asked to complete the questionnaire concerning subject matter structure (Figure 1). Several minutes of undisturbed time were provided for each teacher to complete this task. When the teachers felt comfortable with the answer (usually after 5 to 10 minutes), the teachers were asked to describe their SMS and elaborate on the relationship between their SMS and their classroom teaching. Teachers who filled out the SMS questionnaire prior to the classroom observations were asked to reflect on the impact of recording their SMS earlier in the study and to compare their current views to those they stated earlier.

Triangulation of Data Sets

All sources of data and the results of the data analysis from each phase were considered in totality to help judge the congruence of the overall case study developed for each teacher and to answer the original research questions. For example, general statements concerning a philosophy of education described in the initial interview were judged against what actually occurred in the classroom situation and similar philosophies described in the final interview. Points of reaffirmation or contradiction were noted and discussed in the case studies developed for each teacher.

Data analysis and triangulation were used to answer three general questions: 1. What is the nature of Biology teachers' SMS? 2. What is the source of teachers' current SMSs and what factors have influenced its formation? 3. What is the relationship between teachers' SMSs and classroom practice? The first question addressed the nature of teachers' SMS of biology and the potential consistency of such structure across teachers. The teachers were asked whether they had ever thought about biology in the manner recorded in their SMS prior to this time. The answer to this question, and the comparison of the answers across teachers, helped establish whether the teachers in this study possessed teacher-recognized structures of biological knowledge to which they consciously referred. Teacher-generated

SMSs were also analyzed in several ways. Similarities and differences in SMSs in terms of content, organization and rationale were sought among the teachers' descriptions of the SMSs. Potential reasons behind the differences and similarities noted were sought in the individual case studies and were compared in order to generate hypotheses which would account for the noted patterns. Finally, a global analysis of the teachers' SMSs was conducted in order to identify the key elements selected and the formats used. This analysis was used to permit subsequent comparisons between the results of the data collection procedure used in this study with those used in other research attempts of this nature (specifically, studies using card sort tasks). Any lack of similarity between the topics mentioned by the teachers in this study and those provided by teachers in other studies was considered evidence for a lack of validity of the instruments used in other studies and is a partial validation of the procedures used here.

The second question related to the potential sources of a teacher's SMS and the possible factors which may have influenced its formation. Hypotheses concerning the sources of a teacher's SMS evolved and were tested as an ongoing part of this investigation. Specific hypotheses concerning teaching load, the role of the textbook, involvement in curriculum work, and years of teaching experience were explored. The answers to many of these questions were sought in an analysis of classroom and interview transcripts. In several cases, questions specifically addressing these issues were added to the final interview. Comparisons within and across teachers were conducted to test the stated hypotheses. If teachers stated that they had thought about the structure of their subject matter, specific accounts of when and why were analyzed. The identification of specific situations which encouraged the creation and translation of a SMS into classroom practice were sought. Comparisons among the structures drawn by the teachers of various levels of experience and expertise were also made in order to assess the possible influence of general teaching experience and educational background.

To understand the role of the textbook in the SMSs evidenced in classroom teaching, a SMS of the textbook was derived using the same procedures used to construct those generated from the classroom data. Comparisons between these two structures then acted as an independent assessment of the influence of the textbook. This information was used in addition to the information provided by the teacher on the perceived role of the text on classroom practice.

The third question addressed the relevance of the stated SMS to classroom practice. To determine the influence of SMSs on classroom practice, a comparison was made between the SMSs described by the teachers and those derived through the analysis of classroom data. The degree of consistency between the structures acted as an objective measure of the influence of SMS on classroom instruction. High congruence was taken to indicate a direct relationship between a teacher's SMS and classroom practice. Limited congruence was taken to suggest a more complicated relationship, or no relationship at all. Factors contributing to any type of relationship were sought in both classroom and interview transcripts. These factors were compared across teachers in order to generate hypotheses about the potential importance and impact of SMS on classroom practice.

Results and Discussion

A total of 69 classroom observations were conducted during the Fall semester, generating over 1100 pages of single spaced field notes. Though it was initially intended that observations would take place once each week, exam schedules, vacations, testing, and teacher absence often prevented the realization of this schedule. Three of the teachers, Alex, Ben and Ed, were observed 15 times during the semester, Don 14 times, and Carl was observed 10 times. Observations of Carl were interrupted by teacher illness, absence due to coaching, and a "floating" schedule in which Carl saw each class only six of every seven school days. Despite these interruptions, Carl's ten observations provided the same percentage of observations to teaching days as the observation schedules of the other teachers ($\bar{X}$ = 17.6% observations/teaching days, range = 16.9 - 18.2%). Carl had 17.2% observations/teaching days.

In addition to the field notes and transcripts, over 250 samples of classroom materials were collected in addition to copies of the semester's lesson plans from each teacher. Copies of the textbook and lab book used by the teachers were obtained for analysis. The data described were used to generate a case study for each of the five teachers. Each case study was organized into the following subsections: Academic and Professional Profile, Course Specific Perceptions and Concerns, Classroom Profile, Classroom Subject Matter Structure, Self-Described Subject Matter Structure, Summary. Due to the extensive nature and length of the individual case studies ($\bar{X}$ = 70 pages), only an overview of the findings of this investigation will be reported.

The Nature of Biology Teachers' Subject Matter Structures

In general, all teachers' SMSs can be claimed to be content based (see Figures 3-9). The primary terms used in the SMSs related to major groupings of content (e.g., cells, ecology, evolution, genetics, botany). This terminology is consistent with the terms used to classify content into textbook chapters or university content courses. The use of such terminology is consistent with that found by Gess-Newsome and Lederman (1991) when they used a similar questionnaire with preservice biology teachers. However, the use of such terminology is inconsistent with that provided by card sort tasks typically used to elucidate biology teachers' conceptions of SMS.

Insert Figures 3 - 9 about here

In all cases, the teachers in this study seemed to recognize an interaction among the content items which they listed in their SMSs, though the degree of integration varied with each teacher. Such interactions were illustrated in a variety of ways. For instance, Don's pretest SMS (Figure 3) showed the interrelationship among content topics as a series of double headed arrows. His posttest SMS (Figure 4) represented such interrelationships as a series of concentric boxes which described the foundational designation of some of the content components. Carl and Ed also used arrows and lines to indicate the relationship of the various content components, though this use differed for each teacher. Carl's lines (Figure 5) represented a logical order used in the presentation of content and the foundational

importance of the content taught earlier in the year (i.e., cells). Ed constructed the framework of his SMS (Figure 6) on three content related themes. This initial framework then acted as the foundation for the connection of the remaining content. In his final SMS, Alex (Figure 7) listed his content in essentially the same order as that in which it was presented, but had earlier indicated "blocks" of these topics which were more closely related. For Alex, integration of topics was more a function and responsibility of the teacher's classroom presentation through the "building" of background knowledge in students, but he verbally acknowledged that all content had the potential to be integrated with other content. Thus, though the integration and interrelationships of the content topics were recognized verbally, such relationships were not particularly evident in the SMS he created. The teacher with the least evident integration of content was Ben. Ben (Figures 8 & 9) divided his content into the categories of Theoretical and Applied biology, terms which were primarily used to describe the ability of the content categories to be directly "observed" within the classroom context. The content items listed below these two initial categories did not seem to have an interactive nature in terms of the SMS drawn or described. However, it should be noted that Ben specifically stated that he recognized that the nature of the content topics in biology were "interwoven."

If one were to actively seek the presence of themes in the SMSs of the teachers in this study, such themes, when they did occur, can generally be limited to those which have strong content orientations. For instance, Don (Figure 4) verbally stated on his posttest that he viewed evolution as an integrating theme which superimposed itself across the other content listed. Carl (Figure 5) talked about the importance of students understanding the complexity of life and the ability to classify organisms into the five kingdoms. Though these goals did not actually appear in the SMS which he created, they could be considered themes. Ed (Figure 6) can be considered as having recognized four themes. The first three were represented by the three major categories listed in his SMS: interdependence, alikeness, and the great diversity of living things. In addition, Ed verbally recognized the role of quantification in each of the areas listed in his SMS. Ben (Figures 8 & 9) did not seem to recognize or include any themes in his SMS.

Themes not specifically related to the content topics found in typical biology classes were not particularly evident in the SMSs created by the majority of teachers included in this study. The one exception to this generalization was Alex. Alex (Figure 7) identified five themes which he tried to incorporate across his SMS and into the teaching of his content: scientific processes, critical thinking, current events, ethics, and study skills. For Alex, the recognition and integration of these themes across his content was a vehicle to "kill two birds with one stone" by teaching more (in terms of both content and the themes) within a single lesson. Thus, Alex valued the presence of the themes for their pedagogical efficiency (Lantz & Kass, 1987) within the classroom context, as well as for their importance within his philosophy of science and science teaching.

The relatively elusive nature of themes in the SMSs of the teachers included in this investigation is important when one considers the types of card sort items constructed by other researchers in this area. The study by Baxter, et al. (1985) used content related themes for their card sort. However, the

terminology which they used was distinct from the types of content themes found in this investigation. Recent work by Gess-Newsome and Lederman (1991) has demonstrated the presence o nes in preservice biology teachers which more closely resembled those identified by Alex (e.g., the nature of science, science process skills, STS interactions). Again, these themes were distinct from those used in the Baxter, et al. study. In the case of the Gess-Newsome and Lederman study, the themes reported by preservice biology teachers seemed to be a direct reflection of the themes reinforced in their science education coursework. Alex acknowledged similar sources for the themes he incorporated into his SMS.

It is interesting to note that, though most of the teachers acknowledged having some form of a SMS in place prior to the onset of this investigation, several of the teachers admitted not actually thinking of their SMS in the terms of a schematic or diagram. Both Ben and Don admitted that they thought about the topics which would be included in their courses and recognized the interrelationships among the topics, but usually just listed the topics in outline format. Ed also admitted not really thinking of his content in terms of a diagram. In addition, he admitted to not really considering the structure of an entire year of biology on a regular basis. For Ed, it was much more typical to consider the structure of a unit or a lesson than to consider the structure of an entire year. This comment, though not explicitly stated, may also be true of other teachers in this study.

Furthermore, both Ben and Don, when asked to record their SMSs for biology prior to the classroom observations, asked if the diagram should indicate how they thought about biology or how biology should be taught. When asked to explain the statements made, neither seemed able to do so. The SMS which they and the other teachers in the study drew seemed to be the SMSs of how biology should be taught. This highlights some interesting questions regarding the nature of the SMS and the potential influence of the background of the interviewer (biology in terms of teaching rather than biology as a science). Hauslein & Good (1989) suggested that structures of pedagogy and content are not two separate structures but one, built on the stronger pedagogical knowledge base. The evidence from the current study seems to reinforce such a notion at least in terms of the fact that teachers do not seem able to think about their content separate from how it is used within the context of teaching. Such findings are similar to those proposed by Brown, Collins and Druguid (1989) in the discussion of knowledge acquisition within contextual constraints.

The second question relates to the influence of the teaching context and the nature of the researcher/interviewer's background. It is unclear whether the teachers in this study would have provided similar answers if they were addressed in a biology context as opposed to a biology teaching context. However, since the interv ews concerning content were done in the context of the teaching of biology by a researcher with those obvious interests, it is difficult to separate such a potential "interviewer effect" from the results obtained. In addition, it is possible that the more direct translation of some of the teacher's SMSs may be a function of a tighter coupling of pedagogical knowledge and subject matter knowledge in the form of the SMS, resulting in a synthesis of the two knowledge bases into a single framework as opposed to two distinct frameworks.

Although the teachers in this study freely indicated a belief in the conceptually integrated nature of biology, the teacher-described SMSs indicated views consisting of fragmented concepts held together only by elusive threads which could be used to support conceptual integration. Such findings call into question the ability of these teachers to successfully present biology as a conceptually integrated whole.

Source and Formation of Subject Matter Structures

When asked about the original formation of the SMS which was recorded as part of the final interview, most of the teachers in the study acknowledged that they had held a general framework for their conceptions of biology for a relatively long period of time. This framework to which the teachers referred typically took one of two forms: a recognition of the integrated nature of biology, or a logical order for content presentation. Alex, Ben and Don all seemed to feel that their understanding that all biological topics were interwoven occurred prior to or as part of their college experiences. Alex remembered the integrating power which ecology concepts had for him. The learning of this content, primarily on his own, provided him with a source of reflection and an understanding of the connections which were inherent within the content. In addition, the new focus on environmental awareness which occurred near the end of Alex's college experiences helped him recognize the changing nature of science and the impact of society on science. This realization fostered much of Alex's impetus to focus on a process rather than a content orientation since "these kids are going to face problems we don't even know about yet."

Ben and Don both stated that they felt that a synthesis of the primary topics in biology and an understanding of the integrated nature of the biology content occurred sometime early in their careers, but neither teacher was specific about the source of this understanding. Don vaguely acknowledged that he had been aware of the major topics which composed biology and the interrelationships which existed among them since his high school science experiences. However, Don was unclear how this understanding was formed, seemed unable to articulate the nature of the relationships among the content topics identified and lacked confidence that his own students had an understanding similar to his own. Ben was able to consistently describe the major topics in biology but only tangentially mentioned the interconnected nature of the content.

Carl and Ed also recalled their college experiences as key in the formation of their SMSs. Carl remembered having a "logical order" for content presentation already in place while in college. In addition, the ideas which Carl expressed about the content to be included in his SMS came from his college courses, biology textbooks, and the teaching of biology. It is interesting to note that Carl did not feel that he had the time to really think about his content until he was actually teaching a full year of biology and could see the content "all in one place." Ed also talked about the content making "logical sense," but this sense came from the culmination of all of his content knowledge, not just that gained while in college.

Four of the teachers mentioned that the SMSs described were dynamic and changed as a result of their experiences. Ben described much of his appreciation of biology as resulting from the

culmination of his experiences and his level of maturity. For Ben, the formation of his SMS was analogous to the formation of his personality. The idea that the SMS represented a culmination of experience and knowledge was also echoed by Ed who felt that his increasing level of content knowledge was continually influencing the conceptions which he held about biology. Ed's explanation of the dynamic nature of SMS emphasized that early content learning occurred as the mastery of isolated pieces of knowledge but, with increasing experience and exposure, these pieces could be synthesized into a larger, more comprehensive framework. Carl also felt that his SMS was changing and would continue to change. However, for Carl, the influence on his SMS came as a result of his teaching. Topics in his SMS would be added, deleted or would change in importance based on his teaching experiences and his students' reactions to the content taught. Don was the only teacher who did not discuss influences which continued to effect his conceptions of SMS.

Of the teachers in this study, Alex can be considered to be the most stable in his conception of SMS. Alex felt that the SMS which he had described had been formed primarily in the first 16 of his 26 years of teaching. The SMS, which now guided his teaching practice, was in the process of being fine tuned in terms of implementation rather than in its actual format.

If a comparison were to be made among the teachers in this study in terms of the strength of commitment to their SMSs, Alex might be on one end of a continuum, representing a well formed, thought out and highly valued SMS. Alex would then be followed by Ed. Carl may be considered to be about midpoint on this continuum with Ben and Don about equal in terms of fairly weak commitments to and only vague ideas concerning the meaning and value of the stated SMS. A comparison of the backgrounds of these teachers may be used to make inferences about the strength of the commitments involved. In particular, two general areas seem to differentiate these teachers along this continuum: opportunities for reflection, and opportunities which would reinforce the proposed SMS.

Both Alex and Ed seem to have had many opportunities to reflect on their SMSs and to then have those SMSs reinforced through both positive and negative confrontations. Alex felt that he was initially introduced to many of the ideas included in his SMS while in college. These ideas were reinforced and challenged during his student teaching and early teaching experiences. In particular, Alex was given reason to reflect on his thoughts about teaching when asked to write his own labs, move to new teaching positions, select textbooks, design biology programs, and when observing other teachers teach. The commitments which Alex made were positively reinforced by other teachers in the department with similar philosophical orientations or by watching student reactions to various teaching styles. The importance of the reinforcement of teachers' beliefs, often through conflict of opinions, has been supported by the work of Hollingsworth (1989). In addition to these opportunities, Alex taught at least one biology class for all of his 26 years of teaching as well as having taught biology exclusively at various points in his career. The combination of these events seem to have fostered many opportunities for Alex to reflect on his SMS and to have his beliefs reinforced.

Ed's opportunities for reflection were quite different. Rather than having a strong teaching orientation, Ed's opportunities to think about his content were often stimulated through extended

opportunities in biology. In particular, Ed noted the importance and value of the NSF workshops which he attended and acknowledged the value of staying current in his content through science related activities, coursework, and workshops. Ed's content coursework, similar to that of Alex's, was extensive. Both men essentially had the equivalent of a master's degree in biology to support their background in education. In addition, Ed was continually challenged in his own content understandings by the opportunities to teach advanced sections of biology classes. The fact that Ed had an established set of courses which he taught on a regular basis seemed to help Ed prepare for these classes. Such chances to think about his content were complemented by opportunities to discuss and justify what he believed. Ed enjoyed the opportunity to hold professional discussions about his teaching and fostered such opportunities through department and district-wide science meetings. In addition, Ed noted the role of Parent's Night in acting as a stimulus for reflection and source of clarification about his own thinking concerning the teaching of biology.

In contrast, Ben, Don, and Carl to a lesser extent, seemed to have had few opportunities in their teaching careers which encouraged them to think about their content or the teaching of their content. In all three cases, these teachers had only the equivalent of a bachelor's degree in their content areas, had a limited number of courses beyond what was needed to gain or maintain their teaching certificates, and were not generally involved in workshops which increased their knowledge of pedagogy or content. In addition, all three teachers seemed to have had teaching responsibilities in a wide number of courses throughout their teaching careers. Teaching load requirements were most varied for Ben and Don, partially due to the small size of their schools, and least varied for Carl, Ed and Alex. Such heavy teaching responsibilities in addition to limited time and opportunities to think about their content may have contributed to the somewhat weaker philosophical commitments to the SMSs by Carl, Don and Ben. It is interesting to note that the number of years teaching did not seem to directly affect the commitment of the teachers to their SMS as much as the quality of this experience. Thus, teaching experience was not enough to facilitate learning "on the job," calling into question the simple assumption that teachers automatically learn from experience. Similar cautions have been provided by Buchmann (1982). The teachers in this study were only able or willing to concentrate on the SMSs of their content after they had moved past the mastery of basic skills which were needed to survive in the classroom. These conclusions are similar to those formed in studies which have looked at novice teachers (Doyle, 1977) or compared information processing by experts and novices (Berliner, 1987; Carter & Doyle, 1987). Until basic teaching skills and content mastery were established, the formation of a SMS in a form which could be translated to classroom practice seemed to take a position of low priority. A concentration on such issues then seems to be only possible once the complexity of the classroom has been diminished.

In summary, SMSs, or the components from which they are formed, can be attributed to early content experiences such as college content courses and are modified as a result of additional experiences involving the learning or teaching of content. Thus, SMSs are dynamic in their format and structure over the course of one's career, but seem relatively stable within the context of a single

semester (at least for the teachers in this study) for experienced teachers. In addition, situations which allow teachers the opportunity to reflect on their SMSs or reinforce the beliefs held seem to be essential in the development of a coherent SMS. Such opportunities vary with individuals, but can be characterized by the time to reflect on the meaning of the content as it is used in practice. These opportunities occur throughout one's career, but teaching experience alone cannot account for the presence of such opportunities. Teachers who have heavy course loads, unusual teaching situations, poor pedagogical skills, and limited content experiences beyond those needed for certification do not seem to have the time or perceive the need to reflect on the SMSs of their content.

Subject Matter Structures and their Relationship to Classroom Practice

Uses and Translation of Subject Matter Structures into Classroom Practice

The degree of relationship of one's SMS to classroom practice seems to vary. Such a relationship was determined through a comparison of teachers self-described SMSs (Figures 3-9) and those generated by the researcher from classroom observation data (Figures 10-14). Three different levels of relationships were initially inferred: direct translation, limited translation mediated by the complex interactions of other variables, or no relationship. For the teachers in this investigation, Alex can be considered to have a direct relationship between his SMS and classroom practice. The remaining teachers can be considered to have limited translation mediated by complex variables affecting this translation. How teachers used the SMSs they described the variables which influenced the translation of the SMS into classroom practice will be described in the following paragraphs.

Insert Figures 10 - 14 about here

The teachers in this study used the SMSs which they possessed in a variety of ways. For Carl, his SMS (Figure 5) embodied a general organizational pattern which reflected his perceived logical sequence for the order of content for classroom presentation. This pattern was used in his selection of biology textbooks, though he recognized that other patterns of presentation were potentially as effective as the one which he selected. Since the text (through Carl's purposeful selection) mirrored his own logical organization of biology, this basic sequencing of content was reflected in Carl's teaching (Figure 2 vs. 10). This order was deemed important enough that Carl would reorganize a text which did not match his preferred pattern. Superimposed over Carl's SMS were his goals for students. These goals, developed from his own experiences with learning and teaching the content of biology, were to permeate his teaching. However, it was noted that the translation of these goals into the lessons which were observed was not obvious.

Ben used his SMS (Figures 8 & 9) for the selection and organization of material for a new course or in the selection of chapters to be included in a course which had a large text. Again, since the basic selection of content was part of Ben's designated use of his SMS, there seemed to be a translation of a

portion of his SMS to classroom practice (Figure 11), especially since the selection of a text was based on the presence of the content which he felt essential. However, different than Carl, Ben felt that there was no sequence implied as part of his structure. Thus, Ben rearranged several of the content units in order to have suitable weather to take his classes outside for the collection of materials. In all other situations, Ben deferred to the order of the content presented in the text Figure 2 vs. 11). Since Ben recognized no additional connections or integrations in his SMS, a direct translation of the SMS into practice would suggest the presentation of units with limited interactions (Figure 8 & 9 vs. 11). However, analysis of the classroom data showed that a direct translation of SMS was not the case.

It was difficult to determine what role Don's SMS (Figures 3 & 4) played in his classroom practice. Though Don admitted to having the SMS which he described for at least 12 years, this SMS seemed to have no real value or purpose other than reminding him of the major content components in biology and the integrated nature of this content. No real sequence of content was suggested as part of his SMS. In practice (Figure 12), Don seemed flexible in content sequence, easily adapting to district guidelines or the order presented in the text. The translation of Don's stated integrated nature of biology was only noted in Don's area of content expertise: ecology. However, it should be noted that the very nature of this content area may also foster such an approach.

Ed used his SMS (Figure 6) as a framework upon which to attach biology content (Figure 13). Ed's SMS was composed of three major themes from which all the additional content included in a biology course could be connected. This structure then represented the manner in which Ed was able to make "logical sense" of biology. This logical sense orientation was evidenced not so much in terms of the SMS which he drew, but in the connections of content through his set of larger ideas or themes. Thus, the SMS which Ed designed represented some, but not all, of the content understanding which he had developed as a result of his own content experiences.

Of all of the teachers in this study, Alex was the only teacher who seemed to have a direct translation of his SMS into classroom practice (Figure 7 vs. 14). For Alex, SMS represented the grand total of all of the understandings and philosophical orientations which he held toward the teaching of biology. This SMS, carefully formed and clarified through many years of experience, acted as a guide for Alex's teaching practice. Thus, Alex's SMS was actively recognized and directly translated into his teaching of biology. The order in which content topics were taught were of less value than the importance of integrating content presentations with the various teaching themes which he valued. The identification of themes versus content provided Alex with a pedagogically efficient manner of teaching a greater amount of content at a higher level of quality. Simple changes in the order of the items listed in his SMS did not seem to affect the meanings of the items, but could affect Alex's ability to effectively introduce these topics and themes in an integrated manner into practice. Since Alex's teaching was carefully planned to articulate the content and themes which he valued, changes in the order of presentation represented a necessary rethinking of his content and the appropriate reinforcement of ideas which he had developed in his current order of presentation.

Comments such as those made by Alex highlight the importance of the content sequences with which the teachers had become accustomed. It can be generally stated that the teachers in this study were conservative in terms of content sequence, whether that sequence had been adopted through the well thought out implementation of a program or the sequence with which the teachers had personally learned or taught biology. Few teachers relished the idea of changing the sequence which they had established. Based on these observations, it is possible to assume that "traditional" sequences may act to reduce the cognitive complexity which is found in the act of teaching. Support for such ideas can be found in research conducted by Leinhardt and Greeno (1986) which proposes the idea of classroom routines to reduce teaching complexity, and Putnam (1987) who suggested the presence of curriculum scripts upon which classroom presentations of content are structured.

It is obvious from the comments made thus far that three important ways in which SMSs are translated into practice include the scope of the course, the sequence of presentation, and the selection of textbooks. Since these forms of translation are so basic to the structure of the course itself, they can almost be considered to be subconscious. Such a subconscious translation into classroom practice was specifically noted by Ben, Carl, Don and Ed. Only Alex admitted to consciously making the transfer of this SMS to classroom practice. It is interesting to note, then, the varying levels of influence the above three variables had on the teachers in this study. Of the five teachers, only Alex seemed willing to use the textbook as a resource rather than as the source of his content presentations. Ed embellished his content presentations beyond that included in the text, though the text and district guidelines seemed to establish the basic sequence of content presented. The other three teachers seemed to follow the scope and sequence of the text closely. When variations were made, they were typically in terms of minor adjustments in the sequence of topics or in the "watering down" of content below the level presented in the text.

Variables Which Influence the Translation of Subject Matter Structures into Classroom Practice

Six variables seemed to affect the differential translation of SMSs into classroom practice. These were: teacher intentions, content knowledge, pedagogical knowledge, students, teacher autonomy, and time. Each of these factors will be discussed in terms of their influence on the SMSs held by the teachers (Figures 3-9) and the translation of their SMSs to classroom practice (Figures 10-14).

Teacher intentions. The degree of translation of SMSs into classroom practice in terms of course scope and sequence has already been discussed. Less obvious levels of translation of SMSs into classroom practice exist in terms of recognizing and presenting the integrated nature of biology. All of the teachers in this study, at one time or another, admitted to believing that all biology content was related. However, the teachers varied in their ability or desire to translate this concept into practice. In fact, teachers varied in their beliefs about whether such understandings should be the basis for classroom teaching.

Alex strongly believed that all of the content of biology was integrated. This integration existed among the various content topics as well as through the use of his teaching themes. This perception of his content was directly translated into classroom practice through his "building of background" when moving to new content areas or the consistent integration of his teaching themes.

Carl believed that the SMS which he held should be translated into practice, but was not clear if such a translation was actually taking place. Carl felt that the integrated nature of the content was probably not realized by his students, but that they should leave his classroom with a minimum of a "table of contents" of the main topics of biology. His hope was that his goals of complexity and the identification of organisms into the five kingdoms would provide his students with a framework from which the rest of the biology content could be integrated. It should be noted that Carl's lack of emphasis on the actual teaching of the integrated nature of biology was based on the perception that his students would not be able to synthesize information at that level.

Ben and Don also seemed to think that the ability of their students to generate a SMS and an integrated understanding of biology was beyond their students' cognitive level. Ben felt that such a cognitive level and appreciation for the integrated nature of biology would only come with experience and maturity. Thus, directly teaching such an understanding did not make pedagogical sense. Don did not seem to feel that there was any particular value to his students having such an understanding, though Don felt that he personally held such conceptions as a high school student. For Don, a "basic understanding" of the content was deemed sufficient for his students.

The idea that his conceptions of the SMS of biology could be considered as a topic to teach seemed to surprise Ed, though Ed seemed to generally value the translations of his personal understandings of biology into classroom practice. Although Ed felt that presenting such information may provide his students with a "road map" of the content which they would cover, such coverage had not occurred in the past. To be taught effectively, Ed felt that a SMS would have to be presented early in the year and referred back to constantly and consistently. Students' mastery of this framework could not be measured simply by their ability to repeat the structure, but in the ability to explain and embellish the framework with examples from the content taught. Ed seemed to think that his students were capable of learning such content, though he recognized that their explanation of the SMS, as well as his own, would change as a result of their new content understandings.

Thus, Alex and Ed felt that the translation of their SMS into classroom practice was important and possible in terms of student understanding. Carl and Ben felt that student understanding of a SMS for biology would be desirable, but a potentially unrealistic goal for their students. For this reason it is difficult to determine the personal importance they placed on making such a translation. Don seemed to value the SMS which he had, but did not seem to place any value on the transfer of this information into the classroom context. Thus, this information can be used to identify one of the variables which seemed to affect the translation of SMS into classroom practice: teacher intentions. Specifically, the level of teachers' commitment to their SMSs and the value of the SMS for student understanding of the content seemed to differentially affect the translation of SMSs into classroom practice. Additional information

concerning teacher commitment to their orientations has previously been discussed in the section concerning the sources and formation of SMSs.

Content knowledge. Level of content knowledge seemed to have a significant impact on how content was taught and on the SMSs as derived from observations of classroom practice. Specifically, teachers seemed to make a greater number of integrative connections among content topics which they considered part of their content specialties than they did when teaching content outside of this area. Such a generalization was particularly obvious in the cases of Don and Ed. When Don was teaching content concerning ecology he made more connections, presented more examples from beyond the coverage in the text, related the content more closely with STS issues and his students lives, and spent more time in the active presentation of content in whole class contexts (i.e., providing lectures and answering questions) than when involved in teaching content from other areas. The suggestion that teachers may utilize whole class instruction in content areas in which they feel confident and use small group or individualized instruction where they lack this confidence has been proposed by Carlsen (1989) and is supported by the results of this investigation.

Similar results can be found in the analysis of Ed's classroom data. Ed made more connections when teaching content related to molecular and cellular biology than he made when teaching content concerning ecology or the nature of science. In addition, Ed's strong content background allowed him to extend and expand the content he presented beyond that found in the text, thus fostering more content connections than may have been otherwise formed.

Content knowledge seemed to affect Ben in a different way. Ben seemed to have several areas in which his content understandings were weak. Perhaps because he felt uncomfortable with his personal level of content understanding or perhaps for reasons related to time, Ben taught his content in a superficial manner. This degree of coverage actually seemed to foster content connections by forcing Ben to refer to examples outside the current unit since few concepts had been developed as a function of the current unit.

Carl and Alex's classroom performance did not seem to be as affected by differential levels of content understanding. Carl seemed to have incomplete content knowledge in a couple of areas, but this incomplete knowledge did not seem to affect the manner in which his content presentations were conducted. However, it is interesting to note the effect of Carl's classroom SMS and content knowledge in terms of the role played by the DNA/RNA and Evolution units. Each of these units, for different reasons, were sources of concern for Carl. However, these "troubling" units also acted as primary points of content transition and connection for many of the other units which Carl taught during the first semester.

There were also few variations which could be detected in terms of Alex's content knowledge. It may be that Alex's general level of content knowledge, his focus on themes, and his relatively large backlog of teaching experience in biology may have neutralized any effects which differential levels of content understanding may have produced in the past. However, it should be noted that Alex seemed

to avoid the teaching of a unit on DNA/RNA, a content area which he admitted as having less knowledge in than others which he taught. Such an avoidance may have been a manifestation of Alex's level of content understanding. However, since Alex eliminated this content from his course, it is impossible to determine how this lower level of confidence in content knowledge would have been translated into the teaching of this content.

Pedagogical knowledge. A third factor which may have influenced the ability of the teachers in this study to translate their stated goals for content and students' outcomes into classroom practice was level of pedagogical knowledge. Alex and Ed seemed to have very few problems implementing the types of programs which they desired and achieving the results they felt were possible. Though other factors such as time for lesson planning and for presentation of content in the class may have prevented the total implementation of all such ideals on a consistent basis, the majority of the goals which they set out to achieve were accomplished in some form.

This ability to translate stated goals into practice was not evident for the other teachers in this investigation. Carl talked about the importance of teaching for process but did not attempt such tasks with his biology students. This lack of a process orientation can perhaps be explained by Carl's inability to effectively teach to the level of his biology students. In addition, Carl did not seem able to present his classes in such a way as to achieve the basic goals he stated for his students (i.e., complexity and the five kingdoms). Again, it should be noted that these goals may have been more evident if the second semester of biology had been observed.

Both Ben and Don discussed the value of their students learning how to solve problems, but neither teacher provided opportunities for such learning to occur in their classrooms. In addition, both Ben and Don seemed to have problems with the management of classroom activities. For Ben, management problems were evidenced in his inability to effectively organize a laboratory experience. In Don's case, classroom management concerns seemed to reinforce his use of seat work as the primary source of content delivery and reinforcement. More risky modes of learning (in terms of classroom management), such as group discussions, questions from students, and laboratories, seemed to be avoided. Such use of classroom teaching methods as a means of classroom management has been suggested by Doyle and his colleagues (Doyle, 1986; Doyle, Sanford, Schmidt-French, Clements & Emmer, 1985).

It is difficult to determine from the data collected in this investigation why differential levels of pedagogical knowledge seemed to exist. Further exploration of the educational experiences of these teachers, particularly in terms of their teacher education classes and experiences, may shed some light on such matters. It is equally possible that differences in pedagogical knowledge and ability may be a function of individual personalities and perceptions of adequate levels of classroom control. However, it seems appropriate to state that years of classroom experience alone (as supported by Buchmann, 1982) can not provide a sufficient explanation for these differences.

Students. Students, as they rightly should be, seemed to be one of the most significant variables affecting what actually occurred in the classroom. However, the extent of this effect on each teacher's own conceptions of SMS is somewhat surprising. As has been suggested by a number of studies (Brickhouse, 1989; Brown, 1989; Housner & Griffey, 1985; Lantz & Kass, 1987; Thompson, 1984, to name a few), that students exert a strong and real influence on the classroom teacher in terms of what is taught and how it is taught. Such influences were evident in the teachers included in this study. For instance, Alex was sensitive to students' levels of frustration and interest. When shifts in students' attention were noted, Alex changed from the more "rigorous" academic content he was teaching to optional units which he hoped would stimulate more student interest and diffuse frustration. Ed also changed his order of content coverage to help students feel more comfortable. Specifically, Ed and his department elected to teach ecology early in the year based on the perception that this content acted as a less threatening introduction to biology (as opposed to content dealing with biochemistry or cell biology).

Both Carl and Ben were influenced by their perceptions of student ability to effectively learn some content topics. Carl's perceptions of students, which seem to have been consistently reinforced over the course of the semester and his years of teaching, molded his content coverage in such a way that he avoided the introduction of mathematics into lectures or laboratory situations, decreased the complexity of his content coverage, avoided situations in which students were expected to think on their own (deductive versus inductive labs), and continued the practice of having students read the text (despite the difficult reading level) because some students had returned to thank him for emphasizing this practice. Influences on Ben were similar in that Ben eliminated content which his students considered "boring" and "watered down." For both Carl and Ben, the responses of their students to the curriculum taught caused them to rethink the goals of the biology class and to struggle with the ultimate goals and the target audience for which biology classes should be structured.

In similar ways, all of the teachers in this study received feedback, either positive or negative, for the methods by which the content was taught. Alex and Ed received positive feedback for their teaching methods. Such feedback for Alex came from his observations of other teachers and the subsequent reactions of students exposed to their teaching methods. For Ed, positive feedback was obtained in the general success his students had with learning the content which he had taught.

Feedback for Carl, Ben and Don was typically more negative. Poor student reactions decreased the tendency to use laboratories, especially in terms of utilizing labs for problem solving or inquiry, or to ask higher level questions within the context of classroom discussions. In addition, Ben and Don's relatively poor ability to control classroom management had encouraged them to use methods of teaching (lectures and worksheets) which presented fewer management concerns and considerations.

Finally and perhaps most importantly, it is interesting to note the influence students had on the teachers' personal conceptions of SMSs. Four of the teachers in this investigation noted the difficulty of teaching the topics of DNA/RNA. For Alex, resistance to teaching this topic was caused by a personal lack of knowledge. But, for many of the other teachers, hesitancy to cover this topic was based upon

past experiences with attempting such a task and the noted resistance and difficulty which students had with such content. The critical effect of these student responses was in the effect of the teachers' placement of DNA/RNA within their personal SMSs of biology. Such an effect in terms of teachers' SMSs was probably most evident in Carl. Though Carl saw DNA/RNA as vital content in terms of biology, he felt ineffective in his presentation of this content to students. Based on student reactions, Carl was willing to drop this content not only from his course, but to decrease its importance in terms of his personal SMS. Thus, students seem to have a critical role in the shaping of the SMSs that teachers hold for the content they teach.

Findings such as these renew the question as to whether the SMSs offered by these teachers are their SMSs for biology, or their SMSs for biology teaching. Other researchers have suggested (Brown, Collins & Druguid, 1989; Hauslein & Good, 1989) that SMSs may be "situated" in their use, meaning that the way in which SMSs are formed and subsequently used cannot be separated. Such situated understandings seem to be the case for the teachers in this study and may partially explain the differential transition of SMSs into classroom practice. Specifically, teachers who more closely "situated" or aligned their SMS of biology with that of biology teaching may exhibit greater levels of classroom translation. This alignment supports the contention that teachers with limited translation of SMSs into classroom practice may have SMSs which are more weakly held or conceived. In addition, when these teachers report their SMSs for "biology," the result may only be an artifact of the teachers' SMSs for biology teaching.

Teacher autonomy. Several of the teachers in this investigation can be described as taking actions which potentially suggest an external locus of control, whereas others seem to feel comfortable in taking charge of their classroom situation and the content which they taught. Variations along this continuum seemed to affect the implementation of SMSs into classroom practice.

Both Alex and Ed seemed to have strong feelings of teacher efficacy and exhibited control over their classroom teaching. For instance, Alex and Ed both took personal responsibility for the learning of their students, modified their content presentation to more closely align it with the perceived needs of their students and their personal perception of SMS, used the text as more of a resource than as the primary source of content, and controlled the academic calendar to meet their teaching needs. In addition, Ed was explicit in his manner of controlling the classroom climate by establishing strong teaching routines and regulating student socialization patterns by controlling the seating arrangements. Such characteristics can be considered as indicators of rather high levels of teacher autonomy and control.

Ben and Don both seemed to exhibit a general loss of control over the substance and timing of their content coverage in the classroom. Both relied on the text, were heavily influenced by the school calendar by letting it determine the quantity and quality of their content coverage, and took little personal responsibility for the learning of their students. Such characteristics can be considered to be indicators

of low levels of teacher autonomy and control. Carl can be characterized as existing somewhere between these two groups.

Based on these characteristics, Alex and Ed, with nigher levels of teacher autonomy, seemed to be more successful in the implementation of their SMSs into classroom practice. It is difficult to determine why these differential patterns existed and no attempt will be made to specifically categorize these teachers in terms of the psychological definitions of locus of control (since no such measure was directly used). However, these characteristics do seem to demarcate the two groups. It is possible that Ed and Alex, through the use of more proactive rather than reactive teaching choices, allowed their own thinking and conceptions of biology to be evidenced in the classroom. Teachers using more reactive teaching choices, such as Don and Ben, may have essentially mitigated the influence of their personal thoughts and perceptions in terms of classroom practice.

Time. Finally, time seemed to have a tremendous influence on the teachers in this study. Time was mentioned by all of the teachers and affected them in two ways: time to teach and time to reflect and prepare to teach. Each of these time constraints influenced the teaching which occurred in terms of SMS translation and is consistent with the concerns expressed by teachers in other investigations (Brickhouse, 1989; Lantz & Kass, 1987; Lederman & Gess-Newsome, 1991; Thompson, 1984).

Time to teach, in terms of simply having enough class time to cover the material required in order to assure student mastery, was mentioned by many of the teachers. Specifically, a tension between covering a quantity of material versus the quality of coverage seemed to exist. For Alex, a conflict between covering district and department guidelines while still having the freedom and time to emphasize process skills and objectives became a source of concern. In addition, increased class sizes and the number of classroom preparations increased the cognitive load of the classroom, for both Alex and his students. Ed's struggle with time typically seemed to occur in terms of presenting content and discussing it in class in the time allotted. However, Ed seemed more willing than the other teachers in this investigation to extend the original time schedule in order to bring topics to closure and/or assure student understanding before moving on to the next topic. Carl's struggle with time was increased by his "floating" schedule, as well as the large number of days which he was not able to be in the classroom.

Ben and Don also seemed sensitive to the issues of time, but in different ways. Ben seemed to be racing against a school calendar which did not always complement the content he was teaching. Don seemed to use the school calendar as an arbitrary scheduling cut-off for units. Beyond this, Don's primary objective seemed to be to fill the time that he was allotted.

Though time in the classroom was definitely a variable in the content which could be delivered to students (and thus the match of the classroom scope of content with the teacher's SMS), time may have been more crucial in terms of teacher reflection and planning. All of the teachers in this study complained about not having enough time to effectively reflect upon and plan for their content presentations. Time was especially crucial for teachers such as Ben, Carl and Don who had multiple

daily classroom preparations during the current year, as well as across the expanse of their teaching careers. Such time commitments and constraints may have been critical in terms of the relative inability of these teachers to have well formed SMSs and goals in place for their teaching of biology and the expected outcomes for their students. In addition, time may have influenced the relative inability of these teachers to implement such structures and goals into practice.

Such statements can be confirmed by Ed and Alex who talked extensively about the need to carefully think through the biology content before teaching it. Such opportunities for reflection occurred at different times for each of these teachers. For Ed, some of this reflection was stimulated through department meetings where weekly schedules were planned. In other instances, such reflection occurred as a result of the science content workshops which he attended. Alex was much more specific in his need for time. He attributed the integrated nature of his classroom as being a direct result of long and careful planning and articulation of content goals into practice. Though shifts in content order did not seem to affect Alex's overall conceptions of the content, they did require large amounts of time and rethinking in terms of his ability to present a well orchestrated unit. For Alex, changing his content and not allowing him the time to adjust and plan for creative integration of content and process was the same as reducing him to a "first year teacher," making his teaching erratic and choppy.

Limitations of the Study

There are several aspects of this study that limit the generalizability of the findings reported. First, no special attempts were made to assure that the teachers included in this study were representative of the biology teaching force in general, largely for logistical considerations. To further strengthen the generalizability of these findings, a much larger sample of teachers with characteristics more closely aligned with the nation's teaching force would need to be studied. However, little evidence exists to suggest that the lives and experiences of these teachers were so unique as to preclude the use of these findings as the basis and stimulus for future investigations with other teaching populations.

Secondly, the SMSs for the teachers in this study were generated from observations which constituted less than 20% of the total number of teaching days. Though attempts to mitigate such limited observations were sought through the analysis of lesson plans and classroom materials, it cannot be denied that the final SMSs constructed in this research were a direct function of the classes actually observed. Had a different sample of lessons been observed, the results may have varied to an unknown degree. In addition, observations were not made of the second semester.

Thirdly, the method designed for the construction of SMSs from classroom observations and materials, by it nature, sought incidences which suggested the connection of content topics to one another. Such an assumption may have created SMSs which were more integrated than may actually be the case since all instances of connections were considered to be equal in magnitude of importance. Thus, the inferred SMSs may represent levels of complexity and integration greater than may have actually existed. In addition, it was assumed that relationships and strong integration would naturally exist among content units. Though this generally seemed to be the case in this investigation (though

such connections were not specifically explored), such an assumption may warrant further research and exploration. Such assumptions, as well as the findings of Marks (1989), may warrant additional thought and research on the appropriate unit of analysis for the study of teachers' conceptions of content.

Implications and Recommendations for Science Teacher Education

Research which has been conducted in the past has assumed that the SMSs which teachers possess are coherent during all phases of their teaching careers and directly translate into classroom practice. The results of this investigation question these assumptions on two levels. First, it does not seem that past methodologies, particularly those of card sort techniques, are sensitive to teachers' personal understandings of content. The more open-ended methodology used in this investigation produced significantly different results from those produced in other investigations. Secondly, past research has elected to determine the degree of translation of SMSs to classroom practice through the use of laboratory exercises which simulate classroom experiences. Such practices greatly reduce the complexity of the situation to which teachers need to respond. This fact may have contributed to the assumption that SMSs have direct translation to classroom practice. The results of this investigation demonstrate that the translation of teachers' thoughts into action are much more complex than may have been previously realized. Though there are elements of teachers' SMSs which do directly affect classroom practice, many of these elements are mitigated by factors which only exist in actual classroom contexts. Similar findings have been noted in investigations which have explored the transfer of knowledge of the nature of science into classroom practice (Duschl & Wright, 1989; Lederman & Zeidler, 1987). Thus, in order to adequately measure the translation of SMSs into practice, such assessments must be conducted within the context of actual classrooms.

The SMSs which the teachers in this investigation reported can be considered to be content-oriented and were claimed to be initially formed as a result of college level content courses and then reinforced by the act of teaching. Such statements have two implications. First, teachers seem to be heavily influenced by the types of courses which they take in college, at least in terms of the scope of topics which should be taught in the high school context. Such observations place renewed emphasis on the organization and breadth of coverage found in college level content programs. Programs which are skewed toward a narrow focus of content may inhibit teachers from offering well rounded programs to their students. Second, the order and scope of the SMSs described seem to have a fairly direct relationship to classroom practice. In fact, once the teachers in this investigation determined a teaching sequence, they seemed hesitant, and in some cases resistant, to changes in that order. It is possible that an established teaching sequence acts as a means of decreasing the complexity of both the interactive and preactive aspects of teaching. Though this assertion should be further explored, such a finding does have implications for the manner in which teachers are prepared to think about their content. It seems that careful thought and purpose, in terms of the initial structure of a class, needs to be introduced very early in teacher education programs. Such an introduction may help to assure that the course structures which are established are built on careful thought and consideration of alternative

sequences rather than on the mimicry of programs similar to those which students have been exposed in the past.

Both of the above implications have direct bearing on the feasibility of currently suggested science education reforms and their potential to impact the type of science teaching which currently exists. Many of the current reform movements in education, both science specific (e.g., American Association for the Advancement of Science's Project 2061, 1990; National Research Council's Fulfilling the Promise, 1990; etc.) and generic (Carnegie Foundation, 1986; Holmes Group, 1986) suggest that many of the problems plaguing education today can be simply solved through the increased level of content mastery in the teaching workforce. Specifically, many of the reforms for science education suggest that science should be taught as an integrated whole with an emphasis on a few concepts which can act as frameworks upon which all of the science curriculum can be connected. Thus, suggested recommendations for improving educational practice usually come in the form of increased college requirements in the academic areas. Though the results of this investigation suggest that teachers tend to do a more integrated job of teaching the content they know well, caution must be exercised in making such blanket recommendations and assuming that increased content coverage alone will facilitate the teaching of science to a more integrated degree. All teachers in this study had content degrees in biology. Despite this background, inequities in their content expertise still existed. In addition, the possession of a certifiable level of content knowledge alone was not enough to increase the integrated nature of the conceptions of content. It may be that for college content courses to impact a teacher's global conceptions of SMS, especially in terms of integration, they must be taught in an integrated manner, not in the current style of offering courses as isolated pieces of content knowledge, fragmented from a conceptual whole (Cheney, 1990; Kennedy, 1990). In addition, it is critical that teachers be given the time and opportunity for reflection once content knowledge is gained if it is to be integrated into their SMSs and effectively incorporated into their classroom teaching.

It is interesting to note that, although the teachers in this investigation had varying levels of classroom teaching experience, a simple correlation of years of experience to the degree of SMS articulation or the transfer of SMS and other teacher stated goals into classroom practice could not be used reliably. As suggested by Buchmann (1982), teaching experience alone does not equate with teaching expertise, though the two are often mistakenly confused. However, opportunities for a teacher to reflect on classroom practice and implement identified changes does seem to be of great influence on teaching "expertise." In addition, feedback concerning teachers' beliefs, both positive and negative, seemed to have a significant influence on the commitment which teachers had for such beliefs. In line with such observations, the most vital factor which seems to mitigate reflection and reinforcement seems to be too many classroom preparations, especially early in one's teaching career. If it is in fact believed that teaching is a purposeful act, it seems critical that teachers be allowed the opportunity to develop an explicit SMS which can act as a guide to their practice. For this to occur, several things need to be concurrently in place: content knowledge, a forum for the application of this content knowledge to a specific act (such as teaching), the time to reflect and formulate a personal SMS, and the time to devise

and experiment with methods which will translate this SMS into practice. Such practice most appropriately occurs at two places in one's career: preservice teacher education and inservice teacher education.

Preservice education, particularly in the form of subject specific methods classes, is the first opportunity which teachers have to reflect upon the actual use of their content knowledge within a specific context. Since the application of knowledge seems to be an essential step in the formation of a SMS which can be explicitly used in practice, the importance of such opportunities through such a course cannot be overly emphasized. Specific opportunities for SMS formation should be provided, as well as the introduction of themes which may most appropriately guide instruction (i.e., process skills, nature of science, science-technology-society interactions). As suggested by Gess-Newsome and Lederman (1991), SMSs utilizing such themes seem to be fostered through consistent reinforcement in science specific methods courses. In addition, preservice teachers must be provided with specific opportunities to translate the SMSs they devise into classroom practice. Though many students at this stage in their careers find such a translation difficult to achieve due to their concerns for classroom management, sensitization to the formats through which such translations can take place should occur at this stage, as well as feedback concerning the effectiveness of such attempts.

Provision of similar opportunities would also need to occur early in one's teaching career. As noted above, management concerns often overwhelm the novice teacher, suggesting that refinement of the teaching process in a manner which may effectively translate one's conceptions of SMS and classroom goals may not be able to occur until management and classroom routines are mastered. In order to facilitate the transition from "survival teaching" to "reflective teaching," it may be necessary to provide novice teachers with a limited number of classroom preparations and with relatively greater amounts of time in which to design and evaluate their curricular programs in comparison with more experienced teachers. In addition, novice teachers should be given repeated opportunities to reflect on the effectiveness of their practice as fostered through formal feedback and questioning about the goals of their teaching and the best means to achieve those goals. The provision of time and feedback may be adequate in reducing the time that it takes for novice teachers to achieve a more expert status in terms of implementing beliefs, ideas and goals into classroom practice through pedagogically effective techniques.

In addition to the implications just mentioned, the results of this investigation highlight several additional areas which may facilitate the disentanglement of many of the issues which surround the complexity of the teaching situation and the translation of teacher knowledge into classroom practice. Of primary importance may be the issue of knowledge structure formation as it is related to use. As previously mentioned, the teachers who exhibited the greatest degree of SMS translation into classroom practice were also those teachers who seemed to be reporting their knowledge structures of biology teaching rather than biology Are there two knowledge structures used in teaching (content and pedagogy) or only one which is a result of the application of knowledge in the domains of content and pedagogy to a single act, subject matter teaching? If this is the case, it is possible that knowledge

structures for the teaching of biology can only be formed through the process of teaching or thinking about teaching biology. Consequently, a renewed emphasis may need to be placed on content specific methods courses as well as the support and reinforcement of these knowledge structures as they form over the first several years of a novice teacher's career. Additional research needs to be conducted that would determine the best experiences which should be incorporated into preservice and inservice education programs to promote such a welding of knowledge bases, as well as for the determination of the most developmentally appropriate placement for such subject matter reflection.

In addition, since SMSs do seem to potentially guide teaching practice, methods for the facilitation and formation of effective knowledge structures need to be explored through experimental means. Of particular importance may be the exploration of the specific types of information and experiences which are necessary for the formation and reinforcement of SMSs. For instance, many of the teachers in this study suggested that SMSs could be formed only as a result of the learning of numerous content pieces and then the reflection on this knowledge. What implications do such statements have for learning theory? Are SMSs a result of inductive learning and synthesis, or is the act of SMS formation more recursive in nature? With such data in hand, it would be important to determine the relative effectiveness of the various SMSs which teachers develop, as well as the role which SMS coherence plays. The relationship of SMSs to a teacher's ability to teach as well as its ability to facilitate the learning of new content would be equally important. Such information may lead to a greater understanding of what it means to be an "expert" teacher and provide avenues which will enhance the progress of teachers from novice to expert status. Ultimately, and perhaps of greatest importance, this line of research would need to include the influence of teachers' SMSs on student learning.

In tandem with the line of research suggested above, the issue of the appropriate unit of analysis for looking at teachers' conceptions of subject matter knowledge (unit, semester, year or disciplinary field) will need to be addressed. Such information would not only facilitate research efforts in this area, but would also help guide efforts in developing teachers' conceptions of content at both the preservice and inservice level. In addition, such results would be vital in the formation and implementation of curricular reforms. For example, if teachers cannot effectively conceive of content coverage over the course of a year, it is possible that curricular reforms and inservice programs may be more effective focusing on units and would only later attempt an integration of units into a conceptual whole.

And finally, many of the results of this study suggest that teachers' abilities to effectively achieve the results that they desire within a classroom context may be closely tied to teacher characteristics such as teacher autonomy, risk taking and reflectivity. The further elucidation of such factors and ways in which such influences can be mitigated may help produce a more effective teaching workforce as well as promote the professional development of individual teachers.

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What topics make up biology?

If you were to make a diagram of these topics, what would it look like?

Have you ever thought about biology in this manner before? Please explain.

Figure 1. Subject Matter Structure Questionnaire

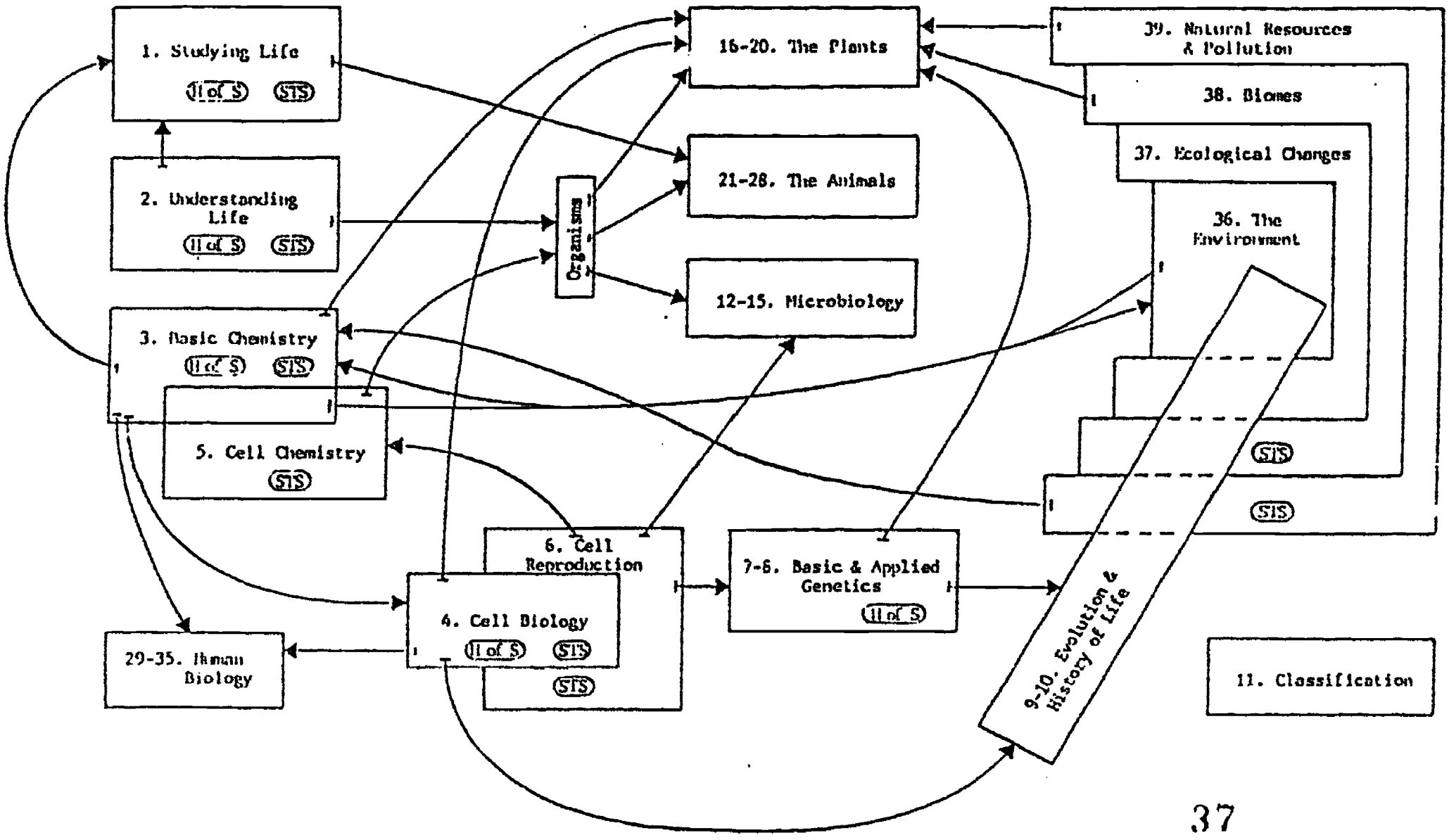

Figure 2. Textbook Subject Matter Structure

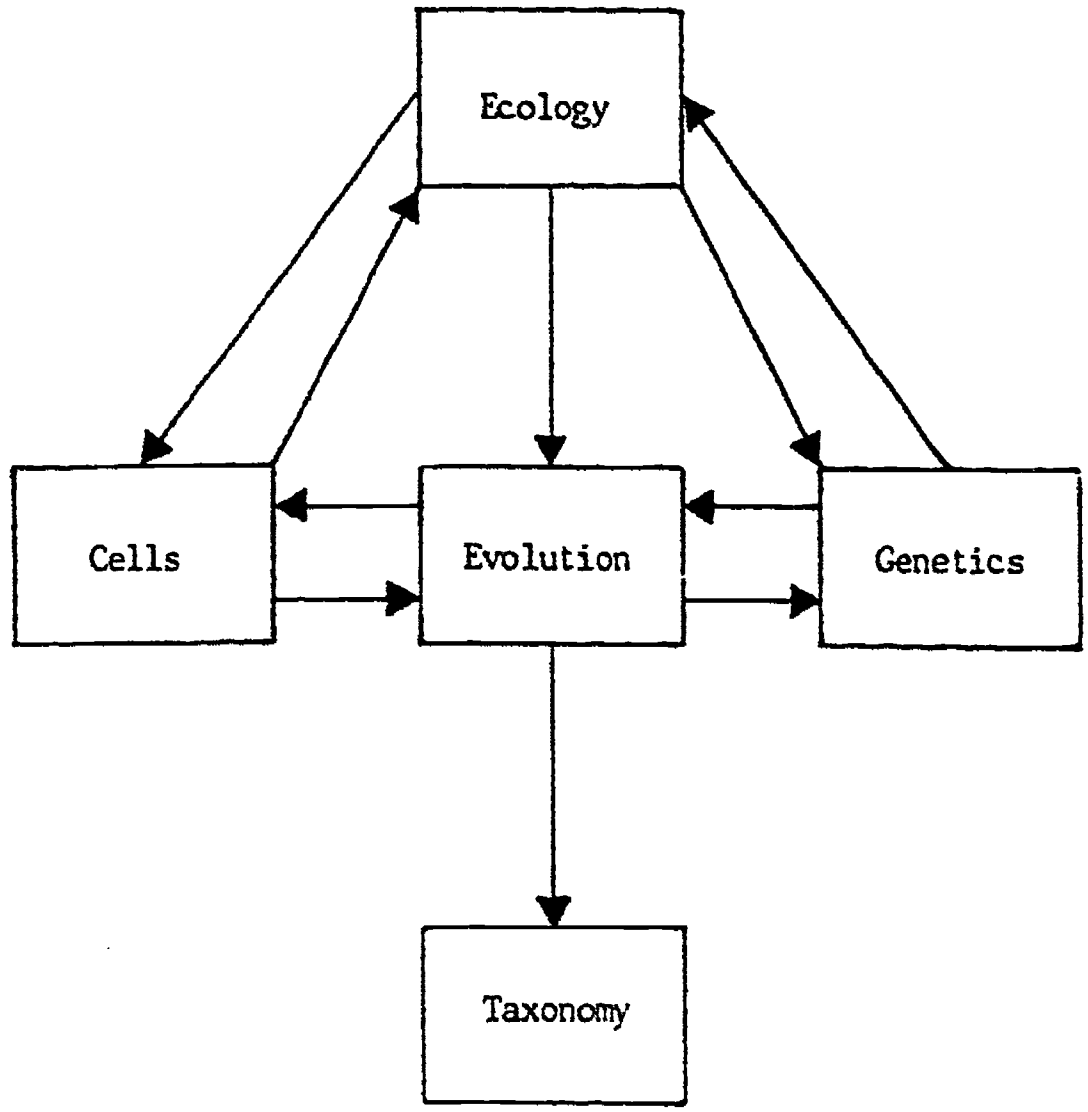

Figure 3. Don's Self-Described Subject Matter Structure (Pretest)

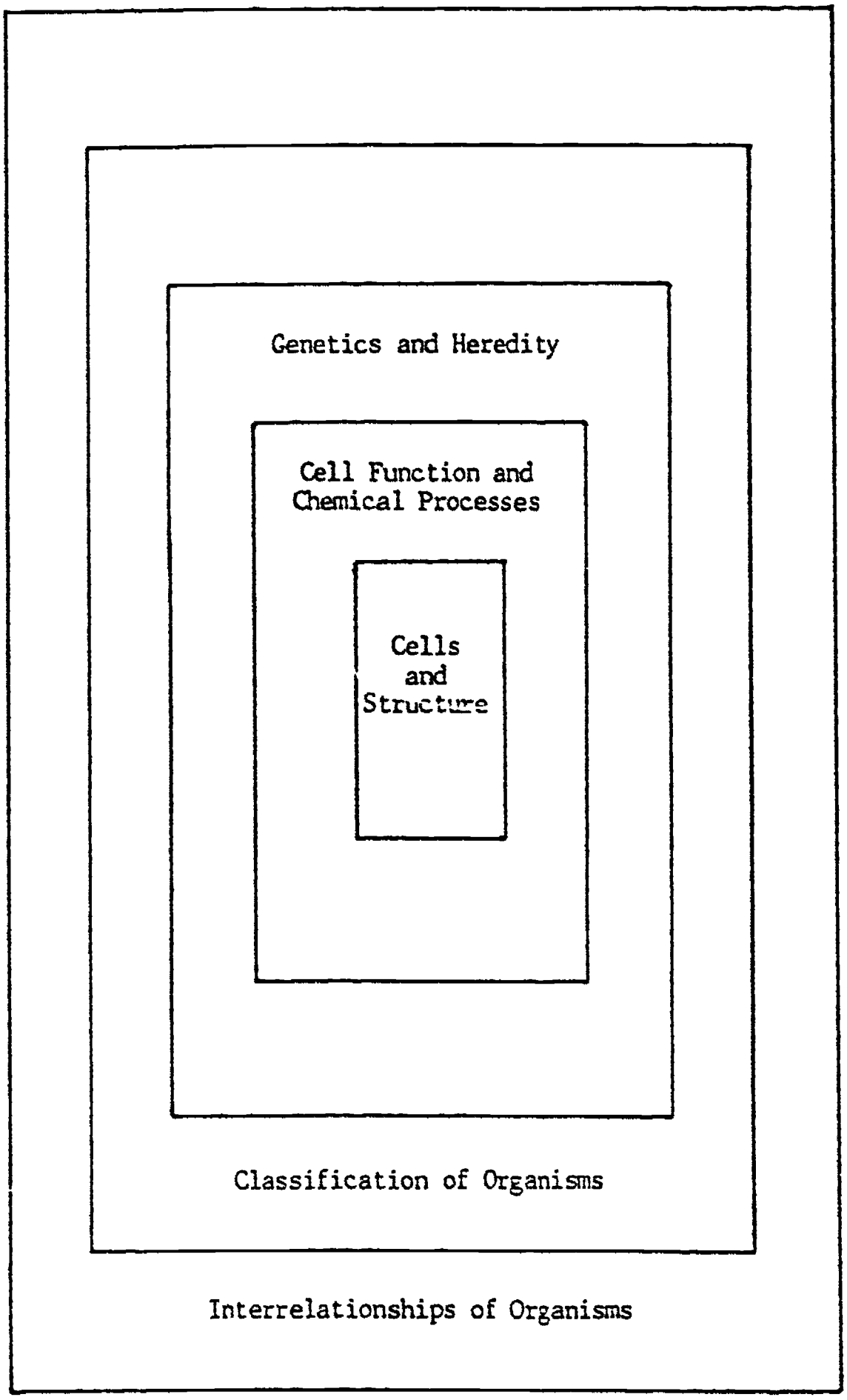

Figure 4. Don's Self-Described Subject Matter Structure (Posttest)

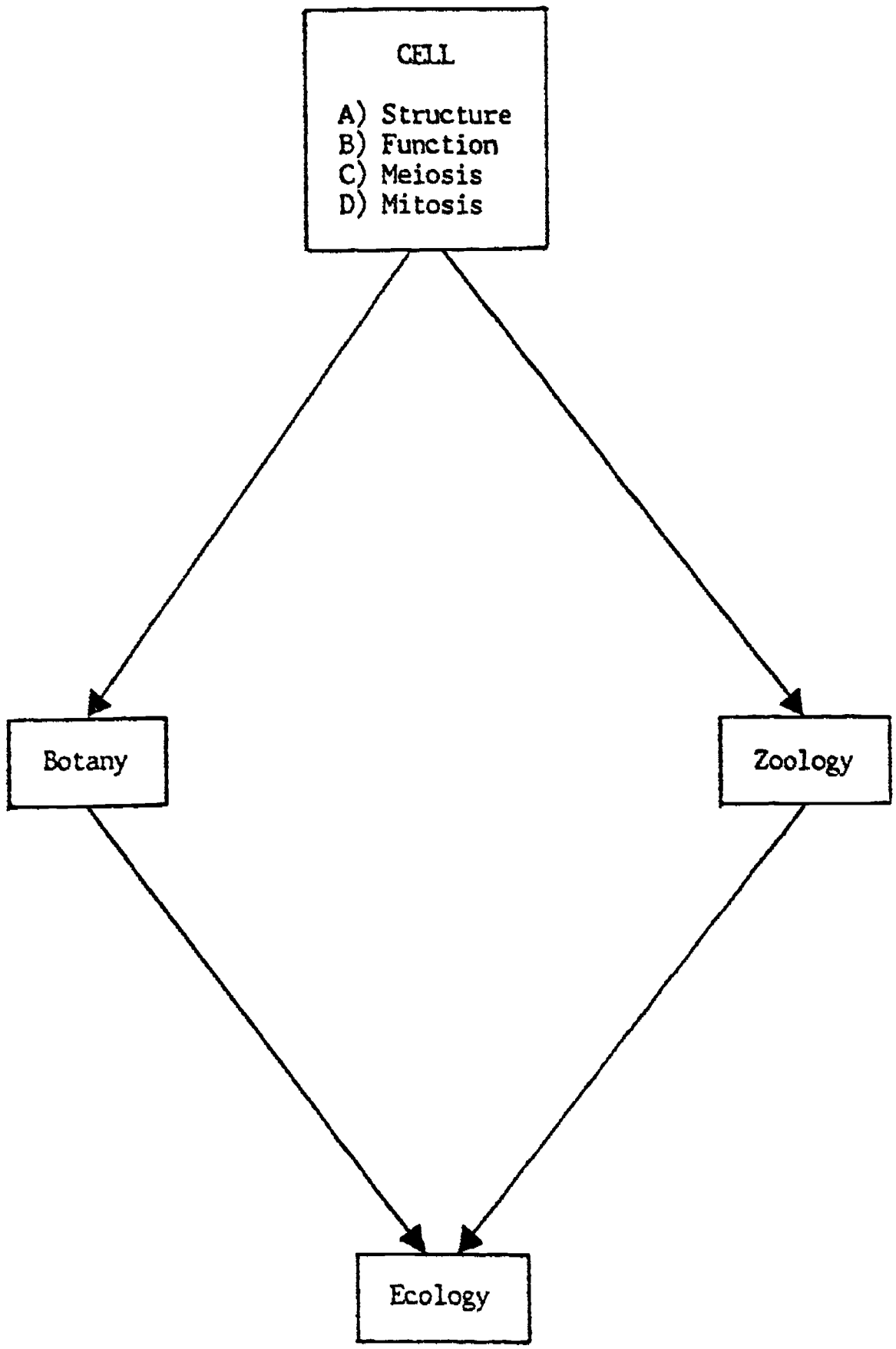

Figure 5. Carl's Self-Described Subject Matter Structure

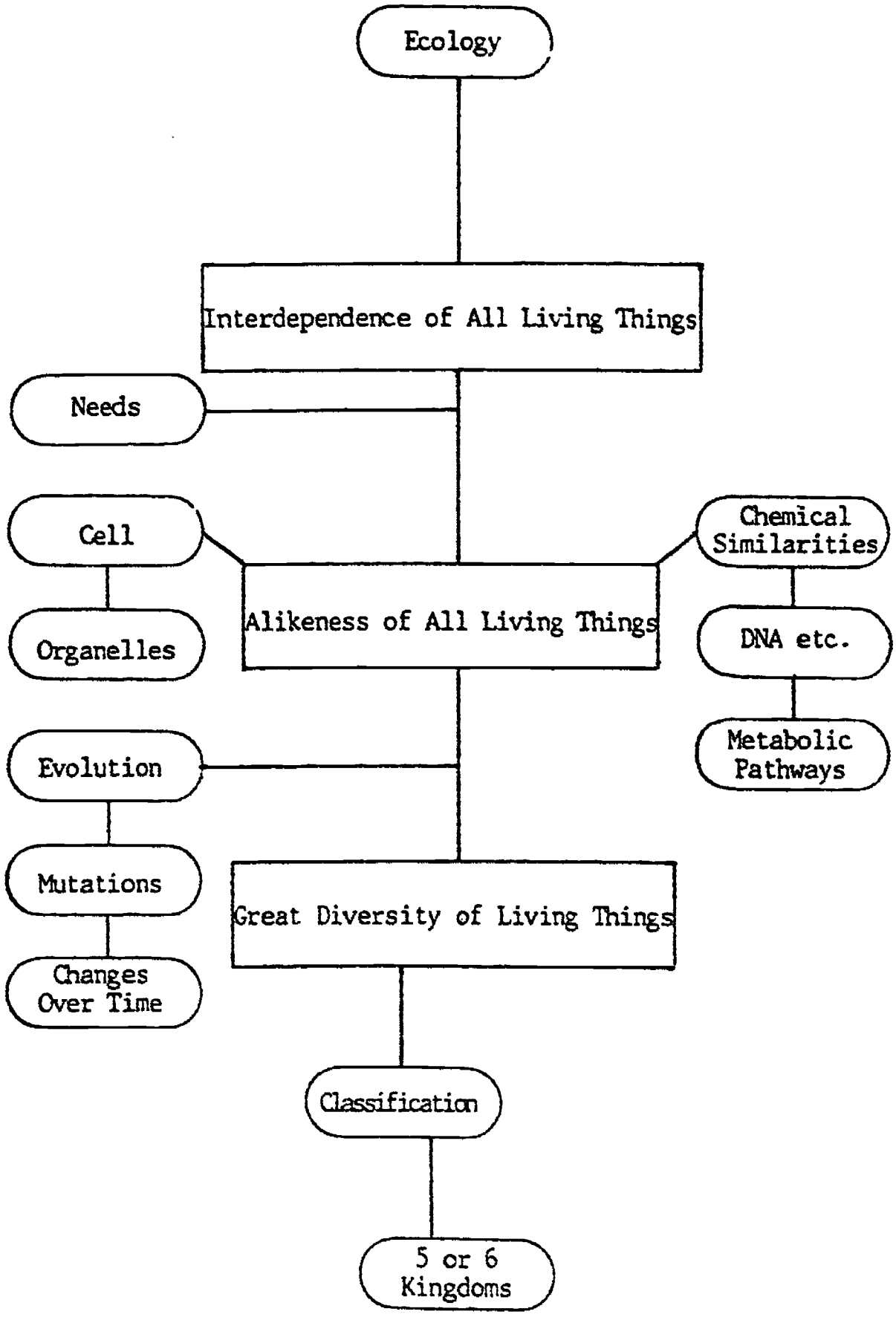

Figure 6. Ed's Self-Described Subject Matter Structure

Descriptive Materials

1 - Cell - Parts and Function

2 - Compounds of the Cell

3 - Translocation - Cell

4 - Photosynthesis and Respiration

5 - Taxonomy

6 - Invertebrates

7 - Vertebrates

8 - Plant Diversity

9 - Plant Physiology

10 - Ecology

11 - Reproduction (Meiosis and Mitosis)

12 - Genetics

13 - Evolution

Protists

DNA/RNA

Process

- Observation
- Inference
- Measurement
- Experimentation
- Prediction

Critical Thinking

Current Events

Ethics

Study Skills

Figure 7. Alex's Self-Described Subject Matter Structure

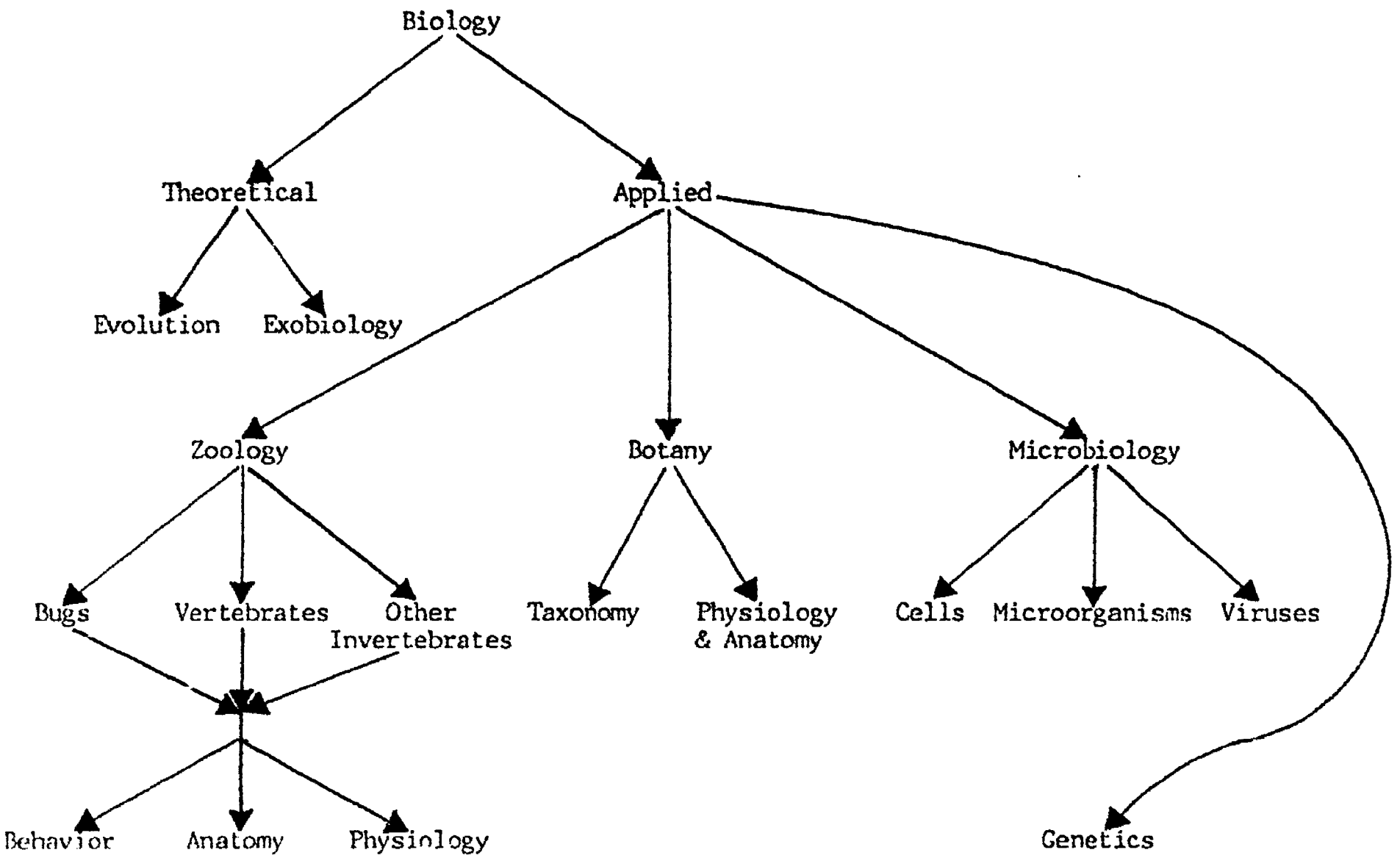

Figure 8. Ben's Self-Described Subject Matter Structure (Pretest)

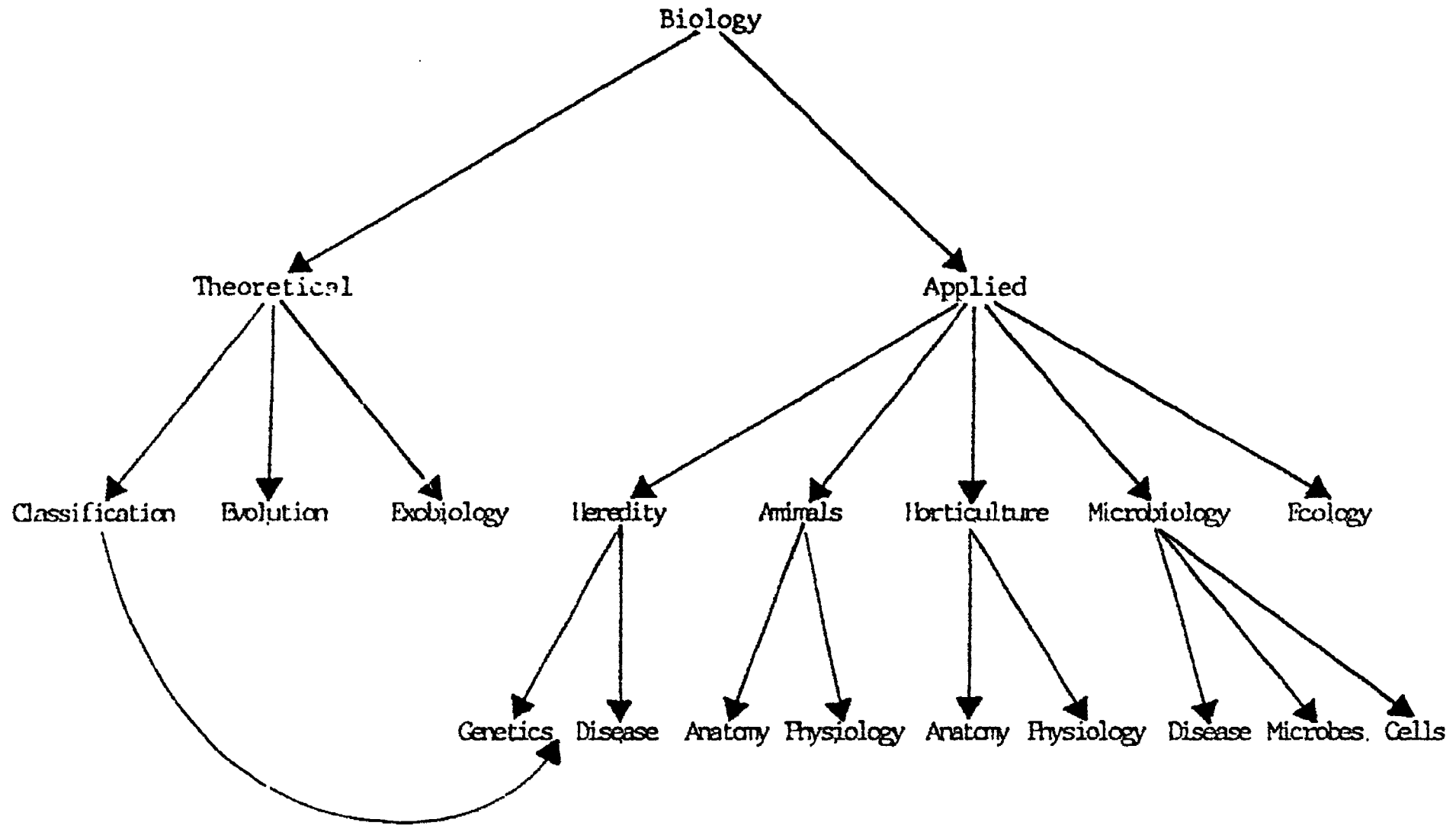

Figure 9. Ben's Self-Described Subject Matter Structure (Posttest)

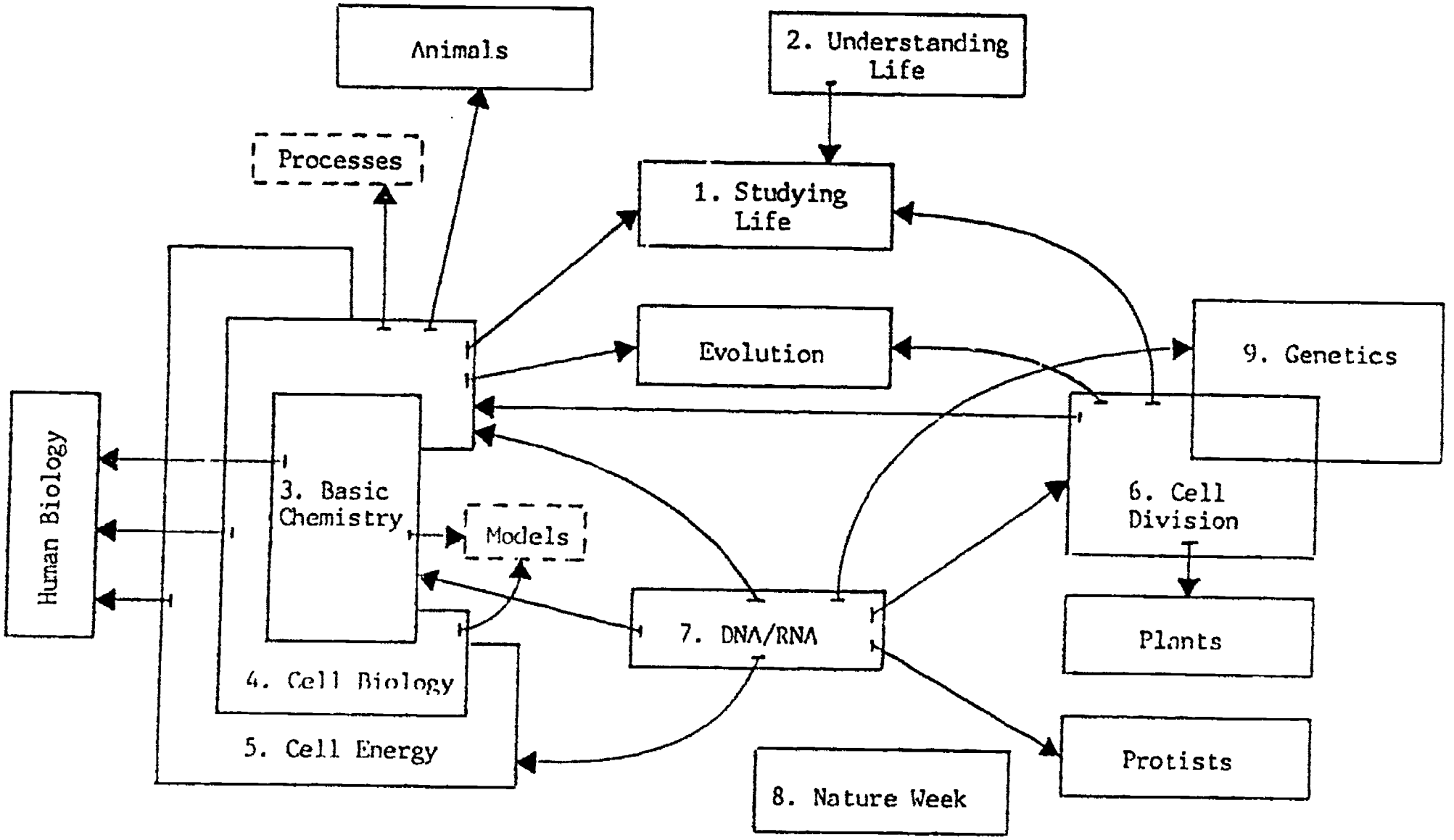

Figure 10. Carl's Classroom Subject Matter Structure

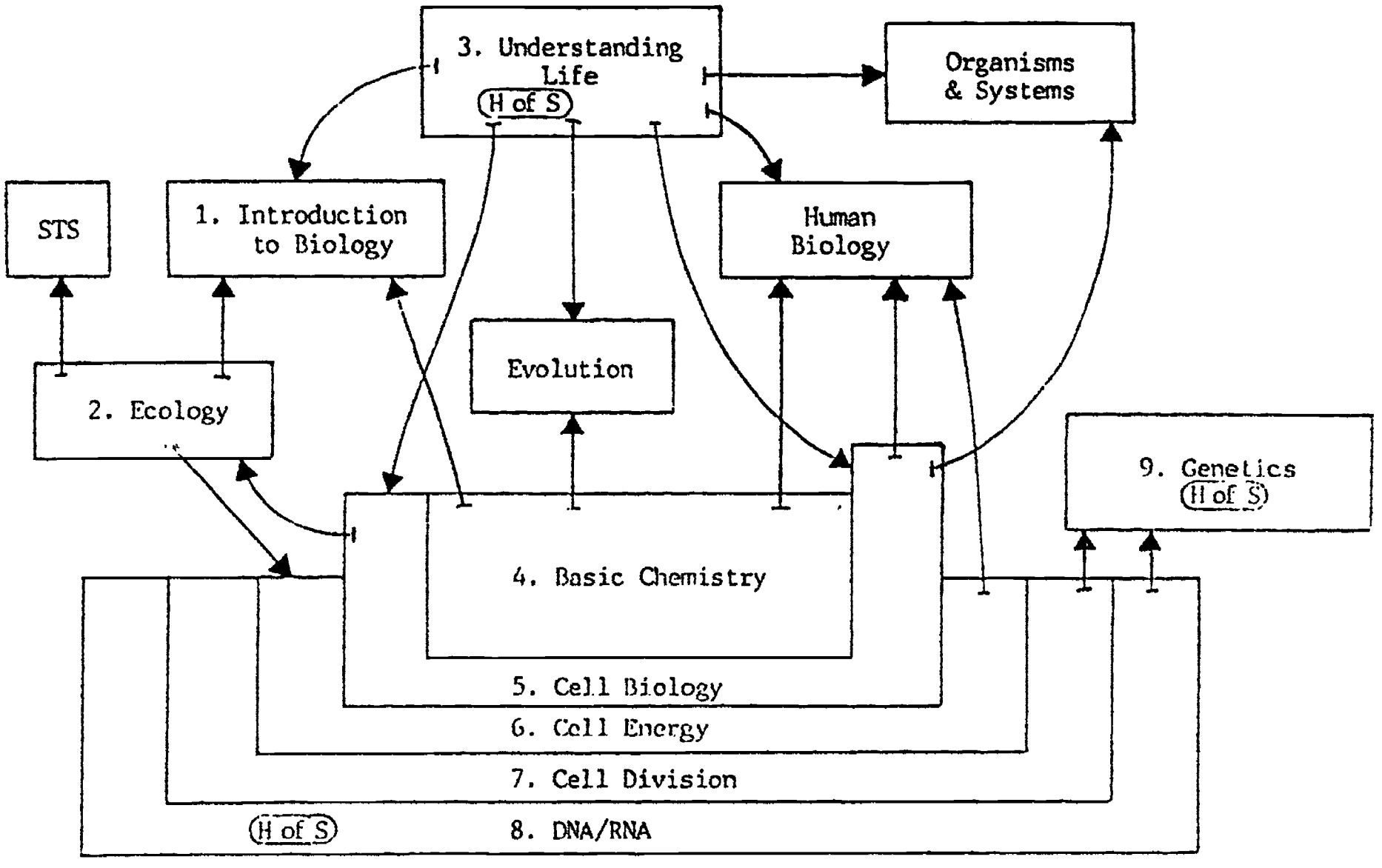

Figure 11. Ben's Classroom Subject Matter Structure

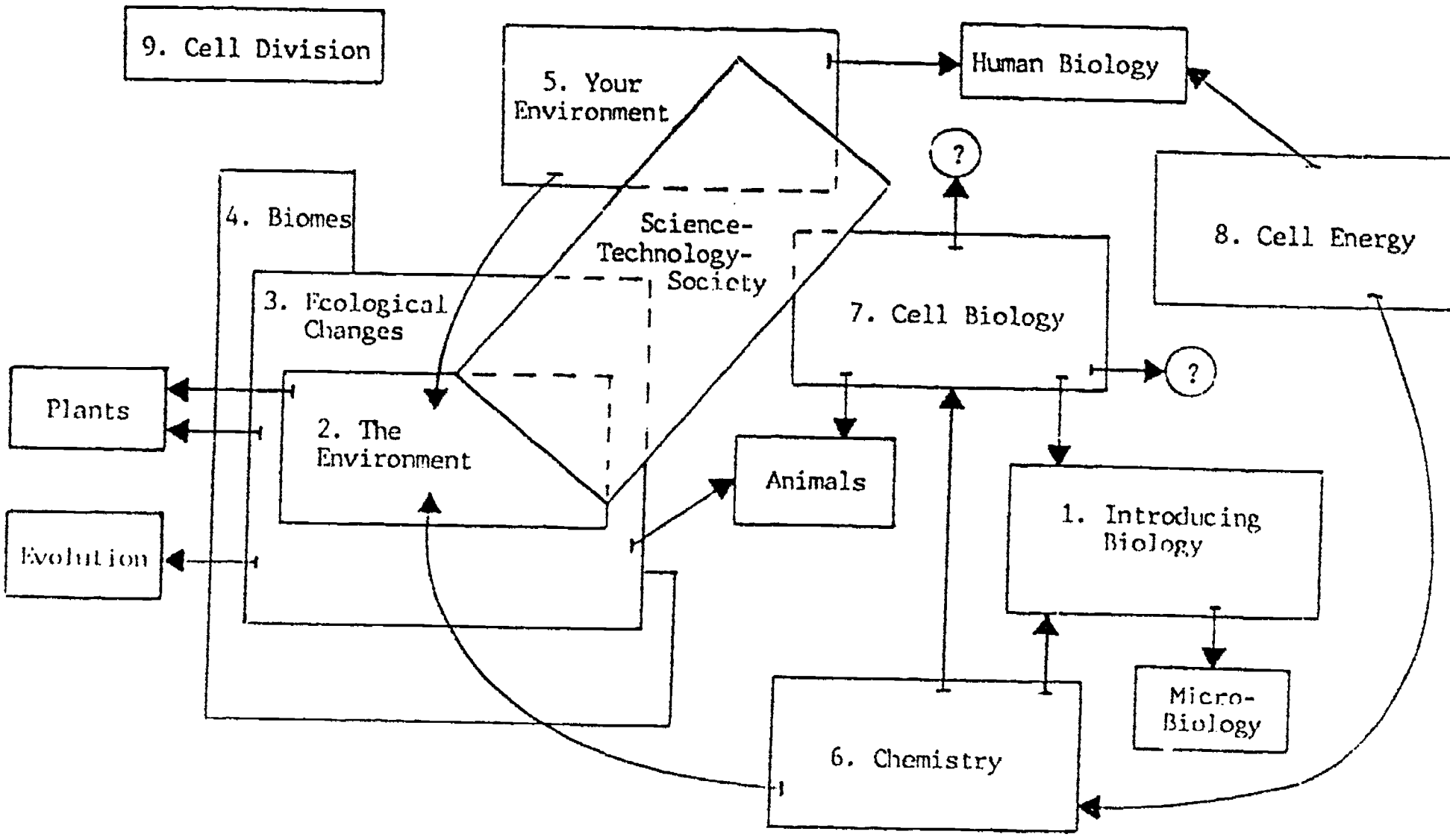

Figure 12. Don's Classroom Subject Matter Structure

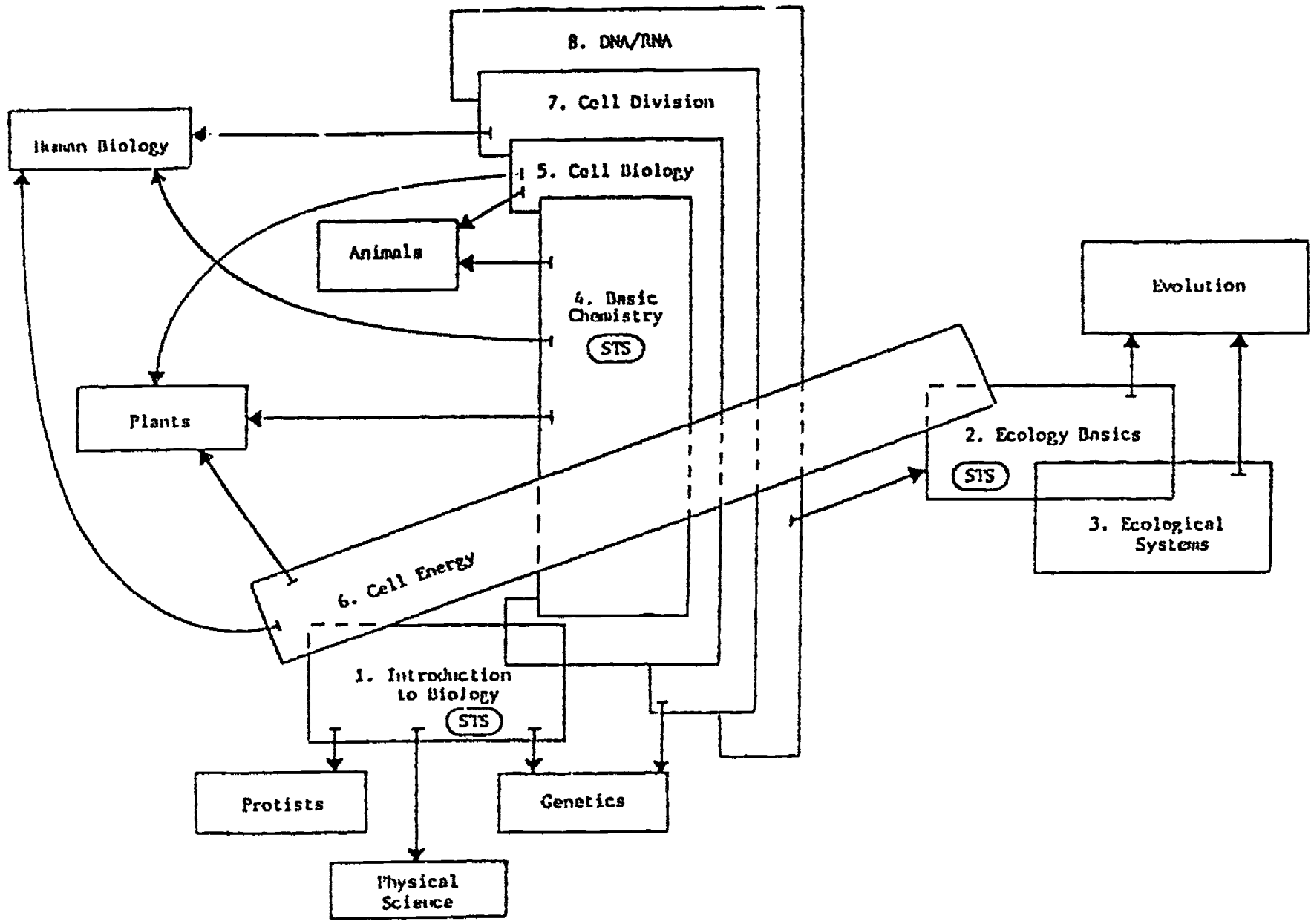

Figure 13. Ed's Classroom Subject Matter Structure

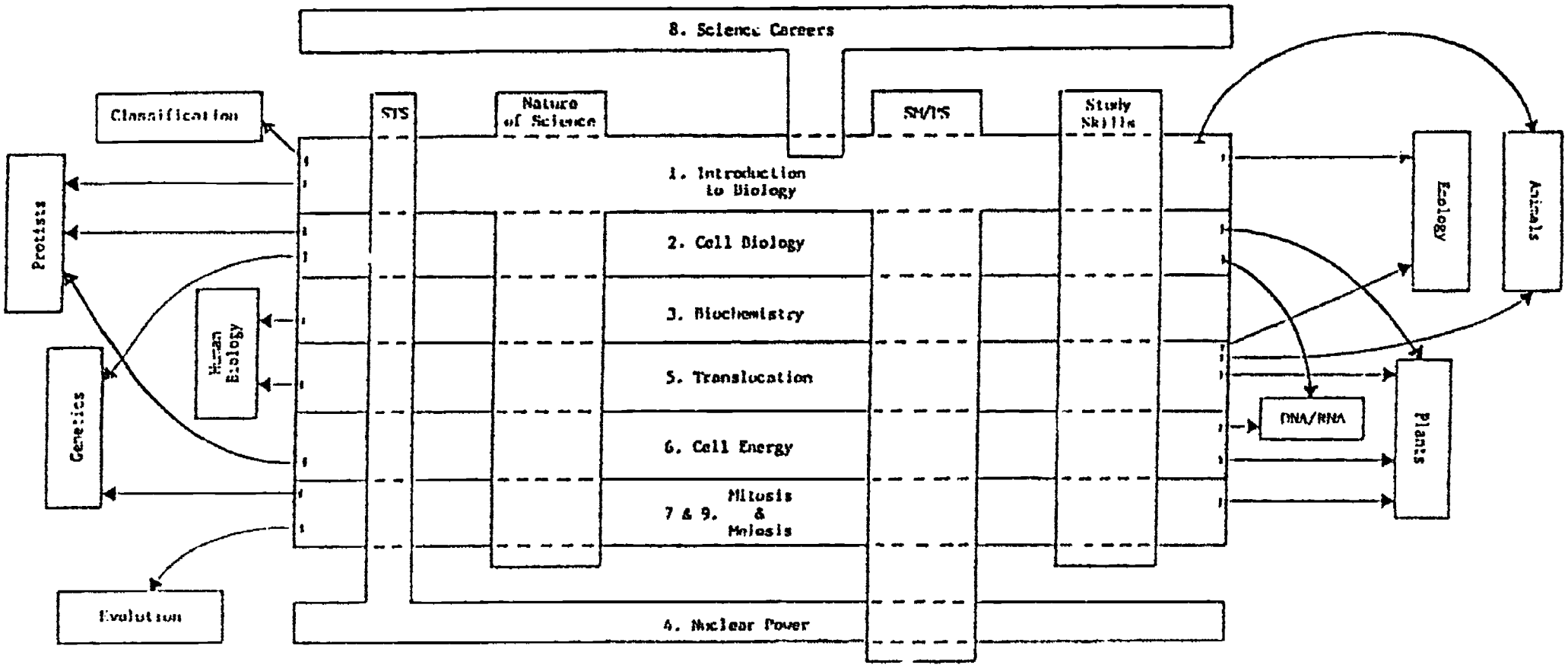

Figure 14. Alex's Classroom Subject Matter Structure