Integration of Ausubelian Learning Theory and Educational Computing

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Computers and learning theory are two of today's most rapidly developing subjects in education. Our goal is to explore their interaction, to consider some of the possible benefits when Ausubelian learning approaches are integrated into computer assisted education.

Learning Theory

Crawford (1981) points out the intimate link between the learning theory we use and the type of instructional program, whether it be text or computer program, that we create. He particularly emphasizes the implications our learning theories have for the strategies that we use in the development of instructional computer programs.

Given our purposes, discussion here is limited to the implications of Ausubelian learning theory for instruction. Students are not blank slates. They come to our biology courses and their learning tasks with preformed cognitive structures. During learning, students expand and revise these structures based upon the new experiences to which they are exposed. In the epigraph of his book, Ausubel (1968) states: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." Two heuristic devices, Novak's concept mapping (1977) and Gowin's vee-mapping (1981) help to translate this theory into practice.

Concept mapping (fig. 1) is a visual representation of cognitive structure. It has four major components: concepts, relationships (propositional linkages), hierarchy, and cross-links. First, "concepts" are "descriptions of some regularity or relationship within a group of facts and are designated by some sign or symbol" (Novak 1977). Thus, concepts are what we think with. Second, concepts are related to each other by linking words. Two concepts with a labelled relationship form a "proposition." Third, the concepts are linked together into a hierarchy from the most general concept at the top of the map to progressively more specialized concepts at the bottom of the map. Finally,

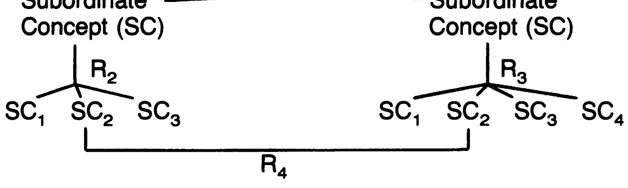


FIGURE 1. Generalized Concept Map. Concepts are circled. $R_{1,2,3,4}$ represent linking words defining the relationship between concepts. Note the hierarchy from general to more specific concepts. Note R_4 is a cross-link between two major subsections of the map.

cross-links are relationships that are made between concepts in two different domains on the map. These connections are particularly significant because they point out interrelationships which might not be obvious when the material is first learned. These relationships become clearer with increased experience and more differentiated knowledge.

Why are cognitive structures particularly important to us in scientific fields? First, it is from our cognitive structures that we and our students generate questions. We approach these questions with the scientific method, including experimental design, collection and analysis of data, and drawing conclusions. New discoveries may influence how we initially thought about things. In other words, the process of scientific research has the power to alter our cognitive frameworks. Vee-mapping (fig. 2) is a heuristic device which illustrates this interactiion between knowledge and research. Another value of the Vee is that it enables us to respond satisfactorily to the issue of content vs. process in science education. *Both* content and process are important. Each relies on the other. Students learning scientific method (lab skills and experimental design) in the classroom are limited by their cognitive structures. But building cognitive structure without understanding that the structure is built and modified by ongoing research leads to the misconception that "what we read in science textbooks is Truth." Vee-mapping offers our students a model for the *development* of understanding about facts, records we make in the laboratory or field, and the conceptual, theoretical ideas that give meaning to these records or facts we observe. As such it becomes a tool to redirect students. Students can learn to abandon the attitude of, "just tell me the right answer." In its place they will approach a subject with the realization that learning it involves a progressive deepening of knowledge and periodic modification of the way pieces of knowledge about the topic are related to each other.

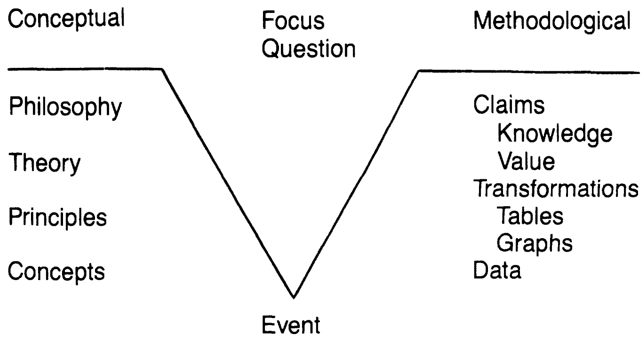


FIGURE 2. Gowin's Vee. The left side of the vee is conceptual in nature and shows increasingly complex levels of cognitive structure from concepts to principles, theories, and finally philosophy. From this framework, we generate questions. The right side of the vee illustrates scientific method, our procedures for seeking answers to questions, from collecting data to analysis to drawing conclusions. Conclusions may lead to the generation of new knowledge, a change in the conceptual framework within which we work. Note that this heuristic shows the interaction of content of subject matter with the process of scientific method.

Computers In Education

Computers have been used in bioeducation for over 25 years (Crovello 1974; Crovello and Smith 1977). But their availability to significant numbers of bioeducators at the high school and college levels really only occurred around 1980. This was due to the sudden availability of microcomputers. Reasons included their relatively low price, versatility, expanded memory storage, effective graphics, portability, and a growing generation of students and educators who were becoming more comfortable with them in the classroom (Crovello 1982).

Educomputing now has expanded far enough so that many teachers are ready to go beyond the gimmicky attraction of such machines. Armed with a sound understanding of both the potential and limitations of computers in the classroom, they refuse to use a program simply to be able to say that they are part of the computer generation. Rather, they want to know what programs are pedagogically sound for their particular course and students. This has produced increased analysis of the educational system operating in their classes (e.g., how relatively important are lectures, the text, other students, etc. in the learning process; does the importance vary with the topic and individual students?). Just as importantly, we now see widespread demand for the evaluation of educomputing software and for research to determine characteristics of good educational programs from the point of view of educational psychology. Emerging desirable characteristics include the following (Crovello 1983; Peard 1983): maximum student control; immediate feedback; user helpful; high level of user interaction; simulation of biological events and experiments that otherwise would be impossible. At a still more refined level are characteristics such as the optimal order and frequency to retest students on drill and practice questions that they answered incorrectly.

Perhaps the most important realization for educators is that we still are at the very beginning of computer assisted education. The state of the art of computers is changing rapidly. In its wake is the development of educomputing programs that not only will cover more biological subjects, but also will do so in pedagogically more effective ways. In the next section we sketch a possible scenario that integrates Ausubelian learning theory and computers.

Synthesis of Learning Theory and Computers

Consider a computer program with four parts. The first part introduces new conceptual knowledge to the students. It need not differ greatly from textual material. The second part engages the student in interactive concept mapping of the concepts introduced in Part One. The student would not be a passive reader of knowledge, but would interact with it, using it to create a concept map to relate individual concepts in a meaningful way. It might be possible to create an "expert's map" against which the students could compare their relationships and hierarchy. Part Three would offer a menu of simulations in which students could experiment with real-world data and explore different dimensions of the basic knowledge and concepts to which they were exposed. Finally, in Part Four students could construct Vee diagrams to show the interaction between experiments and their cognitive frameworks. Exploring via many simulations might lead to additional and altered linkages in students' cognitive frameworks. Let's look briefly at an example dealing with introductory ecological concepts.

Part One. Tutorial—The following paragraphs appear on the screen, a few sentences at a time, with the speed controlled by the student:

Scene 1. Ecology is the study of interactions of abiotic and biotic factors in the environment. Abiotic, or nonliving, factors include temperature, light pH, and inorganic compounds, such as water, carbon dioxide, potassium, phosphorous, and nitrogen. Biotic, or living, factors in our environment include producers, consumers, and decomposers.
Press Spacebar To Continue.

Scene 2. These organisms obtain nutrients in different ways. Producers are usually green plants, which are capable of making their own nutrients through the process of photosynthesis. Consumers are animals which obtain nutrients by eating other organisms. Consumers, such as rabbits and cows, which eat only plants are called herbivores. Those, such as coyotes and lions, which eat other animals are called carnivores. Omnivores are consumers which eat both plants and animals. Decomposers, such as bacteria and fungi, obtain nutrients from dead plants and animals.
Press Spacebar To Continue.

Part Two. Interactive Concept Mapping—Now that the concepts have been introduced, the students interact with the concepts and build a conceptual framework. Four alternatives would be the following: 1) have the computer begin the mapping to introduce students to the skill; 2) give the student concepts, linking words, and a skeletal conceptual framework to fill in; 3) give the students concepts and linking words and have them build their own structures; 4) have students define their own concepts, linking words, and conceptual structures. The last step is the most flexible but also most difficult both to program and to give appropriate feedback to students.

A sequence of screen scenes in Part Two for the above material might look like the following. For ease of illustration we will use alternative 1) described above (i.e., the student lets the computer build the concept map). The student presses the spacebar to advance to the next segment of the screen, or to the next screen.

Scene 3. (Student is asked to choose the most general concept):

Let's make a concept map of this information, beginning with the most general concept and working down to those that are more specific.

LINKING WORDS	*CONCEPTS*
is, between, of	ecology study interaction abiotic nonliving biotic living

What word in the list at the right that is the most general concept, the central idea of the whole program?
(Press Spacebar)
ECOLOGY
(Press Spacebar)

Scene 4. (The term, ecology, moves to the center of the screen in a pedagogically effective way; the student is asked to indicate what ecology is):

LINKING WORDS		*CONCEPTS*
is, between, of		
	ecology	study interaction abiotic nonliving biotic living

Ecology is the most general concept in this lesson.
Now indicate what ecology is:
(Press Spacebar)

Scene 5. (Ecology is described using a linking word from the left and a concept from the right).

LINKING WORDS		*CONCEPTS*
is, between, of	ecology is | study	study interaction abiotic nonliving biotic living

—"ology" is a suffix meaning "study of."
—"Study" is a specific term describing "ecology." Therefore, it is mapped below ecology.
—The linking word *is* describes the relationship and is written in on a connecting line between the concepts.
(Press Spacebar)

Scene 6. (User is told that linking words can be used more than once, but concepts can only be used once):

LINKING WORDS — *CONCEPTS*

is, between, of

ecology
is |
study

interaction
abiotic
nonliving
biotic
living

Note that linking words may be used more than once.
Concepts are only used once.
What is ecology the study of?
(Press Spacebar)

Scene 7. (Student is asked what ecology is the "study of"; after pressing Spacebar the first time, the two question marks are replaced by "of" and "interaction"):

LINKING WORDS — *CONCEPTS*

is, between, of

ecology
is |
study
? | of
? interaction

interaction
abiotic
nonliving
biotic
living

Ecology is the study of??
(Press Spacebar)
Interaction implies that something is happening between two or more things.
What things interact in ecology?
(Press Spacebar)

Scene 8. (To respond to the last question of the last screen scene, the linking word, "between" and the concepts, "abiotic" and "biotic" move dynamically to the concept map):

LINKING WORDS — *CONCEPTS*

is, between, of

abiotic
nonliving
biotic
living

ecology
is |
study
of |
interaction
between
abiotic — biotic

Where would the concepts "living" and "nonliving" fit on this concept map?
(Press Spacebar)

Scene 9. (Since "living" and "nonliving" are the same as "biotic" and "abiotic," they go on the same level and are linked by "is"):

LINKING WORDS

is, between, of

ecology
is |
study
of |
interaction
between
nonliving is abiotic — biotic is living

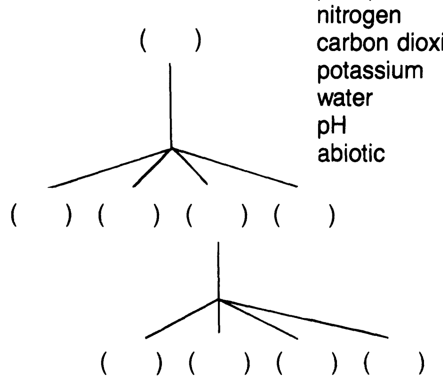
Notice that this is just the beginning of a bigger concept map for this unit. Now you try to build a concept map of the next set of concepts and linking words!
(Press bar to begin mapping)

Scene 10. (The program, advancing to the second alternative for indirect concept mapping, provides the skeleton for the new set of concepts, and asks the student to do the rest):

LINKING WORD — *CONCEPTS*

includes

temperature
light
inorganic compounds
phosphorous
nitrogen
carbon dioxide
potassium
water
pH
abiotic



This time I provided the skeleton of the concept map.
Your job is to type in the concepts. The linkage word is always, "includes."
(Press Spacebar)

Alternatively, the program could ask the student to provide the entire concept map. In this case the student would type in a concept or linking words. If it is incorrectly placed, the program could indicate that, and provide hints to help the student discover its correct placement. As another alternative, the computer could request the student to combine each of several smaller concept maps into one large one, complete with cross-linkages. Another valuable additional option would allow comparison of the student's concept map with that of an "expert" biologist which is stored in the computer. This option is exactly analogous to one available in artificially intelligent expert systems. The reason is that the concept map is a type of logical hierarchy, and expert systems also store data as a hierarchy.

There are some ideas we should keep in mind with the interactive concept mapping section. It should get progressively more difficult as students develop concept mapping skill. Varying levels of difficulty should be available depending upon the skill of the individual learner. As students progress to the point of identifying their own concepts and linking words, student maps will diverge more from the expert's map. This development is an understandable one, which can make the task of computer evaluation of concept maps quite complex.

Part Three. Simulations—Using a series of simulations, students explore the meaning of the conceptual material, develop skill in applying the scientific method, and draw additional relationships between the concepts in their maps. Each simulation should be based on real-world data. Ideally, students should collect and analyze their own data as well as draw conclusions. A choice of simulations for this example might look like the following:

Choose the study you would like to explore in more detail.
1. How do populations of coyotes and rabbits interact?
2. How does nitrogen influence the growth of corn?
3. How do light intensity and plant growth interact?
4. Grass and grazers, or how many heifers per hectare?

Part Four. Vee-mapping—In an interactive manner similar to the concept mapping of Part Two, students would vee-map the results they obtained from the simulation. They could compare their results with those of the experts. If their results did not agree with the experts, they could return to the same simulation and obtain more insight or they might try other simulations. Creative animation graphics could illustrate on vee-maps the interaction of scientific method and concepts. Finally, they could obtain a printout of their vee or concept maps for further study and modification.

Summary and Conclusions

Educational computing is entering its most exciting and promising phase to date. This is due to the sophisticated capabilities of affordable microcomputers and also to the increasing number of educators who know the potential and limitations of computers in education.

Correctly presented subject content, while necessary to educational software, is not sufficient. It is also necessary that educational programs present the subject in a pedagogically effective way. In the present article we gave an example of how one popular learning theory approach could be integrated with computer technology. Due to space limitations our example had to be kept simple. Yet it conveys the potential value when advanced principles of learning theory form the general context of a program. The creation of such programs will challenge today's microcomputer resources, but more importantly they can challenge and excite our students, both cognitively and affectively. As educators our job is to help assure the development and use of such educational software!

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