Online Symposium: Piaget, Constructivism, and Beyond

Novak’s Theory of Education: Human Constructivism and Meaningful Learning

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These are exciting times in chemistry education. Faculty are working tirelessly to develop more meaningful college chemistry curricula and to investigate the benefits of new pedagogies (e.g., collaborative learning, discovery learning) and technologies such as the WWW. In order to understand and sustain the effectiveness of these classroom reforms, chemists are now conducting education research in ever-increasing numbers. As Tobias has written, though, chemists

“...inevitably bring the habits of doing science to the problem of [chemistry education] reform. First, they believe there is one best curriculum or pedagogy waiting to be discovered, like the laws of nature. If it hasn’t been discovered so far, it’s because researchers haven’t worked hard enough. Second, by pursuing abstract studies of the nature of knowledge and cognition, researchers can find this curriculum or pedagogy and experimentally prove it is the best. And third, such experimental evidence will persuade instructors everywhere to adopt the program.”

Therefore, when issues of data collection and analysis are considered, Champagne, et al. argue that the experimental design considered most “scientific” by chemists is

“...to identify a single student characteristic (e.g., Piaget level) and demonstrate that the characteristic is correlated with success in [chemistry]; then, typically instruction is modified to take into account student inadequacies with respect to this characteristic, and studies are conducted to demonstrate that student achievement improves.”

Not surprisingly, such research has been criticized as “method driven instead of theory driven.” That is, the familiarity of such a control-experiment design has all but overshadowed attention to designing research from the principles of a theory about learning or teaching. At the same time, however, given the multitude of educational contexts, it would be simplistic to assume that one, or even a handful, of theories would be suitable in all situations; different theories will be necessary in different classrooms. This paper aims to familiarize chemists with one such theory, specifically Novak’s Theory of Education known as Human Constructivism, and, by doing so, provide chemists with a theoretical framework not only for improving their classroom teaching but also for conducting chemistry education research.
The Influence of David Ausubel

Novak’s Theory of Education draws strongly from the work of philosopher David Ausubel. Ausubel’s assimilation theory has been described in this Journal in great detail; its basic premise is that “reasoning capacity is primarily a function of the adequacy of the relevant conceptual framework a person has in a specific domain of knowledge.” Consequently, what Ausubel describes as meaningful learning occurs when new information is purposefully connected to a student’s existing knowledge, i.e., the formation of “non-arbitrary” relationships among ideas in the learner’s mind.

In order for meaningful learning to take place, three conditions must be satisfied: i) a student must have some relevant prior knowledge to which the new information can be related in a non-arbitrary manner, ii) the material to be learned must be meaningful in and of itself; that is, it must contain important concepts and propositions relatable to existing knowledge, and iii) a student must consciously choose to non-arbitrarily incorporate this meaningful material into his/her existing knowledge, a disposition which Ausubel labels as the meaningful learning set. This idea of meaningful learning stands in direct contrast to rote learning, in which new concepts are not connected in any substantive manner to prior knowledge, but are merely memorized. A concept map showing the relationship of these ideas can be found in Figure 1.
The difficulty with using Ausubel’s assimilation theory in the chemistry classroom and in designing chemistry education research arises when the chemistry teacher tries to operationalize these three prerequisites. Only one of these conditions is dictated by the teacher as the other two factors are solely in the student’s control. That is, students bring prior knowledge (although Ausubel’s assimilation theory fails to address the obvious concern of how correct such knowledge might be) and students control whether they choose to forego memorization in favor of learning meaningfully. That leaves only one variable available to the chemistry teacher: organizing the material to be learned in such a manner that it can be connected to students’ prior knowledge and be of sufficient interest that they might choose to do so. This is where Novak’s Theory of Education, Human Constructivism, becomes powerful as it guides the chemistry teacher in how to help students achieve meaningful learning.

**Human Constructivism**

Earlier papers in this symposium⁷, as well as in *this Journal*,⁸ have argued that knowledge is a human construction. Therefore, Novak believes that the business of education must be to enable people to construct knowledge; that is, education should consist of

![Diagram of Requisite Conditions for Meaningful Learning]

**Figure 1. Requisite conditions for meaningful learning.**
those experiences that will empower a person to manage his or her daily life. Novak classifies such experiences as occurring within either the cognitive, affective, or psychomotor domain. Examples of learning chemistry content within each of these three domains are provided in Table 1.

Table 1. Domains of Chemistry Learning.

<table>
<thead>
<tr>
<th>Learning Domain</th>
<th>Types of Knowledge</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>cognitive</td>
<td>concepts, reasoning skills</td>
<td>equilibrium, enthalpy, periodic trends</td>
</tr>
<tr>
<td>affective</td>
<td>attitudes, motivations</td>
<td>risk assessment, careers in chemistry</td>
</tr>
<tr>
<td>psychomotor</td>
<td>dexterity, precision</td>
<td>molecular modeling, titrations</td>
</tr>
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How do these three domains of experience connect to meaningful learning? Novak's theory of education, known as Human Constructivism, states that “meaningful learning underlies the constructive integration of thinking, feeling, and acting, leading to human empowerment for commitment and responsibility.” That is to say, meaningful learning will only occur when education provides experiences that require students to connect knowledge across the three domains. For example, students studying energy transformations must not only read of (thinking) concepts (e.g., enthalpy and entropy), but must also design and carry out experiments in the laboratory (e.g., combustion of foods with varying fat contents) which allow them to connect these abstract concepts to choices they must make in their daily lives (feeling and empowerment). Chemistry faculty who design a learning experience which attends to only one or two of these three domains will prevent their students from succeeding at meaningful learning.

What does education look like that is capable of promoting these connections? In 1973, Schwab first put forth the idea of “irreducible commonplaces” that combine in any educational experience: the teacher, the learner, the content, and the context; Novak’s theory argues for the addition of a fifth commonplace, evaluation, given the obvious importance of measuring whether we
achieve our outcomes. These irreducible commonplaces in education are analogous to the elements on the periodic table in chemistry which combine to produce an infinite number of compounds. Similarly, in any educational experience, these five commonplaces will integrate time and again to produce new meanings, feelings, and actions. Given that the learner’s world and the teacher’s view never will be isomorphic with one another, we come to the crux of Novak’s thesis: education must provide experiences for the sharing and negotiation of meanings between the teacher and the learner. These ideas are summarized in Figure 2.

The Importance of Shared Meaning

Gowin has written that meaning is constructed from shared experience and that to educate is, therefore, to change the meaning of experience. The challenge for teachers and students of chemistry alike then, is to achieve shared meaning as shown in Figure 2. Teachers of chemistry should strive to weave concepts into contexts familiar to students’ everyday lives; this goes beyond offering a mere example, but providing for students a real “need to know.” Chemistry in Context, a text for undergraduate nonscience majors is a sterling example of this philosophy in practice.

Undergraduate students enter the chemistry classroom with not only a variety of previous educational and real-life experiences, but also with equally diverse goals and purposes for their education. The sum of an individual student's prior knowledge (what she knows) and experiences with chemistry will influence how successfully the student can integrate new knowledge (what she needs to know). Meaningful learning requires the student to detect similarities
Figure 2. Novak’s vision of education through the irreducible commonplaces.
and differences between new and existing knowledge, and in doing so, tackle the difficult challenge of making connections, i.e., of constructing learning. Assimilating new concepts not only provides meaning for this new information, but can also restructure (sometimes slightly, sometimes significantly) the meanings of the previously known concepts. In the epigraph to *Educational Psychology: A Cognitive View*, Ausubel writes:

"The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."  

This powerful idea liberates chemistry faculty from feeling the need to “cover” everything in the text. When faculty make content selections based more on the suitability for their students and the connections to their lives and chosen careers, students of chemistry will move toward meaningful learning. By emphasizing meaningful learning over memorization, students can translate the skills of connecting what they do know with what they need to know, i.e., they can learn how to learn.

**Improving Chemistry Classrooms: Applications to Your Teaching**

While many exams and pre-tests exist for ascertaining what a student already knows, Novak’s work in defining the field of Human Constructivism has led to the development of a much more powerful tool known as **concept mapping**. A concept map is essentially a two-dimensional representation of the three-dimensional knowledge network within a student’s mind. Such knowledge is organized in the mind as a collection of concepts and propositions with the meaning of a particular piece of knowledge deriving from the composite of all propositions that contain a given concept. The power of concept maps lies in their ability to not only represent the meaning of knowledge to a particular person but to visually represent it to another person.

Concept maps can also serve as advance organizers when beginning a new topic or chapter. For example, at the beginning of the fall semester in general chemistry (before I give any lectures), I ask students to construct a concept map from a list of terms about atomic and molecular structure. While many students’ maps contain valid propositions (e.g., nucleus contains protons and neutrons), without fail, each and every semester this assignment points out the diversity of misconceptions with which my students begin the course (e.g., elements contain compounds). The very act of creating this concept map alerts students to the fact that they do have some relevant prior knowledge to draw upon and to which they can connect new knowledge; it also alerts them to the fact that while they may know something about the subject at hand, they clearly have more to learn. Concept maps now appear in chemistry textbooks and are used for both the planning and delivery of chemistry lectures.

**Improving Chemistry Education Research**
While concept maps are more familiar to chemistry faculty as a teaching/learning tool, they actually originated as a tool for research in order to analyze, distill, and communicate findings from qualitative inquiry, namely semi-structured interviews. Given the growing importance of qualitative research amongst the chemistry education community, the need for such a valid and reliable method of data collection and analysis becomes increasingly important. Furthermore, the strengths of concept maps in representing knowledge networks will allow research studies to be more focused in their target questions by using this tool to pinpoint specific gaps in students’ conceptual understandings. Concept maps are also a valuable tool, in particular, for the constructivist researcher who places emphasis on process, i.e., how the individual student constructs her own meanings. Concept maps are uniquely suited to provide a “window” into the student’s mind.

In summary, Novak’s Theory of Education encourages both chemistry students and teachers alike to view their shared experiences in the classroom as opportunities for meaningful learning. Chemistry students must have an understanding of, and a commitment to, the requisite conditions for meaningful learning. Chemistry teachers bear an equally important obligation to inform themselves of what their students already know, so that they can teach accordingly. And while the flurry of activity in chemistry curricular reform will continue to debate just what qualifies as teaching accordingly, Novak’s Theory of Human Constructivism ensures that chemists will have a firm theoretical foundation on which to base their educational decisions.
Literature Cited