

**INDONESIAN UNIVERSITY OF EDUCATION (UPI) FACULTY
OF SCIENCE AND MATHEMATICS EDUCATION
DEPARTMENT OF PHYSICS**



Teaching Physics

Summery on;

Why Should We teach Sience for Understanding?

What Does It Mean to Understand Science?

Patterns of Thinking by Scientists and Adolecents

The Workplace, Student Minds, and Physics Learning Systems

Less Is More: Trimming the Overstuffed Curriculum

Rethinking the Content of Physics Courses

Definition and Varities of Learning

Three Types of Learning Cycles

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TCTP Program

Why Should We teach Science for Understanding?

The dominant paradigm in science teaching in most class room in United States from elementary school to college is as follows. The teaching is a means of transmitting information to students who are passive participants. Learning is perceived by both teachers and students as memorizing rather than understanding this information. Assessment is viewed as summative rather than formative. This means assessment comes at the end of an instructional unit to determine which students remembered the information for the sake of grading purpose. This is also true in many other nations including Ethiopia. It is the dominant paradigm in science teaching and learning in spite of many efforts to enable a different approach.

A New Paradigm for Science Teaching and Learning

About a century, reformers such as John Dewey and Alfred North with many teachers, scientists and leaders in business and government, called for a different approach. Currently in USA and in most nations of the world, reform leaders are promoting a *new paradigm in which teaching is viewed as providing students an array of experiences that enables understanding and then guiding students towards understanding and use of science knowledge. In this paradigm, students must be active participants in doing science and constructing meaning from their experiences.* Thus learning always must involve some memorization is not the end point of the learning process. Students also make personal sense of their experiences to developing understanding and learning to apply their knowledge. Assessment does not just come at the end of instruction, but it is a continuous process used by both the teacher and students to guide both teaching and learning.

Why Is a New Paradigm Essential?

In 1983 the Secretary Education, the member of the President's Cabinet who directs the USA department of education issued a report titled *A Nation at Risk* which explains the decline in quality and effectiveness of schools. The author of this work identifies diluted curriculum in science and in mathematics, low level standards for learning, and poorly prepared teachers

among the major reasons for the problems. The reports commented that students in USA were not required to study science and mathematics in secondary schools as compared to other advanced nations. In addition, as shortage of qualified teachers for both subjects was also identified as serious problem in affecting curriculum. The report also claimed that certification requirements for teacher were lax in many states and that teachers frequently were assigned to teach course out side of their field of experience. This report resulted in many important actions that changed the environment of schooling across the nations. Most states strengthened state wide testing programs to raise **standards** for both teaching and learning. Most states also developed new curricular and instructional standards to guide teacher, students and test makers. Universities engaged in strengthening their teacher education programs. Many schools responded with new curricula, text books, laboratory materials, organizational plans and staff development efforts. Generally, the new paradigm is essential to improve teaching and learning in nations.

Formulating a New Paradigm Science Education

In 1985, Project 2061 was developed by leaders at the American Association for Advancement of science. This began with the creation of a series of panels of specialist in science who were given the charge of thinking freely about how science teaching and learning should change so that students would be adequately prepared for the future. This activity extended over two years and resulted in publication of an important book titled *Science for All Americans* (Rutherford and Ahlgren, 1989). This formulated a highly integrated plan for science teaching and learning that includes a far broader view. It included important science ideas that were familiar parts of science, but it also added many other features such as an emphasis on nature of science, and how science **integrates** with mathematics, technology, and design. *Science for All Americans* made the point that we must teach science effectively to much larger segment of students than in the past. In addition to these the book focuses on teaching science for **understanding** instead of only memorizing information. Thus the goal was created for achieving understanding of science through reduced the amount of complex terminology.

Emergence of New Standards for Science in Schools

Beginning in 1993, three large working groups were formed to prepare standards for teaching, assessment, and science contents. Several drafts of the *National Science Education*

Standards were prepared and disseminated widely to gain national consensus among teachers, educational policy makers, legislators, teacher educators and school administrators. A final draft of *National Science Education standards* was published in 1996 containing chapters on standards for teaching, teacher professional development, assessment, and science content to be included in the school curriculum. Standards were also presented for programs and systems to guide district leaders and policy makers at local, state and federal levels in planning and for providing the needed resources for effective science teaching. The content standards reinforced the broad picture of science that was found in science for all Americans by including eight content dimensions:

Unified concept and Processes

Science as inquiry

Physical Science

Life science

Earth and Space Science

Science and Technology

Science in personal and Social Perspectives

History and Nature of Science

The cumulative work of Project 2061 and National Science Education Standards had substantial effect on the science education community among university faculties in science education and governmental agencies such as state department of education.

Impacts of Project 2061 and the National Science Education Standards

Beyond generating an agenda of reform in the USA, the project influences other nations' educational system. For example Japanese reduced the number of science concepts included in the science curriculum by approximately 1/3. This step enables Japanese science teachers to *provide more depth of understanding* rather than much coverage of science knowledge. Nations like Korea, Czech Republic Netherlands etc... change their educational system in the same way on the basis of their need.

A New, Long-Term approach to Change in Science Curriculum, Teaching and Assessment

The concept of long-term change, initially promoted by Project 2061 which provides in science schools. Changing in teaching, learning, and assessment doesn't occur easily and quickly. New curriculum materials and instructional resources need to be developed and teachers need to learn how to use them. Curriculum guides and testing have been influenced by some combination of *Education Standards and Project 2061*. Publishers of educational materials for science have also played their own role. Understanding and success on external tests go hand in hand. The mental skills and knowledge development that are part of teaching and learning science for understanding and applications are the same as needed for success on external exams. When students understand science concepts and can apply science reasoning skills instead of simply memorizing factual informations, they score better on tests.

How Have New Ideas about Learning Science Changed Our Thinking

For decades, scholars who study learning and teaching had increasingly recognized that learning requires more than transferring information from someone who knew it to who didn't. This was especially important when it came to understanding and the use (application) of knowledge. The understanding of and the ability to apply knowledge can not be simply transmitted. Factual knowledge can be easily transmitted but understanding and application are more complex. They require that learners make personal sense of the new information and fit it in with what they already know. Therefore learning with understanding requires that students make sense of ideas and experiences and connect them with other related ideas and experiences that from the prior knowledge. To apply knowledge also requires that students see the connection between knowledge and its application which comes through practice.

Guiding students through investigations to obtain reliable data and experiences with scientific phenomena is not a simple process. Then helping students develop understanding at three levels related to inquiry process to identification of patterns and meaning in the data and then to the formation of explorations based on the experience is determining for both students and teachers. Generally, the connection among investigations and related experiences, finding patterns in the data, and forming explanations at the base of science learning.

Constructivist believes that knowledge is socially constructed, meaning that understanding of science knowledge depends on interaction with both the real world and people who help to

formulate ways of describing and giving meaning to data and experiences. This interaction allows people to clarify their understandings by comparing and contrasting their thoughts with those of others. In general, to get scientifically literate workers and citizens, we should to adopt anew paradigm for teaching and learning science.

How Should Science Teaching Change?

Science teaching should change learners, in such way students can achieve understanding and applications of knowledge to the real world. Science teachers should help students integrating facts in to a meaningful story that leads to understanding of at least small part of the world. And as the school year progresses, when help students build this small story into big picture.

What Does Teaching for Science Understanding Look Like?

In teaching for science understanding, students and teachers engaged in laboratory or hand on activities. Students are also engaged in demonstrating physical processes, and practice doing physics while the teacher is present to give feedback. Student and teacher should be outdoors to study the natural and the constructed world beyond the class room. Generally, students should spend much of class time actively engaged in doing, thinking and talking physics –not listening to someone else talk about physics and guided to construct their knowledge of physics concepts by direct observations of the physical world.

What Does It Mean to Understand Science?

To start from the meaning of understanding,

To know or be able to explain to your self the nature of some body or something.

To interpret and explain the meaning of some body or something.

To be able to use or apply knowledge in solving a problem.

All definitions imply that understanding is not abstract, but instead involves something or somebody to be understood. These definitions are more helpful to us as a teacher. As we think about teaching science for understanding, we need to think in terms of understanding some aspects of science (its concepts, its process, its applications and its nature.)

Ideas Underlying the New Paradigm

Science As Public Knowledge: Scientific understanding is not only individualistic.

Understanding in a science is public and shared among all people who comprehend a scientific idea or a science process. When a scientifically literate person uses science term or describes a scientific process, other who have understanding of science gain the same meaning as the speaker. Each of discoveries, follows similar patterns. These are interpreting data to give them meaning, convincing scientific peers of validity of the interpretations and model used to explain them. In this process scientific canon becomes public, shared knowledge that all members of science community accept and find useful.

Students learning science, interpretation and creating shared meaning is an essential part of their learning. One of the difficulties with science learning is the creation of personal meanings by students that differ from scientific canon. This is one of the reasons for the new instructional approaches that have been found to be effective in science classrooms. By continually connecting scientific ideas and the data on which they are based__through group work, group writing, group discussions, and student-teacher interactions students learn to communicate their ideas and make them public.

Understanding the Multiple Dimensions of Science

Science is complex. At least four dimensions of science must be understood if a person scientifically literate:

1. Conceptual knowledge of science-- the body knowledge that comprises science. This is **what we know**.
2. Science process—the mental tools that scientists use to carry out inquiry and create the concepts that make up the body of knowledge. This concerns how we know the concepts that comprises the body of science knowledge.
3. Applications of science—the way in which science concepts and processes are used in the world of experience. This concerns the value or importance of science in daily life.
4. Nature of science---the way in which scientists work collectively to generate, validate, and communicate scientific knowledge. This concerns the internal working of scientific professions and their relationship to each other and to the large society.

All four are essential for understanding science in ways that are useful people who will be citizens in a world strongly influenced by science.

Teaching and learning with understanding

As we have seen in chapter one learning with understanding requires that students make sense of ideas and experiences that from their prior knowledge. To apply knowledge also requires that students see the connection between the knowledge and its application. This is the essence 'constructivism' which is a view of learning that is central to the new paradigm in science.

Understanding is Demonstrated Through Action

David Perkins defines understanding, the ability to think and act flexibly with one knows. He explains two ideas that follow from this view. First gauge a person's understanding at a given time, ask a person to do some thing that puts the understanding to work—explaining, solving a problem, building an argument, constructing a product. Second, what learners do in a response not only show their level of current understanding, but very likely to advance it. This statement not only gives operational definitions of understanding but also define an instructional response. Tasks such as explaining, using ideas in science to solve solve problems and constructing arguments are essential means of teaching for understanding. In requiring these tasks, teachers both aid advancement of students understanding and gaining insight in to what students do not understand about the topic at hand. Thus, such tasks are

both instructive to students and useful tools for assessing students understandings in ways that can guide both the teacher in planning for teaching and student becoming self directed learners.

Elements of Understanding

Understanding Concepts: Understanding concepts is a central part of understanding science.

White and Gunstone (1992) include propositions, images episodes, intellectual skills, strings and motor skills as elements of understanding concepts.

Elements	Brief Description	Examples
Propositions	Facts, opinions, beliefs	There are many forms of energy, atoms are made up of protons neutrons and electrons.
Images	Mental representations of sensory perceptions	The feel of springiness of the plunger in an air pump compressing air.
Episodes	Memories of events that you experienced directly or vicariously	Recollection of an experiment you did in lab or demonstration you observed
Intellectual skills	Capacity to carry out classes of mental tasks	Distinguishing among different forms of energy.
Strings	Similar to proposition but in an unvarying form	Using 'VIBGYOR' to recall the sequence of colors in the visible spectrum.
Motor skills	Capacity to carry out physical tasks	Riding bicycle, connecting electric circuits

Understanding Is Neither Dichotomous nor Linear.

Understanding fits what Perkins calls incremental learning in which students' performances of understanding, like performance for sport, music, require attention, practice and refinement to improve. Understanding is not a dichotomous phenomenon. It is incremental, and it grows unevenly in time, with advances followed by plateaus.

According to White and Gunstone (1992), understanding of a concept is not a dichotomous state but a continuum. Every one understands to some degree any thing they know some thing about . It follows that understanding is never complete, for we can always add more

knowledge, another episode, say, or refine an image or see new links between things already know. This statement deserves careful reflection as it has important pedagogical implications. First as teachers you must recognize that development of understanding is continuum. Second, you also must recognize that your students often have varying degrees of understanding when they come to you, based on their experiences and prior instruction. Third, the idea that understanding always is incomplete offers a viewpoint that is important to you as teachers, to recognize about yourselves and the nature of your students.

Understanding Single Elements and Extensive communications

Understanding an extensive communication, such as a textbook chapter or a complex diagram, requires grasping the meaning of each of the constituent parts, as well as grasping the meaning of the whole, which may not be directly expressed. Instead, forming understanding requires that students not only read the passage or examine the diagram with care, but also reflect on it to construct or create the meaning that approximates what the author or graphic artist has intended. In literature classes, the act of interpreting and giving meaning to literary works is part of what reading literature is about. It is an essential part of analysis of data from investigations, texts, diagrams, and lectures.

Model-base Reasoning

Models often compress a large amount of information into small space, representing several concepts and their connection to each other as means of explaining a powerful science idea. Models of the structure of atoms, molecules are common place in science. Models that involve the motion of molecule are essential in understanding and explaining many phenomena, including evaporation, condensation, boiling, freezing, chemical reactions and many others. Models of structure of earth, ground water flow, galaxies, gravitational attractions etc... are central to earth and space sciences. Generally models show the connections and relationships, they are important tools to help students understand and use of knowledge.

Six Facets of Understanding

For further expansion of our knowledge of understanding, Wiggins and McTighe (1998) have identified six facets of understanding: explanation, interpretation, application, perspective,

empathy, and self-knowledge. Each represents an important performance performance of understanding. To explain with example let us see the table below.

Six Facets	Description	Example
Explanation	To ensure students understand why an answer or approach is the right one. Students explain or justify their responses or justify their course of action.	Students develop an illustrated brochure to explain the principles and practices of a particular type of technology (i.e., transportation, construction,).
Interpretation	To ensure students avoid the pitfall of looking for the “right answer” and demand answers that are principled...students are able to encompass as many salient facts and points of view as possible.	Students develop a ‘biography’ of the development of a particular type of technology.
Application	To ensure students’ key performances are conscious and explicit reflection, self-assessment, and self-adjustment, with reasoning made evident. Authentic assessment requires a real or simulated audience, purpose, setting, and options for personalizing the work.	Students analyze a design of a product, taking it apart in order to determine how it works. Students design, develop, test, and revise a solution to a local issue, such as a new roadway system, a water treatment system, or long-term storage of various materials.
Perspective	To ensure students know the importance or significance of an idea and to grasp its importance or unimportance. Encourage students to step back and ask, “What of it?” “Of what value is this knowledge?” “How important is this idea?”	Students investigate about a technological artifact from the perspective of different regions and countries.
Empathy	To ensure students develop the ability to see the world from different viewpoints in order to understand the diversity of thought and feeling in the world.	Students imagine they are politicians debating the value of nuclear power. They write their thoughts and feelings explaining why they agree or disagree with the use of nuclear power.

Self-Knowled	To ensure students are deeply aware of the boundaries of their own and others' understanding; able to recognize their own prejudices and projections; has integrity – able and willing to act on what one understands	Students reflect on their own progress of understanding about one of the standards in Standards for Technological Literacy: Content for the Study of Technology. They evaluate the extent to which they have improved, what task or assignment was the most challenging
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TCTP Program

Patterns of Thinking by Scientists and by Adolescents

Clever and energetic scientists may be able to imagine a means of putting some tentative explanations to the test. This is done by collecting data from nature and comparing those data with the deduced consequences of the tentative explanations. If the data and the deduced consequences are essentially the same, then the tentative explanation has been supported. If the data and the deduced consequences are not the same, then the tentative explanation has not been supported and may be rejected or perhaps modified. The objective of this chapter is to look more closely at the process of science to identify some of its key elements skills and patterns of thinking and then to look at the extent to which typical adolescents have acquired those thinking patterns. We shall explain by example from science.

Homing behavior in Silver Salmon

By tagging young salmon, biologists discovered that mature salmon actually migrate to precisely the same freshwater in which they were hatched years earlier. This discovery raised an interesting question: *How do the salmon find their way to the streams of the birth?*

Creating Hypotheses and Combinatorial Thinking

Many answers to this causal question can be proposed. Using the process of abduction--- borrowing ideas from past experiences and using them as possible explanations in the new context---gives us three tentative hypotheses:

1. Salmon uses sight to find their way home.
2. Salmon smell certain chemicals in the water that are specific to their home stream.
3. Salmon are sensitive to the earth's magnetic field and use it to navigate.

There may also possibilities remain. Perhaps none of these hypothesis correct answer. Or perhaps salmon are able to use all three or perhaps two of three. Psychologists refer to this process of generating all possible combinations of hypotheses as *combinational thinking*. The possibilities:

1. None of the three hypothesis is correct.
2. Hypothesis 1 is correct.
3. Hypothesis 2 is correct.
4. Hypothesis 3 is correct.

5. Hypotheses 1 and 2 are correct.
6. Hypotheses 1 and 3 are correct.
7. Hypotheses 2 and 3 are correct.
8. All three hypotheses are correct
9. One or more of the identified hypotheses in combination with one or more of the yet-to-be identified hypothesis are correct.

Creating Predictions

The next task is to put one or more of the hypotheses to the test. For example, biologist tested the sight hypothesis by capturing and blindfolding a group of salmon and comparing their ability to locate their home stream with the ability of a similar group of nonblindfolded salmon. The thinking pattern used to test the sight hypothesis was as follows:

Hypothesis: If silver salmon locate their home stream by sight.

Experiment: and a group of blindfolded salmon is compared to a group of nonblindfolded salmon, all other things being equal,

Prediction: then the blindfolded salmon should not be able to locate their home stream and the nonblindfolded salmon should be able to locate their home stream.

This pattern of hypothetical deductive thinking is involved in all hypothesis testing.

Identifying and controlling variables

We should remember that the prediction in the previous hypothetical deductive argument follows only to the extent that the experiment is conducted in a manner that allows only the values of one input (an independent) variable to vary. All values of the other possible input variables must be held constant to the extent possible. That is, the experiment should be controlled. One can never be certain that all problems have been eliminated, the result of all such experiments must be interpreted with caution. Consequently, a positive result can never be interpreted as the proof of the correctness of a hypothesis. A positive result allows us to conclude that a hypothesis has been supported. In addition, if the result of an experiment does not support the hypothesis, we can not conclude that the hypothesis has been disproved or falsified.

Drawing Conclusions

The identification and control of variables is an absolutely crucial thinking pattern, but limited in that one can never be certain that all potentially relevant variables have been identified or controlled. Therefore, all scientific conclusions, whether supportive or not supportive of a particular hypothesis, must remain tentative to some extent

Creative and Critical Thinking Skills

Critical thinking is at the core of most intellectual activity that involves students in learning to recognise or develop an argument, use evidence in support of that argument, draw reasoned conclusions, and use information to solve problems. Examples of thinking skills are interpreting, analysing, evaluating, explaining, sequencing, reasoning, comparing, questioning, inferring, hypothesising, testing and generalising.

Creative thinking involves students in learning to generate and apply new ideas in specific contexts, seeing existing situations in a new way, identifying alternative explanations, and seeing or making new links that generate a positive outcome. This includes combining parts to form something original, sifting and refining ideas to discover possibilities, constructing theories and objects, and acting on intuition.

Critical and creative thinking can be encouraged simultaneously through activities that integrate reason, logic, imagination and innovation – for example, focusing on a topic in a logical, analytical way for some time, sorting out conflicting claims, weighing evidence, thinking through possible solutions, and then, following reflection and perhaps a burst of creative energy, coming up with innovative and considered responses. Critical and creative thinking are communicative processes that develop both flexibility and precision.

Communication is integral to each of the thinking processes. By sharing thinking, visualisation and innovation, and by giving and receiving effective feedback, students learn to value the diversity of learning and communication styles.

The Workplace, Student Minds, and Physics Learning Systems

I. Introduction

There is also a growing understanding of how students' minds work and why they have difficulties learning subjects like physics. In recent years, there have been experiments with new learning systems that indicate that we can do better in helping those minds acquire *some* of the desired outcomes.

II. Representing the Educational Center

The educational system can be by transformer model. A transformer is a device that allows efficient transfer

between two objects with different characteristic impedance. For example, the speaker in a high fidelity system is a transformer for converting electrical oscillations into mechanical oscillations of air in front of the speaker. The electrical system is very different from the air. To be an efficient transformer, one side of the speaker should have the same characteristic impedance as the electrical system. The other side of the transformer should have the same characteristic impedance as the air. Designing a good speaker requires considerable understanding of the impedance of the air, the impedance of the electrical system, and care in constructing the speaker's internal components to avoid internal impedance mismatches.

We can use this same model to represent an educational system. The student mind with its characteristic impedance is considered the load. Conceptual and procedural knowledge that we would like a student to acquire is considered the source. Our goal is to build an education transformer, a learning system, which helps student minds acquire this source material. The learning system transformer includes anything we choose: an instructor, the physical environment of the classroom, other students in the class, various pedagogical strategies, different types of classroom activities, books, CDs, laboratory equipment, the format for the course, and whatever we need to make the learning system transformer match impedance.

III. Characteristics of the Source—Desired Outcomes for Our Instruction

Bloom's Taxonomy: In 1956, Benjamin Bloom and others reported on an effort to assess student learning.¹ Their report identified educational objectives that should be a part of education (see Table 3). Their work became known as Bloom's Taxonomy for the Cognitive Domain. The objectives form a hierarchy in which higher-numbered skills depend to some extent on lower-numbered skills—although they often blend together in real practice.

Table 3. Bloom's Taxonomy- the educational objectives developed by Bloom and a committee in assessing educational outcomes.

Educational objective	Brief description of objective
1. Knowledge	Remembers facts, conventions, classifications, methods, and principles.
2. Comprehension	Understands and interprets phenomena when presented in verbal, pictorial, diagrammatic, graphical, or symbolic form. Can translate between these forms and uses them to extrapolate and predict.
3. Application	Applies knowledge productively to new problems without prompting concerning the principles to use. Uses productive problem solving strategies.
4. Analysis	Breaks material into its constituent parts. Detects relationships between these parts. Recognizes organizing principles and knowledge structures.
5. Synthesis	Combines previous conceptual and procedural knowledge with new to form a well integrated whole. Designs investigations and products— creative work.
6. Evaluation	Judges the value of work—its accuracy, effectiveness, and reasonableness. Are assumptions warranted? Are ideas supported by observations and consistent with each other?

Our traditional education focuses on level 1 (knowledge), a little on what is described for level 2 (comprehension), and a little on what is described for level 3 (application). The latter three higher level skills (analysis, synthesis, and evaluation) seldom receive any attention in our physics instruction—even in higher level courses.

Recommendations from workplace studies: According to an American Institute of Physics (AIP) survey of former physics majors, only 15 percent of undergraduate physics graduates go on to earn a Ph.D. in physics and only half of those become professors. Eighty-two percent of B.S. physics graduates have final careers in industry, the autonomous private sector ~such as small companies, software development firms, and their own consulting firms!, and in government doing work in physics, engineering, mathematics, chemistry, and geosciences. Eleven percent either teach physics in high school or teach and do research in colleges.

We can use Bloom's taxonomy and requests from the workplace studies to help choose the goals for our physics courses for science and engineering students. An example of such goals is listed in Table 4.

Table 4. One possible list of educational objectives for introductory courses for science and engineering students. The list reflects the workplace reports described in the text

Develop the skills needed to solve <i>real</i> problems
Learn to design and conduct scientific investigations
Learn the skills needed to design a system, a component, or a process
Develop the ability to function effectively on a multidisciplinary team
Learn skills needed to engage in life long learning
Learn to communicate effectively

V. A Learning System to Help the Mind Achieve The Desired Outcomes

We are now faced with a considerable challenge. The world wants college graduates who have developed the complex skills such as appear in Tables 3 and 4. However, students' initial states when they arrive in our classes are far from this desired outcome. How do we build learning systems that help students move from their initial states closer to the desired final state?

Problem Solving: The problems of the real world differ from the problems found in most textbooks. Real world problems are poorly defined—the solver does not calculate a specified unknown quantity. Real world problems often consist of multiple smaller problems—a divide and conquer strategy is needed. This involves Bloom's analysis and should be a part of instruction and of assessment. The solver must decide what conceptual knowledge to use for each smaller problem and the unknown information that is needed to complete each problem

part. This requires that the student organize and learn to access conceptual knowledge in some sort of an organized structure

Design: Design is one of the most frequent activities of physicists in the workplace. Engineering colleges must show that their majors have developed design skills during their undergraduate careers . Design involves the synthesis of a student's knowledge to complete some task—a higher level Bloom's skill.

Epistemology: John Dewey said that “Science education has failed because it has been so frequently presented just as so much ready-made knowledge, so much subject-matter of fact and law, rather than as the effective method of inquiry into any subject matter.” Students learn concepts by reading a book or by listening to a professor. The author has integrated into instruction an epistemological approach developed by Etkina at Rutgers University.²⁴ In her approach, students use many of the processes of science to acquire their understanding of physics. They observe phenomena, make qualitative explanations, and design experiments to test their explanations. They choose physical quantities to use in a quantitative description of these phenomena and find experimental or theoretical relationships between these quantities. They use the proposed law to make predictions about the outcomes of new testing experiments. As confidence in the law grows, students apply the law in the analysis of contextually interesting problems. The students are developing the scientific investigation process skills that are needed for the workplace. Their knowledge is based on their own observations and explanations.

Active Learning: Consider another important pedagogical strategy—students must participate *actively* in the learning. Many studies indicate that student achievement improves when students participate actively in that learning—when they interact with peers to reason about physical processes both qualitatively and quantitatively.

Teamwork: Another form of active learning involves Teamwork. Helping students develop the skills needed to work effectively with their peers is important for life after college. It is also important for life in school teamwork promotes learning. In 51 high quality studies, Johnson *et al.* found that cooperative learning classes had a 0.88 effect size greater achievement than classes with curved lecture-based instruction—almost a grade point higher

achievement. In physics classes, Heller and Harbaugh found that students who worked in cooperative groups in recitations could solve problems that instructors in traditional classes were unwilling to give their students—the problems were too difficult.

Learning to Learn:

Table 5. Learning-to-learn strategies contrasted with traditional educational practice. Adapted from Downs

Conventional	Developing learning skills
Skills of learning are covert (hidden)	Skills of learning are made overt and discussed
The instructor explains concepts	Learners develop concepts
Learner is passive	Learner is active
Mistakes are mostly avoided	Mistakes are viewed as useful learning opportunities
Instructor poses questions and provides solutions	Instructor poses problems and discusses learner's solutions
Assessment concerns primarily the product	Concerned with the product and the process—both are important

Less Is More: Trimming the Overstuffed Curriculum

Through a science curriculum "diet," districts discover that less topics could fatten students' understanding. This is by Lisa Fratt.

The main educational process in a typical district goes something like this: Some popular topics are taught year after year in the elementary science curriculum. Teachers who introduce other topics are usually responsible for gathering materials for experiments and demonstrations themselves. By fourth or fifth grade, science becomes an exercise in memorizing technical terms and getting through the textbook, which may cover dozens of topics. Heavy on vocabulary and light on actual science, this approach continues through high school.

Undoubtfully, these methods have failed to produce science literacy. The Nation's Report Card: Science 2000 shows that the average scores of fourth, eighth 12th graders failed to improve between 1996 and 2000.

The Third International Math and Science Study characterizes U.S. math and science curricula as "a mile wide and an inch deep." Instead of forcing students to cover more and more content and vocabulary as science continues to advance, experts recommend a *science curriculum "diet" to help take a bite out of the nation's current science achievement troubles.*

Yes, that's right. Less is more. This unburdening of the science curriculum is already occurring as individual teachers eliminate topics in their overloaded textbooks. But there is a better, less disordered, approach.

Eventhough, there's no simple formula for improving scientific understanding and achievement, **Designs for Science Literacy**, a report from Project 2061 of the American Association for the Advancement of Science, *recommends that schools create more time for in-depth study.* Reducing the number of major topics taught, cutting unnecessary details or subtopics, de-emphasizing technical vocabulary and eliminating repetition are the goals.

Science Diet Essentials

While implementing a "science diet" can seem daunting, a handful of districts and several states are meeting the challenge. The first step, says Arthur Camins, elementary math and science director for Hudson Public Schools, is to take a look at how students learn science. Recommended reading? **The National Science Education Standards** and **Benchmarks** for Science Literacy, published by AAAS, which contains statements of what all students should know and be able to do in science, mathematics and technology at the end of grades two, five, eight and 12.

When Hudson improved its science curriculum, teachers and administrators reviewed the national and Massachusetts standards and compared them to what teachers actually taught in the classroom. "We found there was no consistency. Some topics were taught twice; others not at all," says Camins. Repeating topics without developing a broader understanding is a cause of the overstuffed curriculum.

Christina Hilton, curriculum program coordinator for the Indiana Department of Education, suggests that districts *"go through the state standards, find where they meet the standards, fill in the gaps and trim away the extras"*

Based on input from teacher-administrator teams in six districts, Benchmarks gives a true taste of what this means. If a topic was not deemed essential for science literacy or if its importance was out of proportion to the amount of time needed for students to understand the concept, it was eliminated.

When a district is ready to review the nuts-and-bolts of its curriculum, Designs outlines a process to trim topics, sub-topics and vocabulary. Because it's a gradual approach and teachers are involved in the decision-making, the change process is manageable. Here's a summary of the steps:

1. List topics in the current curriculum or textbook.
2. Compare the list with learning goals in Benchmarks.
3. Create a second list of possible topics for elimination—those that aren't linked to a specific learning goal.
4. Ask science teachers to drop one topic at a time and invest additional time in a core topic.
5. Evaluate the effects of the change.

Then repeat the five steps, involving more topics.

Camins recommends that districts review **National Science Foundation-supported programs** based on the less-is-more philosophy. Kit-based programs include Science and Technology for Children, Full Option Science System and InSights. With the option system, for example, the fifth grade curriculum can be scaled back to four modules: food and nutrition, levers and pulleys, solar energy and models and designs.

Most state standards incorporate the national standards and Benchmarks, says George Nelson, director of science, math and technology education at Western Washington University and former Project 2061 director. States tend to fall short, however, in covering historical perspectives on science, common themes that pervade science, math and technology, and scientific habits of mind. While individual districts can still include these subjects, the need to add makes the need to cut ever more important.

A Balanced Diet for Reform

Trimming the science curriculum and aligning it to national and state standards is part of the reform process. Another critical piece is selecting the right type of curricular materials. After all, it is possible to cut the science curriculum in half and be left with a poor program. Nelson says, *"Science educators and cognitive scientists have found that telling kids lots of stuff doesn't result in a lot of learning."*

A quality science curriculum reduces the content. But it also engages students in science and the real world and provides time for students to communicate their thoughts and understanding.

Here is an example of new versus old ways of thinking about science: In a typical high school physics class, students might mistakenly believe in a closed circuit with bulb current is used at the bulb. The teacher tell them simply conservation of charges at the bulb to memorize the unchange of the rate of flow of charges (current). A more effective method would be for students to discuss their understanding of conservation of charges at bulb, complete relevant lab investigations and compare their thoughts to what they learned in the lab. Students could then explain current and conservation of charge in their own words, demonstrating their understanding of the concept, not just the technical terminology.

The new process takes time, but it has a much better chance of resulting in mastery of the subject. Indeed, de-emphasizing technical vocabulary is key to a successful science diet.

Districts working on trimming the science curriculum should also determine the most appropriate grade level for topics. Elementary teachers can spend a fair amount of time teaching about the solar system, for example, but research shows that at this age level children can't easily comprehend the science of the solar system. So a science unit on the solar system is watered down to memorizing planet names. On the other hand, if the unit is introduced at the middle school level, students can begin to develop an understanding of how the solar system functions.

Hudson considered grade levels when overhauling its science curriculum. *"If you take topics accessible to students' level of cognitive development, the curriculum becomes much more efficient,"* Camins says.

Nelson cautions that science reform can't be purchased as a particular curriculum or text book. For example, teachers in Rockford (Ill.) Public Schools have a textbook for each course, but they are encouraged to use a variety of resources. The district provides teachers with binders filled with objectives, activities and assessments. *The point is not to 'do' or 'cover' the entire textbook or binder, but to give teachers an array of tools to help students learn.*

Even with the right curriculum and resource materials for teachers, some districts have difficulty completing the task of trimming the science curriculum. Meaningful and continued professional development for teachers that reinforces science concepts and the underlying pedagogy is critical.

Sticking to the Diet

It may take two or three years just to think through what to leave in the curriculum and what to throw out, Nelson says. *"Any time you take anything out of the curriculum, you're opening yourself up to charges that you're dumbing things down,"* he says. The process should include a substantial professional development program, and it may also involve partnerships with outside organizations and a community education effort. Bringing the community along gives administrators and teachers the chance share research with them.

It's also important to remember that the national standards and Benchmarks are intended to describe the bare core of what students should know about science. Certainly some high school students are ready to digest more sophisticated science topics. Those topics, Nelson explains, can be addressed in advanced science courses.

Like any diet, trimming the curriculum can be painful. Nelson warns that teachers will have to leave out some of their favorite topics and activities as they cut the curriculum. But the results are well worth the effort. Since Hudson initiated its new science program, Camins has heard from almost every teacher how much kids are enjoying science. He says, *"If you want to do anything meaningful and worthwhile, it takes time."*

Rethinking the Content of Physics Courses

Physics students, particularly in today's information age, need to understand the unity of physics and the way in which scientific knowledge is generated. This by Diane J. Grayson

During the past 20 years, the focus of physics education research has shifted several times. In the early 1980s, PER was largely concerned with alternative conceptions that students held about various physics ideas. The mid-1980s saw an explosion of interest in computer-based and computer-aided instruction. In the early 1990s, the PER community published several research-based curricula that promoted activity-based or inquiry-based learning, and throughout the decade the community was increasingly focused on student cognition. As a result of the past two decades of study, physics education researchers know a great deal about how students conceptualize physics and what makes for effective instruction. What is missing is a debate at an international level on the selection of curricular content. In other words, what physics should we teach?

Individual governments usually set kindergarten– 12th-grade (K–12) physics curricula; at the university level, textbook authors or individual physicists largely determine curricula. The resulting products are often perceived by students as strings of unrelated topics disconnected from the real world and irrelevant to their daily. At a time when ever-increasing amounts of information are becoming ever more available, and when workplace success is determined more by employees' mastery of transferable skills and emotional intelligence than by their knowledge base, plugging numbers into memorized equations seems like a futile exercise. Unfortunately, many students do experience physics courses as pointless number plugging. Is it any wonder that the number of students majoring in physics worldwide is lamentable?

Changing curricula can help, both in getting K–12 students interested in physics and in keeping them interested at the university level. In July 2004 an international conference took place in Durban, South Africa, under the auspices of the International Commission on Physics Education and the South African Institute of Physics. Its purpose was to provide a forum for physics educators to discuss and debate what should go into 21st-century physics courses at different levels and for different audiences. Participants and invited speakers, some of whom are shown in figure 1, came from Africa, Asia, Europe, and North and South America to explore seven themes:

- Overcoming fragmentation in physics
- Physics for today
- Blurring the boundaries of physics

- Conceptual organization
- Different strokes for different folks
- Origins and ways of knowing
- Skills

Overcoming fragmentation

Traditionally, teachers present physics topics in isolation from one another, sometimes even in different courses. So, for example, mechanics is disconnected from quantum mechanics and thermal physics. Not surprisingly, students fail to see the links among topics and the unity of physics that physicists find so attractive.

Conference attendees Ruth Chabay and Bruce Sherwood have written a two-volume text that deviates significantly from the traditional approach. Their first volume includes an integrated treatment of mechanics and thermal physics; the second integrates electrostatics, electric circuits, and electromagnetism. Chabay and Sherwood's approach includes several other important features. It connects microscopic and macroscopic phenomena and explanations, and explicitly links classical and modern physics. It stimulates students to reason from fundamental principles rather than to solve specific classes of problems, and encourages them to model physical systems and use those models to explain complex physical phenomena.

Emphasizing the hierarchical nature of physics ideas also serves to highlight the unity of physics. Physicists think in terms of central concepts and fundamental principles, such as fields and conservation of energy, but beginning students tend to think in terms of disconnected fragments of information all at the same level of importance. When the hierarchical nature of physics is made explicit to students and they are required to reason from fundamental principles, their learning improves.

Physics for today

Unlike courses in the newer sciences such as biochemistry, many high-school and introductory university physics courses include only topics that are at least 100 years old. Even at higher levels, students are not often exposed to topics with which research physicists are currently engaged. In principle, it need not be too difficult to introduce students to aspects of contemporary physics if the focus is on qualitative interpretations of phenomena and fundamental principles rather than on rigorous mathematical treatments.

If, for example, students have learned about energy levels in atoms and about wave superposition, then it should not take a big conceptual leap for them to learn about the superposition of energy levels in solids, which leads to energy bands. Follow-up discussions could consider the energy-band structure of semiconductors and the host of practical applications that result. Conference participant Dean Zollman has developed a suite of carefully designed computer program that, among other things, teach students about light-emitting diodes. His program leads students to conclude that if LEDs are to produce bands of light rather than the line spectra produced by gases, they must have many energy levels that are very closely spaced.

Computation is an important aspect of today's physics. Research physics has traditionally been divided into two classes, theoretical and experimental. Now the field has a third class—computational physics. That approach to generating knowledge is particularly well suited to such contemporary physics topics as nonlinear dynamics.

Blurring the boundaries

Several new interdisciplinary areas of study involve physics. Examples include environmental science, materials science, and nanoscience. Such areas provide opportunities for instructors to apply physics principles to new contexts all across the curriculum, and so afford one way to overcome the problem of curricula that contain only "old" physics. Furthermore, interdisciplinary studies allow research physicists to work collaboratively with people from other disciplines who may think and reason differently.

George Ellis's sweeping view of all of science, both natural and social, extends the theme of blurring the boundaries between physics and other disciplines. In his plenary talk at the conference, Ellis ranked various disciplines in a hierarchy of structure, with physics at the bottom and psychology at the top. As the level in the hierarchy rises, so does the level of complexity of the objects studied by the. Emergent properties appear that cannot be determined from lower-level properties; the most complex of them is consciousness. Physicists may be tempted to convey the idea that physics can explain everything.

Ellis also emphasizes the different ways of thinking involved in disciplines at varying levels of structure. Those differences result in different kinds of explanations and types of causality. An important implication of Ellis's view is that any explanation is only partial, and that the use of one type of explanation in preference to another is a choice based on context. Physics is useful for answering questions of what and how; religion, philosophy, and worldview are useful for answering questions of why. Ellis's argument implies that physics teachers need not set up a confrontation between physics and their students' worldviews; rather, teachers should limit physics explanations to questions that physics can answer.

Conceptual organization

If we who teach physics want to be effective, then what we teach should be influenced by what we know about how students learn. Physics education researchers have convincingly shown that even before they set foot in a physics classroom, students have their own ideas about the world and how it works. Many of those ideas differ greatly from scientific explanations. To make sense to students and lead to meaningful learning, physics curricula should explicitly take into account common alternative conceptions among students and include specific strategies for helping students develop scientifically acceptable understandings. One strategy is to introduce new representations of physical phenomena.

The sequencing of physics content is also important. Factors that should influence the order in which topics and concepts are taught include their levels of abstraction and complexity and the extent to which they are familiar to students either through daily life experience or previous teaching. In a conference paper, Chabay and Sherwood propose "A More Coherent Topic Sequence for E&M," which mirrors the presentation of their two-volume text.⁷ They introduce both electric and magnetic fields early on so that students have an opportunity to develop a feel for the field concept and for how fields interact with matter. They also consider electric and magnetic fields in the context of electric circuits, which allows for a microscopic analysis of circuit charges. Only later do they introduce flux, Gauss's law, and Faraday's law. Compared with the traditional ordering of topics, Chabay and Sherwood's sequence reduces the number of new concepts students have to confront in quick succession and gives students the opportunity to work with key concepts in different contexts and to develop physical intuition.

Different strokes for different folks

In an increasingly technological world, a modicum of scientific literacy for all citizens is becoming a prerequisite for both the democratic functioning of societies and the sustainable and responsible use of Earth's resources. To participate meaningfully in debates and decision making about issues that affect us all—including global warming, genetic modification of food, and renewable versus nonrenewable sources of energy—citizens need to understand the process by which scientific knowledge is generated, tested, and modified, and they must be able to judge the trustworthiness of information they obtain. It is indeed useful to understand a few fundamental principles and key concepts and to be able to apply them to a variety of contexts; that is part of learning a scientific way of thinking. But it is more important for citizens to know which questions science can answer definitively and which ones it can answer only tentatively, if at all.

Courses for K–12 teachers deserve special mention. Teachers need to know not just physics but also how to make physics understandable to their students. As noted by Lee Shulman, president of the Carnegie Foundation for the Advancement of Teaching, teachers must "be able to explain why a particular proposition is deemed warranted, why it is worth knowing, and how it relates to other propositions, both within the discipline and without, both in theory and in practice.

Shulman argues that teachers need a special kind of knowledge—pedagogical-content knowledge—that he describes as "subject matter knowledge for teaching." It includes awareness of likely student difficulties along with effective teaching strategies to address them, and analogies, illustrations, explanations, representations, and demonstrations for making the subject matter comprehensible.

Courses offered for teachers should integrate the development of content knowledge, pedagogical-content knowledge, and epistemological knowledge. And teachers' courses need to do more than just describe effective teaching; they need to model it. Dale Gundry, one of the conference attendees, created such a course for secondary-school teachers. It emphasizes conceptual understanding, "big ideas" in both classical and modern physics, the sociopolitical

context of nuclear power, the cost of energy, the nature of science, learners' persistent unscientific ideas, race and gender issues, and laboratory and study skills.

Origins and ways of knowing

Learner who have been introduced to history and philosophy of science, and of physics in particular, will better understand how scientific knowledge is created and evolves, and why some knowledge is judged to be scientific and other knowledge—valuable as it may be for cultural reasons—is not. Since all citizens must be able to judge the trustworthiness of the information they receive, it is particularly important that history and philosophy be included in high-school and introductory university courses.

Igal Galili and Michael Tseitlin make the radical proposal that physics be considered as a set of what they call discipline-cultures, each consisting of a nucleus, a body, and a periphery. The nucleus comprises fundamental concepts and principles, the body comprises applications of those concepts and principles, and the periphery includes elements of knowledge that "conflict with, or cannot be explained by, the statements of the particular nucleus."¹⁴ Knowledge elements that lie in the periphery of one discipline-culture may lie in the core of another. Galili and Tseitlin recommend teaching students to view physics not as a static entity but as a collection of discipline-cultures with knowledge elements that are constantly changing. The students could then see physics as a culture "to be appreciated and explored, rather than a tool to be mastered."

Skills

Manipulating physics requires certain skills, and it can also be a vehicle for the development of certain others. Physicists frequently claim that students in their courses learn useful, transferable skills. The claim is often true. But it could be true even more often, and applicable to a greater number of students, if physicists taught a variety of skills as an explicit, integral part of their courses, particularly at the K–12 and introductory university levels.

Definition and Varities of Learning

Introduction

Learning happens in and around schools. Learning happens frequently and everywhere. Learning goes in the home, the factory, the farm, the street, the movie theater, in front of television screen and so on... Educational psychologists are primarily concerned with the kind of learning that goes in class room and schools. But they recognize that schools have no monopoly on learning or the time and the place of occurrence.

The Definition of Learning

Learning can be defined as the process whereby an organism changes its behavior as result of experience. Because this definition is deceptively simple, we should look closely at its various components.

The idea that learning involves change in organism means that learning takes time. To measure learning, we compare the way in which the organism behaves at time I with the way it behaves at time II under similar circumstances. If the behaviour under similar circumstance differs on two occasions, we may conclude that learning has occurred. In other hand, changes in physical characteristics, such as height and weight, do not count as learning.

Learning is what we infer has taken place when the behavior of animal including humans has changed. Behavior refers to some action, muscular or glandular, and combinations of these actions. The verbal behavior of humans is of prime interest, because from the writing and speaking actions of humans we can determine whether changes in those behaviors have taken place.

Generally, changes those resulting from physiological, mechanical and maturational processes have been excluded from the category of those reflecting learning. But the kind behavioral change from experience with the environment whereby relationships between stimuli and responses are established.

Varieties of Learning

Respondant Learning: (Also called classical, respondent, or Pavlovian conditioning) The process of pairing environmental events with unconditioned stimuli that elicit reflexive responses. Over time, these new environmental events elicit a conditioned reflex response in the absence of any other stimuli.

Fascinated by this finding, Pavlov paired the meat powder with various stimuli such as the ringing of a bell. After the meat powder and bell (auditory stimulus) were presented together several times, the bell was used alone. Pavlov's dogs, as predicted, responded by salivating to the sound of the bell (without the food). The bell began as a neutral stimulus (i.e. the bell itself did not produce the dogs' salivation). However, by pairing the bell with the stimulus that did produce the salivation response, the bell was able to acquire the ability to trigger the salivation response. Pavlov therefore demonstrated how stimulus-response bonds (which some consider as the basic building blocks of learning) are formed. He dedicated much of the rest of his career further exploring this finding.

In technical terms, the meat powder is considered an unconditioned stimulus (UCS) and the dog's salivation is the unconditioned response (UCR). The bell is a neutral stimulus until the dog learns to associate the bell with food. Then the bell becomes a conditioned stimulus (CS) which produces the conditioned response (CR) of salivation after repeated pairings between the bell and food. This can be applied for humans. We may consider the unconditioned stimulus-response linkage to be operating whenever a stimulus (the US) elicits a visceral or emotional reactions (the UR), such as fear, anger, vomit, joy and happiness.

Contiguity:

"stimulus-response" approach is based on the premise of Contiguity, which states, for learning to occur, the response must occur in the presence of or very soon after a stimulus is presented, or an association will not occur. In essence, this is a behaviorist view based on the idea that learning will occur only if events occur relatively close together in time. For example, saying 'eight' to stimulus '3+5' and saying 'car' to the printed word *car*, resulting in pairing stimuli and responses whose association is to be learned. There are ways to make this kind of learning more efficient, such as through use of contingent reinforcement or by requiring more activity in learning situations, more contiguity of stimuli itself bring about learning.

Operant Learning

Another basic type of learning is learning as a result of reinforcement which is widely applied for behavioral modification. This kind of learning is known as *operant conditioning* because the behavior that is of interest appears spontaneously, without being elicited instinctively by any known stimuli, while the organism is operating on the environment. This is found by Skinner.

Skinner showed how positive reinforcement worked by placing a hungry rat in his Skinner box. The box contained a lever in the side and as the rat moved about the box it would accidentally knock the lever. Immediately it did so a food pellet would drop into a container next to the lever. The rats quickly learned to go straight to the lever after a few times of being put in the box. The consequence of receiving food if they pressed the lever ensured that they would repeat the action again and again.

Positive reinforcement strengthens a behavior by providing a consequence an individual finds rewarding. For example, if your teacher gives you \$4 each time you complete your homework (i.e. a reward) you are more likely to repeat this behavior in the future, thus strengthening the behavior of completing your homework.

The removal of an unpleasant reinforcer can also strengthen behavior. This is known as **Negative Reinforcement** because it is the **removal of an adverse stimulus** which is 'rewarding' to the animal. Negative reinforcement strengthens behavior because it stops or removes an unpleasant experience.

For example, if you do not complete your homework you give your teacher \$4. You will complete your homework to avoid paying \$4, thus strengthening the behavior of completing your homework.

Obsevational Learning

Observational learning, also called social learning theory, occurs when an observer's behavior changes after viewing the behavior of a model.

Exposure to a model can affect the behavior in at least three ways. These are observer can learn new behavior, have already learned behavior facilitated and have already learned behavior inhibited or disinhibited.

1. An observer can learn new behavior from model. In the Bandura study, children would often say things like 'Pow' or 'sock-em', repeating verbatim the model's languages.
2. A model can also influence a learner by facilitating a response repertoire already present in the learner. When the behavior of the model resembles behavior the learner

has previously mastered, the model's performance may simply elicit the previously learned responses.

3. Exposure to a model can inhibit or disinhibit the responses of the observer. To inhibit is to restrain or make a response less frequent, and to disinhibit is to free from restraint and thus allow a response to occur.

Reward or punishment of behavior may be obtained vicariously when the consequences of the model's performance are observed, or reward or punishment can be obtained through the observer's own actions. In either case, reward or punishment can markedly affect the performance of behavior. Reward and punishment do not seem to be responsible for the acquisition of that behavior.

cognitive learning

"Cognitive learning is the result of listening, watching, touching or experiencing.

Cognitive learning is defined as the acquisition of knowledge and skill by mental or cognitive processes — the procedures we have for manipulating information 'in our heads'. Cognitive processes include creating mental representations of physical objects and events, and other forms of information processing.

In cognitive learning, the individual learns by listening, watching, touching, reading, or experiencing and then processing and remembering the information. Cognitive learning might seem to be passive learning, because there is no motor movement. However, the learner is quite active, in a cognitive way, in processing and remembering newly incoming information. Cognitive learning enables us to create and transmit a complex culture that includes symbols, values, beliefs and norms. Because cognitive activity is involved in many aspects of human behavior, it might seem that cognitive learning only takes place in human beings.

Three Types of Learning Cycles

There are three types of learning cycles: descriptive, empirical abductive, and hypothetical-deductive. The main difference among the three is the degree to which students merely attempt to describe nature or explicitly generate and test alternative hypotheses.

In terms of students thinking, descriptive learning cycles generally require only imperical-inductive patterns (example; seriation, classification and conservation), while hypothetical-deductive learning cycle demande use of higher order patterns.(example: controlling variables, corrolation thinking and hypothetical-deductive thinking). Eperical –abductive learing cycles are intermidate and require emperical-inductive thinking patterns and generally involve some higher- order patterns.

Descriptive Learning cycles

In descriptive learning cycles students discover and descibe an emperical pattern with a spesific context (exploration). The teacher gives it name (term introduction), and the pattern is then identified in additional contexts (concept application). This type of learning cycle is called descriptive because the student and teacher are describing what they observe with out attempting to explain their observations. Descriptive learning cycles an answers the question “what?” but do not rise the causal question “why?” Basically descriptive learning cycles are designed to have students observe a small part of the world, discover a pattern, name it and look for a pattern elawhere. Little or no disequilibriu may result. Because students may most likely not have strong expectation of what will be found .

The following steps are used in preparing and then implementing the descriptive of learning cycles:

- a. The teacher identifies concept(s)
- b. The teacher identifies some phenomenon that involves the pattern on which the concept is based.
- c. Exploration phase: The students explore the phenomenon and attempt to discover and describe the pattern.
- d. Term introduction phase: The students report their data, and they or their teacher describe the pattern; the teacher then introduces a term or terms to refer to the pattern.
- e. Concept application phase: Additional phenomena are discussed or explored that involve the same concept.

The strong side of descriptive learning cycles is easy for most students to carried out. Because students are not use higher order thinking pattern.

Descriptive Learning cycles have the following weakness.

- It does not enables us use of thinking pattern to examine alternative conceptions or misconceptions. Because it allows us to see small part of the world.
- Most of the time it does not answer the question ‘‘why?’’.
- It may cause dogmatic thinking.

Emperical-Abductive Learning Cycles

In emperical abductive learning cycles, students again discover and describe an emperical pattern in a spesfic context (exploration) but go further by creating possible causes of that pattern. This requir the use of abduction to transfer terms and concepts learned in other context to this new context (term introduction). The term may be introduced by students, the teacher or both. With the teacher’s guidance, the students then shifts through the data gathered during the exploration phase to see if the hypothesized causes are consistet with those data and other known phenomena (concept application). Emperical-abductive learning cycles begins with a look at the emperical world. Further the students’ emprical experiment are not designed with well formulated hypotheses in mind. For example in ivestigation of the causes of decomposition, students take temperature, water and salt as affecting variables. During exploration, they found as temperature and water increases rate of decomposition increases but as salt consentration increases that rate of decomposition decrease. Students conclulde the cause of decomposition of dead organism are temperature and water. But the actual cause the molds and bacterias at moderate temperature and water. One or more students perhaps, made this conclustion after the questions like, ‘‘what do you suppose the cause terrible odor?’’

To go beyond this restricted and incorrect view, students must be given hints and encouraged to think further about the problem until one of them hits on the hypothesisthat the models and bacteria are the actual causal agents. Because this hitting on the right idea involves abduction (i.e the use of analogy to borrow ideas from the past experience rather than direct observation), not induction , and because the process is necessary to arrive at the desired hypothesis. In short any learning cycle that begins with a ‘‘what factors affect...? question and follows by creating hypothetical cause is an emperical abductive learning cycle.

hrough abduction) and intially test causes , hence the name emperical-abductive.

- a. The teacher identifies concept(s) to be taught

- b. The teacher identifies some phenomenon that involves the pattern on which the concepts are based.
- c. Exploration phase: The teacher or students a descriptive and a causal question.
- d. Students gather data to answer the descriptive question.
- e. Data to answer the descriptive question are displayed on the board.
- f. The descriptive question is answered, and the causal question is raised.
- g. Alternative hypotheses are advanced to answer the causal question, and the already gathered data are examined to allow an initial test of the alternatives.
- h. Term introduction: Term introduced that relate to the explored phenomenon and the most likely hypothesized explanation.
- i. Concept application: Additional phenomena are discussed or explored that involve the same concepts.

The strength of abductive learning cycle

- students again discover and describe an empirical pattern in a specific context and go further by creating possible causes of that pattern.
- Since abductive learning cycle is less complicated as compared to hypothetical deductive learning cycle, students use it to find the cause of a phenomena.

Weakness of abductive learning cycle

- Further the students' empirical experiment are not designed with well formulated hypotheses in mind.

Hypothetical-Deductive Learning Cycle

The third type of learning cycle, hypothetical-deductive, involves the statement of a causal question to which the students are asked to create alternative explanations. Student time is then devoted to deducing the logical consequences of these explanations and externally designing and conducting experiments to test the (exploration). The analysis of experimental results allows for some to be rejected, some to be retained, and for terms to be introduced (term introduction). Finally the relevant concepts and thinking patterns that are involved and discussed may be applied in other situations at a later time (concept application). This type of learning cycles requires the explicit creation and testing of alternative hypotheses through

a comparison of logical deductions with empirical results, hence the name hypothetical-deductive.

Unlike empirical-abductive cycles, hypothetical-deductive cycles call for the creation and explicit testing of alternative hypotheses to explain a phenomenon. In brief, a causal question is raised, and students must propose alternative hypotheses. These, in turn, must be tested through the deduction of predicted consequences and experimentation. This places a heavy burden on students' initiative and thinking skills.

Consider for example, the hypothetical-deductive learning cycle "what caused the water to rise?" Like empirical abductive learning cycles, it requires students to do more than describe a phenomenon. An explanation is required.

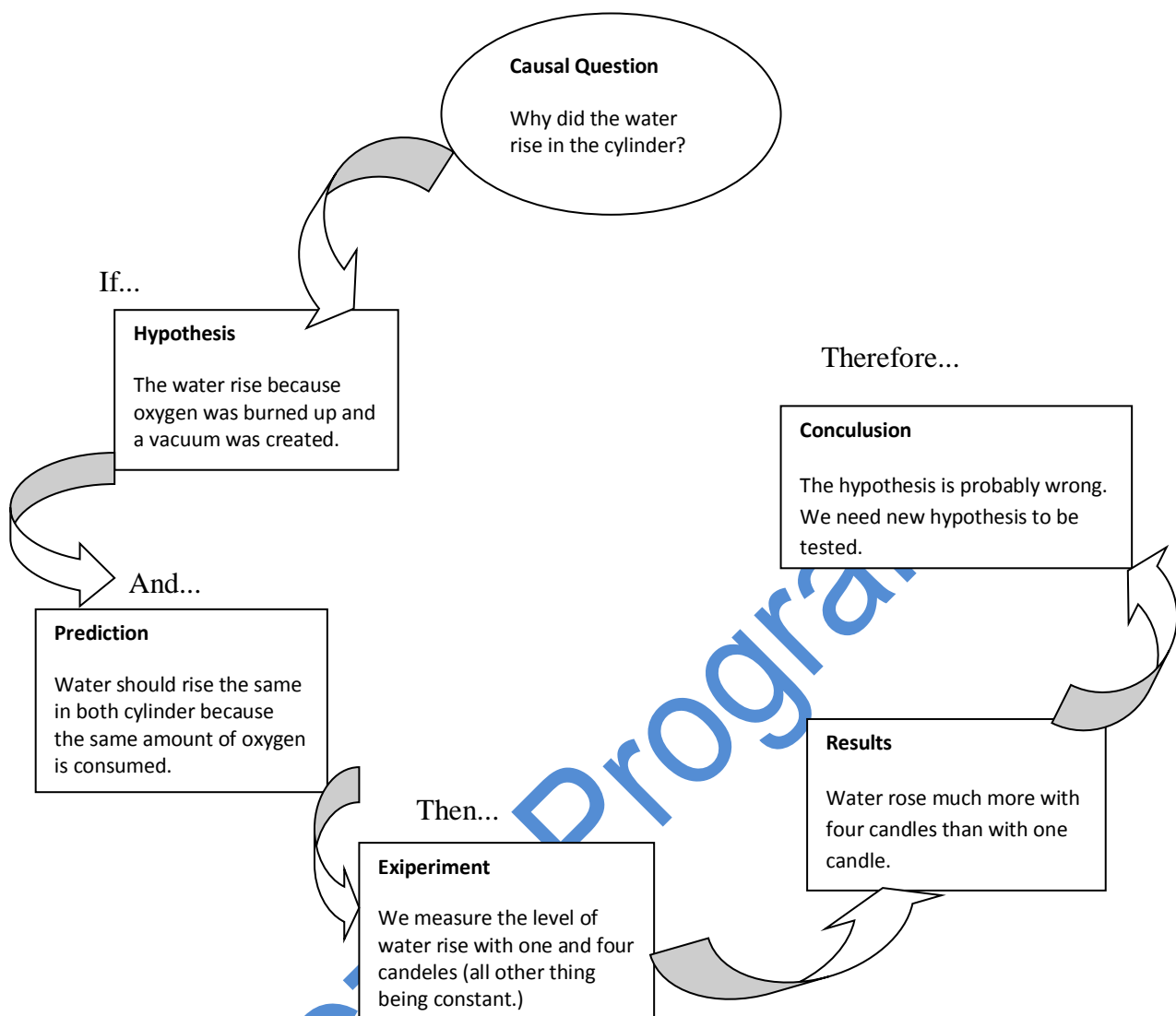
To start, students invert a cylinder over a candle burning in a pan of water. They observe that the flame soon goes out and water rises into the cylinder. Two causal questions are posed.

1. Why did the flame go out?
2. Why did the water rise?

Students typically explain that the flame used up the oxygen in the cylinder and left a partial vacuum that sucked water in from below. This explanation reveals two misconceptions:

1. Flame destroys matter, producing a partial vacuum
2. Water rises because of a non-existent force called suction.

Testing these ideas requires use of hypothetical-deductive pattern of thinking and the isolation and control variables. Let us see the figure below



The strength of hypothetical deductive learning cycle.

- Hypothetical-deductive cycles call for the creation and explicit testing of alternative hypotheses to explain aphenomenon.

Weakness of Deductive hypotheses learning Cycle

- The process of creation and explicit testing of alternative hypotheses to explain aphenomenon, raising causal question and testing through the deduction of predicted consequences and experimentation place a heavy burden on students initiative and thinking skills.

TCTP Program