SYNTHEIS PAPER

Lili CUI

Department of Physics

Kansas State University

Directed by Professor Andrew G. Bennett

Abstract: Based on the half semester’s study, this synthesis paper covered those important ideas that we have talked in class. In class, we talked about those topics in mathematics area, in this paper, for my physics major’s limitation, it dealt with the physics understanding. But the basic ideas are same. Four sections that included in this paper are: what it means to understanding physics, how this understanding develops, two examples in physics and instruction implication.
WHAT IT MEANS TO UNDERSTAND PHYSICS?

“The purpose of computing is insight, not number”—R. W. Hamming

The problem of understanding physics requires, in my opinion, a short presentation of a more general issue, which is the issue of understanding.

Understanding can be treated as a kind of indirect cognition. Bloom treats the understanding, or more generally, human thought as taxonomy: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. These six levels are cumulative and the lower three level (knowledge, comprehension and application) describe a divergent thinking process and the upper three level describe a divergent thinking process. And also this taxonomy is hierarchical, it is assumed that anyone who can work at a higher level can also do work at each of the lower level. Van Hiele’s learning level: Information, Guided orientation, Explicitation, Free orientation, integration basically state the same idea.

I would like to say that based on Bloom’s taxonomy, if one reaches the third level—application, he can be considered to achieve understanding. “The use of an appropriate piece of knowledge or routine at the right time and in the right place is the essential of intelligence.”

I would also like to stress some points about the difference between expert and novices, because we divide these two categories just based on their understanding level of a certain subject. Research shows that it is not simply general, such as memory or intelligence, nor the use of general strategies that differentiate experts from novices. Instead, experts have acquired extensive knowledge that affects what they notice and how
they organize, represent, and interpret information in their environment. This, in turn, affects their abilities to remember, reason, and so solve problems.

Now we come back to physics understanding, which in my opinion is almost the same for all natural science understanding including mathematics, chemistry and so on.

Specifically, for me, one understand physics if he can do all of the following:

1. **Explain Mathematical Concepts and Facts In Terms of Simpler Concepts and Facts.**

   He usually mentioned the major principles or laws that were applicable to the problem, together with a rationale for why those laws applied to the problem and how one could apply them. In contrast, competent beginner typically described which equations he would use and how that equation would be manipulated.

2. **Easily Make Logical Connections Between Different Facts and Concepts.**

   His knowledge is not simply a list of facts and formulas that are relevant to their domain; instead, his knowledge is organized around core concepts or “big ideas” that guide their thinking about his domains, such as Newton’s second law when dealing with the entire concepts in kinetics.

   In other word, it means that he has acquired a great deal of content knowledge that is organized in ways that reflect a deep understanding of their subject matter.
3. Recognize the Connection When He Encounters Something New That's Close to the Physics That He Understands.

He notices features and meaningful patterns of information that in the new question efficiently. For example, physicists recognize problems of river currents and problems of headwinds and tailwinds in airplanes as involving similar mathematical principles, such as relative velocity. Mathematics expert are also able to quickly recognize patterns of information, such as particular problem types that involve specific classes of mathematical solutions.

His knowledge cannot be reduced to sets of isolated facts or propositions but, instead, reflect contexts of applicability: that is, the knowledge is “conditionalized” on a set of circumstances. He do not have to search through everything they know in order to find what is relevant; such an approach would overwhelm his working memory.

4. By Contrast, Understanding Mathematics Does Not Mean to Memorize Formulas, Definitions, or Theorems

Being able to reason is essential to understanding physics. By developing ideas, exploring phenomena, justifying results, and using mathematical conjectures in all content areas and—with different expectations of sophistication—at all grade levels, students should see and expect that mathematics makes sense.

He is an effective problem solver. Effective problem solvers plan frequently. He periodically takes stock of their progress to see whether they seem to be on the right track. If he finds he is not making progress, they stop to consider alternatives and do not hesitate to take a completely different approach.
HOW THIS UNDERSTANDING DEVELOPS?

Constructivism

The understanding developing process is definitely connected with effort. From either Skemp’s schema theory, Van Hiele’s level theory, or Dubinsky’s theory, we can see clearly that one need to construct understanding by himself, or say, constructivism.

What is Constructivism? "Students need to construct their own understanding of each physics concept, so that the primary role of teaching is not to lecture, explain, or otherwise attempt to "transfer" mathematical knowledge, but to create situations for students that will foster their making the necessary mental constructions. A critical aspect of the approach is a decomposition of each mathematical concept into developmental steps following a Piagetian theory of knowledge based on observation of, and interviews with, students as they attempt to learn a concept."

Schema Theory

I agree what Skemp said, “To understand something means to assimilate it into an appropriate schema.” This explains the subjective nature of understanding and also makes clear that this is not usually an all or nothing state. We may achieve a subjective feeling of understanding by assimilation to an inappropriate schema. In this case, an appropriate schema involves the idea of an electric spark. Clearly, the schemas that we build up in the course of our early learning of a subject will be crucial to the ease or difficulty with which we can master later topics. Instead of a stable, growing schema by means of which the individual organizes past experience and assimilates new data, reconstruction is required before the new situation can be understood. A schema is of such value to an individual that the resistance to changing it can be great. One of the most basic physics schemas that we learn is classical dynamics.
Level Theory

Schema theory gives the big picture that how the knowledge building looks like and how those small knowledge pieces are arranged. Now if we want to look deeply that how each knowledge piece develops, the level theory becomes important.

Van Hiele states that when teaching a new subject “It always seems as though I were speaking a different language. And by considering this idea I discovered the solution, the different levels of knowledge.” According to him, when you want to develop any understanding, the following five level is inevitable; I will give specific example in section three on Force:

First level: Visual level
Second level: the descriptive level
Third level: the theoretical level; with logical relations, geometry generated according to Euclid
Fourth level: formal logic; a study of the laws of logic
Fifth level: the nature of logical laws

As for his Learning level (Information, Guided orientation, Explicitation, Free orientation, integration), as I mentioned before, which in my opinion is similar as Bloom’s taxonomy, give us the general picture the thinking process.

Develop Understanding is A Crisis

An important point I like from Van Hiele is that learning is a crisis; it is not easy for the students to transfer from the first level to the second or even high level. There are usually two ways to solve this crisis. “The first method is to explain theorems at school and afterward have them learned by heart at home. The second method is that the teacher changes the subject matter to such a form that the thinking activities needed by the pupil
remain limited to a lower level. Then the crisis of thinking is avoided by them and this is exactly what is necessary for the development of thinking of the pupil. In education, where everything is ruled by schedules, there is little time for a thinking crisis.” Further, clearly, both ways cannot work isolated, we need to got a balance of there two methods in every class.

**Time Consuming Process**

Here I would like to talk a little bit of the learning time issue. I love the point that learning does need certain time. As put forward by Van Hiele, “----Still, it turned out that the results are much better if the problem is given at a later date. If we wait a year or so, it appears that the same pupils have no further difficulties with such proofs, even if the congruence has not been repeated.” But the question here is the teacher requires covering so many knowledge in a limited time. And they do not have enough time to allot to students at certain point. To solve this problem, it should be better at the lower grades, give them enough time to make sure they really understand each point that have been taught. After training, at the college, especially graduate student level, the teacher can cover more knowledge, because at that time, the students have more endurance and have the ability to accept more changeling tasks. But the teacher still should keep in mind that learning is really a time consuming process.

**Spiral Model**

Learning is a spiral process. Teacher needs to go over certain knowledge point again and again. We always heard some teacher complain, “I just taught them the knowledge yesterday, but today some of them even told me that they have never seen this before.” We cannot expect that every student is genius, even us cannot understand just been taught once. “Now we know teaching can be much better. Now in the textbooks the subject matter is repeated many times, and each time it is dealt with from the very beginning.”
**Problem Solving**

I agree with the idea that “Solving problems is not only a goal of learning but also a major means of doing so.” Students should have frequent opportunities to formulate, grapple with, and solve complex problems that require a significant amount of effort and should then be encouraged to reflect on their thinking. By learning problem solving in physics, students should acquire ways of thinking, habits of persistence and curiosity, and confidence in unfamiliar situations that will serve them well outside the physics classroom.

Good problems give students the chance to solidify and extend what they know and, when well chosen, can stimulate physics learning. But what is good problem? Bloom gives the idea Complexity vs. Difficulty. “Complexity describes the thought process that the brain uses to deal with information. Difficulty, on the other hand, refers to the amount of effort that the learner must expend within a level of complexity to accomplish a learning objective. It is possible for a learning activity to become increasingly difficult without becoming more complex.” However regrettably, when choosing problem, teachers are more likely to increase difficulty, rather than complexity, when attempting to raise student thinking. And the teach should posing problems comes naturally to young children.

When talking about problem solving, the relationship between practice and understanding arises. I do not agree the radical idea that practice does not result in understanding. Practice does result in certain level of understanding. The point here is that without understanding’s practice is not effective as the practice with understanding. We cannot negate the use of practice.

Schoenfeld’s control theory is very important in the process of solving problem. The book “How To Solve It” give us a lot of useful strategies of solving mathematics problem,
most of them are also useful for physics problem solving. However having a mastery of individual heuristic strategies is only one component of successful problem solving. Selecting and pursuing the right approaches, recovering from inappropriate choices, and in general monitoring and overseeing the entire problem-solving process, is equally important. It is generally assumed that students will, by working these problems, come to develop efficient selection mechanism. But things turn out that this is not the case. The first reason is that students are generally inefficient in their strategy selection. Second, students do not learn to key their strategy selection to the characteristics of the problems they are working. So strategies must receive instructional attention if students are expected to learn them.

■ TWO EXAMPLES IN PHYSICS

Apply Van Hiele’s Level to Force Education

➢ First level: Visual level
At the beginning of teaching force, the teach would like to ask the students “what does the force mean to them” “Give some examples what is force, where and when they feel it?” So the students can have the real picture in their mind what is force.

➢ Second level: the descriptive level
Then in the laboratory, the students are assigned to do a serious of experiments, so that they could find what are the other variables that are related to force and get the qualitative feeling of the relationship among those variables.
Third level: the theoretical level; with logical relations
By the teacher’s guide, student at this level should find the quantitative relationship between those variables, which is mass, acceleration and force. At last, they need to get to the formula: \( F=ma \).

Fourth level: formal logic; a study of the laws of logic
It should accord to Mechanics here. After a systematic study, the students should understand those basic important mechanics concepts and formulas.

Fifth level: the nature of logical laws
This should accord to graduate student level.

Comments: This is somewhat similar to the genetic deposition by Dubinsky. If we try to find the genetic deposition of Mechanics, at the lowest level, the displacement and time are introduced, then velocity, acceleration, force and so on.

Spiral Model
The physics graduate students who come from China are usually considered a good physics students. I think it is just because of the spiral Chinese physics education system at the high school and university level.

From the second year of junior high school, usually at 13 years old, all of the students start to learn physics. After two years of physics studying, if you keep study (most person did so), then students will study all of the content again through the 3 years Senior high school. Of course, the material is harder and the understanding is deeper. If you go to college as a physics major student, you need to study all those knowledge from the very beginning. The physics here I am talking includes Mechanics, Heat, Electricity and
Magnetism, Optics and Atomic Physics.

So after this spiral studying, three times here compared with other countries once and twice, the physics major college students usually can get very solid background on physics, and which will a lot of benefit to their future graduate level study.

*Comments:* Although this model has these certain benefits, we cannot deny it is a time consuming process. And most important, many of the students will feel boring when they need to study the same content again and again, though the textbook becomes harder and harder. They have no fresh feeling and easy to lose interest in this subject. This issue now is a very important one in Chinese physics education area.

### INSTRUCTION IMPLICATION

Based on those readings and discussion in the class, I got the following ideas that are useful for physics or mathematics instruction:

**Clarity of Task/Motivation**

Strategies must receive instructional attention if students are expected to learn them. Write instructional objective for a course that have both knowledge of content and mastery of the skills you with students to develop. Make the objectives as detailed and specific as possible. These guides make ideal guides for the students: the more explicit you are about what you want the students to be able to do, the more likely they will be to succeed at doing it. Make class exercised, homework assignments, and tests consistent with the objectives. Give the objectives to the students to use as study guide.
Establish Connection Between Course Material and Student’s Pre-Knowledge

Our goal in teaching is to get information and skills encoded in our students’ long-term memories. Cognitive research tells us the information that cannot be linked to existing knowledge is not likely to be retained. Linking the new material to familiar material provides a natural set of cues. Also it will motivate the students learning desire.

So begin teaching each course and each new topic by describing the phenomena to be studied and the types of problem to be solved, if possible, using examples familiar to the students. Discuss several realistic situations in which physicists are trying to understand the phenomena and solve the problem.

The central important of the schema as a tool of learning means that inappropriate early schemas will make the assimilation of later ideas much more difficult, perhaps impossible. “Inappropriate” also includes non-existent. An appropriate schema means one that takes into account the long-term learning task and not just the immediate one. Dubinsky also argues, “Whatever happens, in or out of the classroom, the main concern should be with the students’ construction of schemas for understanding concepts. Instruction should be dedicated to inducing students to make sense these constructions and helping them along in the process.” The responsibility of teachers in the early stages of learning is therefore great. They have to make sure that schema learning, not just memorizing the manipulations of the symbols, is taking place.

Balance Abstraction and Conceptualization in Every Course

Knowledge in physics class may be categorized as abstraction—fact, observation, and experimental data or as conceptualization—concept, theory, model and formula. These two different kinds of knowledge should be balanced in each course. Such as provide
visual illustrations and demonstration, use numbers rather than algebraic variables when illustrating how formulas are applied in the first few examples.

Van Hiele states that “a teacher, beginning with teaching geometry, should address himself to the pupils in a language they understand-----After some time, he must speak to them about subject matter requiring the second level-----” I don’t think this idea is practical. Teacher should address the two different kind of language at each class, probably at first he should use more first level language and after some time, he can use more second level language.

**Promote Active Learning**

All the of literatures that we have read support the notion that active, student-centered learning is superior to passive, teacher-centered instruction. Dubinsky says, “Whatever happens, in or out of the classroom, the main concern should be with the students’ construction of schemas for understanding concepts. Instruction should be dedicated to inducing students to make sense these constructions and helping them along in the process.” People acquire knowledge and skills though practice and reflection, not by watching and listening to others telling them how to do something.

For example, the teacher can outline a strategy for solving the problem just posed, which is according to Schoenfeld’s control theory, draw a flowchart for the process just describes, ask student thinking of as many practical applications as they can, or ask them to put forward their own test question.

Active learning make classes much more enjoyable for both students and instructor. But the challenge is to involve most or all of the students in productive activities without sacrificing important course content or losing control of the class.
Use Cooperative Learning

Cooperative learning is also an idea that be emphasized by all those authors. ‘Weak’ students working individually are likely to give up when they get stuck; working with stronger students to assist them, they keep going to completion. Many ‘strong’ students tend to do the minimal work required to complete the assignment, which may not require deep understanding of concepts; when faced with the task of explaining and clarifying material to weaker students, they often find gaps in their own understanding and fill them in.

However cooperative learning should be arranged carefully, or one or two student will do the whole work and other students have nothing to do. So practically the teacher can:

- Assign some or all the homework to team of 3-4 students, experiments as well
- Form teams that are heterogeneous in ability level
- Form the team himself
- Assign team role that rotate with each assignment
- Get team to assess how well they are doing

Students can learn about reasoning through class discussion of claims that other students make. Young children's explanations will be in their own language and often will be represented verbally or with objects. Students can learn to articulate their reasoning by presenting their thinking to their groups, their classmates, and to others outside the classroom.

Also classroom discussions were not nearly as rigidly structures as the flowchart of the discussion or “stages” in exploration might suggest. The class was encouraged to generate a number of plausible ideas before committing itself to any particular one.
Give Good Problem
Teachers play an important role in the development of students' problem-solving dispositions by creating and maintaining classroom environments, from prekindergarten on, in which students are encouraged to explore, take risks, share failures and successes, and question one another. In such supportive environments, students develop confidence in their abilities and a willingness to engage in and explore problems, and they will be more likely to pose problems and to persist with challenging problems.

Try to Give “Big” Picture

Give Them Enough Time

Proper Assessment Skill

Collect Feedback And Respond
Reference: