Promoting Understanding of Physics Concepts

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What it means to understand physics concepts (Newton’s Second Law of Motion)

Learning and understanding are often discussed together. I believe that meaningful learning occurs only if there’s a coherent understanding of concepts being learned. So what does it mean then to have a coherent understanding of a certain concept? This section of the paper will focus on what it means to understand a physics concept. Specifically, I will attempt to discuss the indicators of understanding physics concepts and some factors that might affect such understanding. In the second part, I will try to discuss my own theory of how an understanding of physics concepts develops based on the works of Skemp and Dubinsky. I would attempt to discuss my own theory in the context of understanding Newton’s Second Law of Motion. Lastly, I will discuss the implication of my theory in the teaching and learning process in physics.

Let me start my discussion by defining what I mean by coherence in understanding of physics concept like Newton’s Second Law of Motion. I believe that coherence in understanding entails the mastery of two types of knowledge – qualitative and quantitative. Qualitative knowledge consists of concepts, facts and is static while quantitative knowledge is composed of rules, skills and techniques (Sabella, 2002). In physics each topic has qualitative and quantitative aspect. Strong linkage between the two types of knowledge is needed in order to have a coherent understanding of physics concepts.

How do we know that one actually has a coherent understanding of physical concepts? The linking of the two types of knowledge is quite complex and I believe it is quite impossible to directly measure the strength of interconnectivity. But there are
certainly indicators of a strong linkage of these two types of knowledge, which gives us a measure of the degree of understanding. **One of the indicators that a student understands a physical concept is that he knows how to use it in a particular situation that calls for the application of such concept. Being able to state and explain Newton’s second law is not a guarantee that one understands that concept.** If one can apply the concept in analyzing the motion of objects acted by a net force, whether in an ideal or non-ideal situations, then I believe that one has a coherent understanding of such concept.

Success in solving complex physics problems is another indicator that one has a coherent understanding of physical concepts. Complex physics problems are problems that cannot be solved by just employing plug-and-chug method of problem solving. Success in solving such types of problems entails a mastery of both types of knowledge-qualitative and quantitative.

Another aspect that we can look into in claiming that one has a coherent understanding of concept is that he can transfer his knowledge to other contexts. Although I know that one can also legitimately claim that it is possible that one has clear understanding of concept but can’t simply transfer knowledge to other contexts. Well, my stand is, if one really has a coherent understanding of a concept then he should be able to transfer it to whatever context that calls for the application of the same concept. If he can’t then his understanding is not that yet coherent.

It should also be noted that understanding might be facilitated or hindered by several factors. I will only mention here two factors, which I believe, are the ones that can significantly affect the understanding of physics concepts. First is the fact that students come into the classroom with their own preconceptions of the material to be learned. Their preconceptions may facilitate or hinder understanding of the materials to be learned.

Second, is one’s level and type of motivation. Students who have high level of intrinsic motivation (students who are motivated by the desire to learn) usually are the ones guaranteed to be successful in gaining a coherent understanding of a concept.

Understanding of a concept usually does not happen instantaneously when a new material is presented. It usually takes time for the concepts to be assimilated or
accommodated in the learner’s knowledge structures. Expertise really comes with major investment in time.

So what can be done in order to facilitate the acquisition of a good understanding of physical concepts like Newton’s Second law of motion? What can curriculum makers or teachers do in order to promote learning with understanding in the classroom? In order to address this question it is imperative to look at the theories about how understanding of a concept takes place.

In their theory of understanding mathematics, Skemp and Dubinsky call for the acquisition of appropriate schemas. A schema tells one what can be done to an idea, integrates existing knowledge, and acts as a toll for future learning and it makes understanding possible. Skemp (1987) proposes that to understand something means to assimilate it into an appropriate schema. Your chances of gaining a coherent understanding of a material to be learned is greatly increased by the possession of robust collection of appropriate schemas which are interlinked with each other. I strongly agree with Skemp’s and Dubinsky’s theory of schematical learning. I strongly believe that understanding of new concept is greatly facilitated if one has the appropriate schema.

Skemp (1962) had shown that schematic learning is much superior than rote learning in terms of recall and understanding of concepts. Results of his study showed that the schemas that one has are really crucial in the ease and difficulty with which one can master later topics. In schematic learning one actually is engaged in preparing a mental tool for applying the same approach to future learning tasks, which likewise results to the consolidation of earlier schema.

The process of assimilation of new concepts to an existing schema is quite complex. It is dependent on several factors. First, if the concept is quite related to the existing schema that one has, and then learning and understanding of the concept is greatly facilitated. Second, the understanding of concepts is affected by the metacognitive skills that a learner has. The better the metacognitive skills of a learner is the easier would be for him to learn with understanding.

Skemp’s schema theory is in consonance with the Constructivist Theory of Learning which argues that human subjects are the constructors of their own knowledge and skills. A basic tenet of constructivism is that for learning to occur, it needs to
recognize and build on prior learning. In other words, learners make sense of the world by relating new understandings to their existing organization of ideas. These networks of meanings are constantly being revised and are built on past experiences. Thus, in constructivist terms learning can be understood as a sort of sifting and winnowing of prior knowledge structures. Learners are also encouraged to see the inter-relationships between areas of knowledge and how these can be inter-connected and integrated. Prior knowledge or our pre-existing schema greatly influences succeeding learning. I firmly believe with the basic tenet of constructivism and Skemp’s view about the significance of prior knowledge in learning every type of material.

According to Dubinsky the building of schema involves five types of construction: interiorization of actions, coordination of two or more processes, reversal and encapsulation and generalization. These constructions may result to an object or a process. Interiorization of actions/objects for example could lead to a process. In the context of Dynamics the object could be the concept that an object acted by a net force is accelerated. Realizing that the acceleration can be computed using the equation \( a = \frac{F_{\text{net}}}{\text{mass}} \) is an example of interiorization which leads to a process. Figure 1 shows the model of Dubinsky on how schema is built.

Figure 1. Schemas and their construction(according to Dubinsky)
Leaning on the works of Dubinsky and Skemp on understanding mathematics, the following is being proposed as a way of capturing how understanding of different concepts in physics develops.

In figure 2 the qualitative aspect of physics corresponds to Dubinsky’s objects while the quantitative aspect corresponds to the process. In building a schema a learner may make constructions based on the qualitative and quantitative aspect of the material being learned and try to assimilate it to his prior knowledge. Assimilation refers to the way in which a child transforms new information so that it makes sense within their
existing knowledge base. That is, a learner tries to understand new knowledge in terms of their existing knowledge. For example, a student learning addition of vectors may find that in adding co-linear vectors is the same as adding scalar quantities except for the inclusion of direction. There’s no need for the learner to restructure his schema of addition in order to assimilate this concept. Or he may make modifications on his cognitive structures doing the process called accommodation. Accommodation happens when a learner changes his or her cognitive structure in an attempt to understand new information. For example, the student learning addition of vectors may find the need to restructure his schema of addition when given vectors that are non-collinear.

In my own view, a particular schema develops as outlined in figure 2. What I am implying here is that the construction process may involve assimilation or accommodation. In the figure those in 2-D boxes pertains to the processes in building a schema which I am supposing would lead to a coherent understanding of physics concepts. Those in 1-D boxes are the aspects that comprise a learners’ schema. So we see the complexity of how a particular schema is built. Unlike Dubinsky’s model I’m highlighting the effect of prior knowledge on the construction of schemas.

Understanding a particular concept in physics entails the acquisition of appropriate schemas. A good schema for learning Dynamics should include a strong linkage between the qualitative and quantitative knowledge. I believe that to have coherence in understanding one must have individual schemas for different concepts involved in dynamics and are interlinked with each other. For example to have a coherent understanding of force a learner should have a schema for adding vectors, schema for describing the behavior of a system acted by a net force, schema for contact forces (i.e. frictional forces), schema for non-contact forces (i.e. centripetal force). A strong linkage among these schemas would guarantee a coherent understanding of forces. Figure 3 outlines how in my view understanding of physics concepts comes about.
How the theory works

Let me now discuss how my theory works in the context of understanding Newton’s Second Law of Motion. In order to fully understand Newton’s second law of motion one must acquire the appropriate schemas. When I say appropriate schema I refer to schema where there is strong interconnection among concepts, facts, and formula. Or we can say that the knowledge are properly structured and organized. Schemas possessed by experts have these characteristics. Because of the strong interconnectivity of concepts within his schema, an expert usually can pull out the necessary schema when presented a new task that calls for its activation in his knowledge structure. This facilitates the learning and understanding of new concept, which can be assimilated to his existing schema.

As mentioned above coherent understanding of force entails the acquisition of different schemas (i.e. schema for contact and non-contact forces) which likewise are interlinked with each other forming a bigger schema, which we may call schema for forces. The development of each individual schema follows the process and contains the different aspects outlined in figure 2. In understanding Newton’s second law one must have a schema for forces and a schema for acceleration. These two schemas separately consist of smaller schemas, which are interlinked with each other. The schemas for forces have already been outlined above. So what are the necessary schemas for the understanding of acceleration? In order to have a good understanding of acceleration one must acquire the following schemas: schema for velocity, schema for determining acceleration from the parameters of the motion of an object, schema for determining acceleration from the forces, schema for describing accelerated motion in one dimension, schema for describing accelerated motion in two dimensions, schema for analyzing many-body problems. To have a coherence of understanding there should be a strong interconnectivity among the individual schemas (see figure 3).
Figure 3. Linking of Schemas and Coherence of Understanding of Acceleration
How the theory can be used (in instruction or assessment or research)

We know that the prior knowledge of students greatly affect how new knowledge is being assimilated in one’s schema. I believe that the process of making appropriate linking of the different concepts, facts, rules and formulas in a particular schema is greatly affected by the student’s prior knowledge. It is therefore imperative that instruction should establish these preconceptions and try to build on them in restructuring one’s schema. For example, students come in the physics classroom with the preconception that velocity means force. It is imperative then that the teacher should design activities that would challenge the plausibility, intelligibility and fruitfulness of their preexisting knowledge and eventually make them restructure their inappropriate schema. This could be done by letting students do hands-on activity on surfaces where the coefficient of friction can be gradually decreased. Doing this will enable students to realize that force is not actually needed to keep an object moving. They will also come to connect their observation with their everyday experiences and finally come to realize in real situations where there is friction we need to counteract this resistance in order to keep an object moving.

In order to help students acquire a schema where there’s a strong linkage between the qualitative and quantitative knowledge, the instructor should not encourage the use of plug-and-chug method of problem solving. The instructor should design problems that would force students to make a qualitative solution of the problem before they can do quantitative solutions. This approach I think would facilitate the acquisition of schemas where the concepts and formulas are strongly linked with each other.

However, despite all these ideas and research results that I’m familiar with, I believe that there’s still a need to do further research on classroom interventions that promotes the acquisition of appropriate schemas in understanding physical concept like Newton’s Second Law of Motion.
References:

