Third Misconceptions Seminar Proceedings (1993)

Paper Title: CHARACTERIZATION OF MEANINGFUL LEARNING: CONCEPTUAL CHANGE OR CONTEXTUAL APPRECIATION?
Author: Linder, Cedric J.

Abstract: One consequence of the abundant literature reporting on students' conceptions of science-related phenomena has been the development of so called conceptual change teaching strategies and curricula (cf Duit, Goldberg and Niedderer, 1992). These efforts are typically framed by mental-model based conceptual-change characterizations of learning such as those of Brown and Clement, 1987; Hewson, 1981; Nussbaum and Novick, 1982; Osborne and Wittrock, 1983, Posner, Strike, Hewson and Gertzog, 1982.
The aim of this presentation is to explore weaknesses in mental-model based conceptual-change characterizations of meaningful academic learning. This is done by using examples drawn from physics to argue that contextual relationships play a critical role in scientific concept appreciation. Consequently it is argued that science education learning characterizations must take contextual relationships into account.

Keywords: Theories,Concept Formation,Philosophy,Educational Theories,Learning Theory,Learning Processes,Epistemology,,
General School Subject: Physics
Specific School Subject:
Students:

Macintosh File Name: Linder - Meaningful Learning
Release Date: 9-12-1994 I

Publisher: Misconceptions Trust
Publisher Location: Ithaca, NY
Volume Name: The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics
Publication Year: 1993
Conference Date: August 1-4, 1993
Contact Information (correct as of 12-23-2010):
Web: www.mlrg.org
Email: info@mlrg.org

A Correct Reference Format: Author, Paper Title in The Proceedings of the Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Misconceptions Trust: Ithaca, NY (1993).

CHARACTERIZATION OF MEANINGFUL LEARNING: CONCEPTUAL CHANGE OR CONTEXTUAL APPRECIATION?

Cedric J Linder

University of the Western Cape, South Africa.

INTRODUCTION

One consequence of the abundant literature reporting on students' conceptions of science-related phenomena has been the development of so called *conceptual change* teaching strategies and curricula (cf Duit, Goldberg and Niedderer, 1992). These efforts are typically framed by mental-model based conceptual-change characterizations of learning such as those of Brown and Clement, 1987; Hewson, 1981; Nussbaum and Novick, 1982; Osborne and Wittrock, 1983, Posner, Strike, Hewson and Gertzog, 1982.

The aim of this presentation is to explore weaknesses in mental-model based conceptual-change characterizations of meaningful academic learning. This is done by using examples drawn from physics to argue that contextual relationships play a critical role in scientific concept appreciation. Consequently it is argued that science education learning characterizations must take contextual relationships into account.

CONCEPTIONS AND CONCEPTUAL CHANGE

What is meant by a *conception* is seldom made explicit in the student-conceptions' literature. However, it is possible to broadly classify the characterization of conceptions into two groups: a *mental-model* based characterization and an *experiential* based characterization[1].

Typically the mental-model group characterize conceptions as *inside-head structures* of sense making. The experiential group, made explicit by the Gothenburg University phenomenographers, characterize conceptions as *person-world relationships*. In the experiential characterization, the essence of conceptualization lies in the *intentionality* inherent in contextual relationships vis-á-vis Franz Bretano (cf Inde, 1977). While the characterization does not preclude inside-head structural representation, its point of departure is that there are simply *no* assumptions made regrading the exact nature of, *or even the existence of*, inside-head structural representation (cf. Lybeck, Marton, Srömdahl and Tullberg, 1988).

---

[1] Marton and Neuman, 1988, go further and describe the points of departure in terms of constructivism and constitutionalism respectfully.

In the mental-model characterization, conceptual change is achieved by any, or all, of the following: adding to the internal structure (acquisition of new information); reorganizing the internal structure (reorganizing existing knowledge); and, discarding some of the internal structure (no longer viewing an understanding as worthwhile knowledge). In the experiential characterization, conceptual change is achieved by changing, or creating new, contextual relationships. Here, being able to have different relationships with a context means that one has a dispersive conceptual appreciation based on functional appropriateness. Furthermore, because of the relationship dimension, experientially based conceptual change means that one changes as a person (for example, see Johansson, Marton, and Svensson, 1985).

The mental-model characterization of conceptualization and conceptual change, because of its structural character, implicitly suggests some sort of conceptualization stability and unity. On the other hand, the *relational* dimension of the experiential characterization explicitly suggests conceptual dispersion (for example, a certain context could have a variety of relationships such as viewing orbiting electrons as either waves or particles).

IS CONCEPTUAL DISPERSION A SOCIAL AND SCIENTIFIC ARTIFACT?

Borrowing ideas from philosophers such as Schutz and Luckmann (1973) and Berger and Luckmann (1976), some educationalists have proposed that people, out of socialization necessity, construct different *domains of knowledge* (for example, Solomon, 1983), or different *modes of perception* (for example, Brauner, 1988). In particular it is argued that people are continually being socialized into a whole social repertoire of knowledge and that "such socialized knowledge *cannot ever*, by its very nature, *be extinguished*" (Solomon, 1983, p. 50, emphasis mine). In other words, there is a social framework for conceptual dispersion.

Let us turn to the scientific perspective. Einstein (1954) maintained that "the whole of science is nothing more than the refinement of everyday thinking" - a refinement of socialized knowledge. Part of what Einstein meant by the refining of everyday thinking must be conceptual extension and delimitation; in other words, refining includes the establishing of contextual relationships for both functional and theoretical boundary conditions.

What do I mean by functional and theoretical boundary conditions? Consider the contemporary physics perspective. It does not have a single encompassing self-consistent theory to explain all phenomena, and even in contexts where there is such theory, it is often not the most functional theory. For instance, one could use quantum mechanics to obtain exactly the same results that some legitimately applied classical physics would yield, however, in such contexts quantum mechanics would be considered less functional than classical physics because of the unnecessary complexity that would be involved. In other instances quite different conceptualizations of a scientific concept are needed, for instance, the concept of time in contexts where the relationship is defined by the magnitude of relative velocity, or geodesics. Clearly the appropriate application of scientific theories and concepts requires an appreciation of context - forging an appropriate relationship with the context. Consequently it would seem reasonable to argue that it is inadequate to depict meaningful learning in terms of a changing of conceptions in the sense of simply generating a new, or altered, cognitive structure. To further appreciate this argument consider the following specific examples.

EXAMPLES OF CONCEPTUAL APPRECIATION DRAWN FROM PHYSICS

1. Conceptualizing contexts using microscopically and macroscopically based relationships

Most efforts to change students' conceptions have been in the realm of classical physics (cf Pfundt and Duit, 1991). The problem with these efforts is that they explicitly depict classical physics as *the* legitimate way to think about relations among force, matter and motion. However, as is aptly pointed out in the *Feynman Lecture Series:*

> The mechanical rules of 'inertia' and 'forces' are *wrong* - Newton's laws are *wrong* - in the world of atoms.... it was discovered that things on a small scale behave *nothing like* things on a large scale. That is what makes physics difficult - and very interesting. (Feynman, *et al* 1963, p. 2.6, emphasis his):

Here, instead of striving to change how students' think, it would be educationally more expedient to focus efforts on introducing students to a way of thinking delimited by contextual relationships which are characterized by an appreciation of relatively slow moving macroscopic bodies in inertial frames of reference.

2. Explanations for the origin of force

Consider a context where the relationship is characterized by quantum electrodynamics (QED) and general relativity (GR) respectively. Using the QED relationship the origin of force is conceptualized as arising from an exchange of particles. Using the GR relationship it is conceptualized in terms of space-time curves.

3. Mass

Students' first depiction of mass is usually in terms of the quantity of matter making up a body - Newton said that mass was density multiplied by volume. What is the functional conceptualization for a student to have? Once again there is not any single conception that is uniquely functional. For instance, should the conception be classical in terms of *gravitational mass* or *inertial mass*? Or in this case should empirical observation, which indicates equivalence of gravitational and inertial mass, mean that they should be conceptualized as being the same thing? On the other hand, in physics we also have the concept of *relativistic* mass which, in this regard, French (1984) has pointed out that:

> Many physicists prefer to reserve the word mass to describe rest mass m_o, a uniquely defined property of a given particle, *but this is essentially a matter of taste.* (p. 233, emphasis mine)

Clearly the goal of physics educators should be to get students to appreciate that the conceptualization of mass that would be appropriate for them to evoke would depend upon their recognizing the relationship which they should be forging with a particular context.

4. Waves

Conceptualization of a wave is another excellent example of conceptual dispersion. For example, waves could be conceptualized as moving-energy through a material medium via the local movements of the material - without any material movement through the medium, for example, sound. Or as moving-energy without the importance of a material medium due to mutual electric and magnetic field induction occurring at a critical speed to facilitate continual regeneration without the loss or gain of energy - light. Or quite radically differently, as an amplitude which when multiplied by itself represents a probability distribution as in quantum mechanics.

5. Light

The following quote from Richard Feynman's book *QED The Strange Theory of Light and Matter* provides a vivid example of the importance of contextual relationship in the understanding of science.

> Newton thought that light was made up of particles-he called them 'corpuscles' and he was right (but the reasoning he used to come to that decision was erroneous .... I want to emphasize that light comes in this form - particles. It is very important to know that light behaves like particles, especially for those of you who have gone to school, where you were probably told something about light behaving like waves. I'm telling you the way that it *does* behave - like

> particles. (Feynman, 1985, pp. 14 - 15, emphasis his)

Without conceptual appreciation of context this quotation is disturbing, especially as Feynman won the Nobel prize for his work in this area. What is needed to understand his statement is recognizing that he was discussing light in the context of absorption and emission of photons. With this appreciation functionality is recognized.

6. Electric current.

Another area of fairly extensive student-conception research has focused on electric current. Conceptual understanding of this is complex. The formal definition of current is that it is the rate of flow of charge. How does one conceptualize that? For instance, would it be functional for students to conceptualize current as a flow of electrons? If we are looking at special cases such as a metal, or a vacuum tube, then the answer is yes, but how about in an aqueous solution? Now the conceptualization must flip to ions. Furthermore, in liquid and gaseous conductors there may be both positive and negative charge carriers and is a charge the same thing as a charge carrier? In the context of semiconductors the conceptualization is a function of the majority carriers. If these majority carriers are *holes*, physicists *conceptually* relate a positive charge with the hole's movement. Then, to make the hole a charge carrier, physicists assign to the hole a positive mass and current is then *conceptually* a flow of positive charges. This semiconductor current conception is considered to be of great importance in semiconductor theory, a functional conceptualization which in other contexts would be totally inappropriate.

Consider a further example: a simple steady state battery-and-bulb circuit with copper wire connections Before we connect our battery there is no applied electric field. In this context, physicists, in the classical sense, would conceptualize *free* electrons in the wire moving around with random thermal velocities (something much like Brownian motion). When we connect our battery we apply an electric field which causes the electrons in the circuit to experience a force. Now, instead of the electrons accelerating so that the current increases with time, physicists see them as hardly having got going before experiencing a collision so that the electrons effectively acquire a *constant* average *drift velocity*. This drift velocity is superimposed on the random thermal motion described earlier. At first this conceptualization seems uncanny. We have electrons which are constantly being accelerated, but which have a constant average velocity. The explanation for this apparent contradiction is that the electrons, in moving along and colliding with each other and with fixed atoms, constantly loose energy. Furthermore, this electron drift velocity is extremely slow: For a 1mm^2 copper wire carrying 1 ampere of steady state current the drift velocity would be a lot smaller than a millimetre per second (actually about 10^{-4} m/s).

The functionality in the steady state current conceptualization described earlier is also determined by the contextual relationship. If this relationship was contemporary rather than classical then one would have to evoke a conceptualization of the free electrons behaving like a highly condensed Fermi gas with lattice collisions which manifest as phonon interactions. If one was working at an engineering level with circuit analysis then the water-flowing-in- pipes conceptualization could be very functional, as it would be for some levels of introductory electricity classes.

SUMMARY AND CONCLUSION

The educational outcomes brought to the fore by the students' conceptions literature should not, I argue, focus on students having alternative conceptions or strong highly resistant-to-change preconceptions *per se*. It should rather focus on how to get students to develop new meaningful contextual relationships which manifest functional contextual-appreciation. Therefore, instead of characterizing meaningful learning in terms of structural mental-model conceptual change we should consider characterizing it in terms of contextual appreciation conceptual change. In other words, the characterization of learning as giving up one way of thinking and adopting another must depend on context appreciation: A way of thinking *in itself* does not necessarily need to be given up since functionality depends on the contextual relationship.

REFERENCES

Berger, P.L. & Luckmann, T. (1967). *The social construction of reality.* Hammondsworth: Penguin.

Brauner, C. (1988). *Perceptivism: A new philosophy of education.* Brief for the British Columbia Royal Commission on education, Canada.

Brown, D. and Clement, J. (1987). *Overcoming misconceptions in mechanics: A comparison of two example-based teaching strategies.* Paper presented at the annual meeting of the American Educational Research Association, Washington, DC, USA.

Duit, R., Goldberg, F. and Niedderer H. (Eds.) (1992). *Research in physics learning: theoretical issues and empirical studies - proceedings of an international* *workshop.* Kiel: IPN press at the University of Kiel, Germany

Einstein, A. (1954). *Ideas and opinions.* New York: Crown Books.

Feynman, R., Leighton, R.B. & Sands (1963). *The Feynman lecture series.* Volume 1. London: Addison Wesley.

Feynman, R. (1985). *QED: The strange theory of light and matter.* Princeton: Princeton University Press.

French, A.P. (1984). *Special Relativity.* Cornwall: Von Nostrand Reinhold.

Hewson, P.W. (1981). A conceptual change approach to learning science. *European Journal of Science education, 4(1):* 61-78.

Inde, D. (1977). *Experimental phenomenology.* New York: Putnam.

Johansson, B., Marton, F., & Svensson, L. (1985). An approach to describing learning as change between qualitatively different conception. In West, L.T.H. & Pines, A.L. (Eds.) *Cognitive structure and conceptual change.* Orlando: Academic Press.

Lybeck, L., Marton, F., Srömdahl, H. and Tullberg, A. (1988). The phenomenography of the 'mole concept' in chemistry. In Ramsden, P. (Ed.) *Improving learning: New perpectives.* London: Kogan Page.

Marton, F. and Neuman, D. (1988). *Constructivism versus constitutionalism. Some implications for the first mathematics education.* Paper presented to the 6th International Congress on Mathematical education, Budapest.

Nussbaum, J. and Novick, S. (1982). Alternative frameworks, conceptual conflict and accommodation: Towards a principled teaching strategy. *Instructional Science, (11):* 183-200.

Osborne, R. and Wittrock, M.C. (1983). Learning science: a generative process. *Science Education, 66(2):* 489-508.

Posner, G.J., Strike, K.A., Hewson, P.W. and Gertzog, W.A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66(2):* 211-227.

Pfundt, H. and Duit R. 1991, (Third edition) *Bibliography: Students' Alternative Frameworks and Science Education.* Kiel: IPN Press, University of Kiel, Germany.

Schutz, A. & Luckmann, T. (1973). *The structures of the life world.* London: Heinemann.

Solomon, J. (1983). Learning about energy: how pupils think in two domains. *European Journal of Science Education, 5(1):* 49-59.