

Promoting Students' Understanding of Science



Students can have great difficulty reading the textbook. Part of the reason for this is that for a student taking a science gateway course, **the language and epistemology of science are akin to a foreign culture.**

The very interpretation of the meaning of a word can have a different sense to a scientist and to a student. The word electron to a nonscientist has the sense of a very small hard particle. To a scientist, the name “electron” corresponds to a series of measured numbers – 1.6×10^{-19} units of charge, 9.1×10^{-31} Kg mass.

There are two difficulties. Firstly, there is **the use of mathematics**. Then there is the question of **the reality of the electron**. Does something that has attributes so incredibly smaller than anything we see in the world around us have any real existence?

Language tells us what the world is made of, not because language somehow accurately captures a world independent of language, but because it is the heart of dealing with the world. **When we create a new way of talking about the world, we virtually create a new world.**

...

Physics shows that while the world shapes us, **the language that we use shapes the world**

B. Gregory, *Inventing Reality: Physics as Language*, (New York, NY: John Wiley and Sons, 1988) pp. 181, 183.

“Scientific theory is a reading of the ‘book of nature,’ requiring circular reinterpretations between theory and observation and also theory and theory, and also requiring ‘dialogue’ about the meaning of theoretical language within the scientific community” (Hesse 1986,181).

For many students in the introductory gateway course, although individual words are understandable, the sentences appear to take the form of an unknown language. Students do not conceive of the subject in terms of a coherent theoretical framework.

Reflective Writing



First I have the book definitely, I start reading it slowly because if I read it fast I'll have to go over it again and again...after reading the sections I underline what's most important

and then whatever's just in my head I just put it in

First it's to prepare yourself before coming to class...(you're, you're just, you're forced obviously to open the book and know what the teacher is going to say...and talk about in class)

Next you start thinking of a lot of things at the same time: what you read; Then when I close the book I start thinking; I argue about this, agree with this, disagree with this, and just *write, ... write, write, write, ...*

The student reads a section of the textbook (*pericope*).

Two “horizons” come into play.

There is the horizon of everything that a student **knows** from the particular vantage point of encountering the pericope. Here we delineate “**known**” from “**understood**”.

The second horizon encompasses the **potential** in the pericope; the sense in which the words, in the pericope, are related within the language game **understood** by the author of the textbook.

The student approaches the pericope with preconceptions [misconceptions] about the material within the pericope.

The key quintessential experience occurs when the student is pulled up short by the pericope. “Either it does not yield any meaning or its’ meaning is not compatible with what we had expected.” (Gadamer P. 237).

At this point a dialogue begins. The student questions what is known within the entire horizon. The horizon may shift in the process. “A horizon is not a rigid frontier, but something that moves with one and invites one to advance further.” (Gadamer,P. 217).

I suppose I should make the meaning of a projectile motion clear in my head. I guess a projectile is an object moving freely under the influence of gravity alone. I don't really understand but I think something about the air resistance being negligible was mentioned ... OK. I'm going to back up my statement with an example. Let's assume we want to look at the projectile motion of a ball ... And to find details about the motion at certain instants, we have to take the horizontal & the vertical components into count. I also have to know a whole bunch of formulas for finding components of velocity of a certain particle. But all of those formulas could be derived from the basic formulas for constant velocity and acceleration that we studied before. (Reflective writing on a pericope by Lelana, a student in a gateway, calculus-based course on mechanics.)

The dialogue between the student and the text within the horizon of meaning yields a reinterpretation of the pericope, which may lead to a further examination of the pericope within the (possibly expanded) horizon—“the parts, that are determined by the whole, themselves also determine this whole.” (Gadamer p. 258-9).

It follows, so it is held, that **the logic of science is necessarily circular**: data are interpreted and sometimes corrected by coherence with theory, and, at least in less extreme versions of the account, theory is also somehow constrained by empirical data. (Hesse, 1980, pp. 171, 172)

The examination by Maxwell of the state of Electricity and magnetism in his day and his discovery of an inconsistency between the treatment of the electric and magnetic fields is likewise a hermeneutical circle between theory and theory.

The hermeneutic approach starts by having students initiate a “dialogue” with an extract from the textbook.

This dovetails with Vygotsky’s notion of the “**zone of proximal development**” (ZPD).

“It is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under ... guidance or in collaboration with more capable peers.”

By using the hermeneutical circle, **scaffolding** is provided for students through self-dialogue.

Alexei (In an interview): it's a little bit like thinking out loud and then putting it on paper, so it's pretty much like what I always used to do, it's just that it's quite surprising to see how much more it's helpful once it's put down on paper,

...

if there is something I don't understand, or if there's a concept I find difficult, at least I can find why I don't understand it

...

at least I'll be able to find the questions, and sometimes I find that is the first step...so in order to find the answers you need to find the right questions...and then with reflective writing it helps me a lot.

The studies comprising this program of research consisted of **three sets of students**, one set from each of **three institutions**. For each set, over half the class volunteered to take part in the study. From the volunteers five students were chosen for each set.

We purposively selected students who represented the disciplines from which the most students in the larger population are drawn. We selected both men and women for equity purposes. The students selected had marks, which fell between the top 25% of the class and 75% on the final examination.

All the students took essentially the same first course in calculus-based physics (mechanics). There were approximately 100 students taking the course at Concordia University, thirty students at Marianopolis College and roughly the same number at Champlain College. **All fifteen students were interviewed by the same person.**

The questioning takes the student from the part (the textual extract) to the whole (everything contained within the horizon. The student then returns from the whole to the part.

The hermeneutical circle begins with the textual extract. **The student has some primitive conception that projects a meaning of the textual extract.** The dialogue between the student and the text within the horizon of meaning yields a reinterpretation of the textual extract, which may lead to a further examination of the textual extract within the (possibly expanded) horizon—"The parts, that are determined by the whole, themselves also determine this whole." (Gadamer p. 258-9).

The circle continues between what is known to what is potential until there is a fusion of the horizon of the student with that of the textual extract: “the circular understanding runs backwards and forwards along the text and disappears when it is perfectly understood. ...thus the circle of understanding is not a ‘methodological’ circle, but describes an ontological structural element in understanding.” (Gadamer P. 261):

Well I guess I was surprised to read that even though an object would maintain constant velocity it would accelerate,
well it kinda doesn't make sense
because if the object is not speeding and is traveling at a constant velocity, how would it accelerate? But then I suppose it was explained to me that acceleration depends on the change in the velocity and since velocity is a vector quantity, its magnitude and direction-I forgot to say change in magnitude & direction of velocity would cause the object to accelerate
then something about the acceleration vector in uniform circular motion is ALWAYS perpendicular to the path of the motion
no it wasn't like this,
no it's right & something about how it's ALWAYS pointing toward the center of the circle.
O.K. I'm making it complicated for me to understand.
Acceleration of an object traveling in a circular motion is perpendicular to the velocity & acts towards the center of motion.
The velocity vector is the tangent to the path of the object and is perpendicular to the radius of the circular path.
I don't know if I can handle all of these circular things.
I mean I have a hard time realizing & figuring things out in straight line motion imagine now I have to go in circles.
This acceleration is called a centripetal acceleration. (Reflective writing on a textual extract by Lelana)

The cognitive activity while doing reflective writing as described by the students is different from simply engaging in rote recall of a text following silent reading. Another comment by Concordia students, Alexei and Solomon, and by Champlain College student Fiona makes this point even clearer.

Solomon: What I typically do is read the chapter, and then I read each section, as was suggested.... I talk to myself throughout the whole reflective writing experience, I almost hear my own voice, I have a very good auditory sort of thing ... so I hear myself speak when I am doing my reflective writing and I just record what I'm sayin ...and I ask myself questions.

Alexei: You are also forced to think about the content. It's not like memorizing. You have to understand what you are reading enough to know something to write about. Sometimes when you start reflective writing you realize you do not understand the content, or that well. While doing reflective writing you can often pin point particular important ideas you don't understand. It causes you to have questions too. Sometimes that is painful because you expect yourself to have answers and don't. I try to look up answers from books I have at home after doing reflective writing. But it has happened that I stumbled upon an answer myself during my reflective writing. Actually I do explore the answers to my questions while doing reflective writing. One more thing. If I really understand a topic, I really don't need to reflective writing about it. But topics I don't understand very well, it helps me a lot to understand them.

Fiona: Since I changed the way I did it I think that I understand more. I try to figure it out in my own. I want to try and understand what the theories are talking about, try and get a more global understanding as to what's going on, not just what the examples want us to do. Also I want to be able to apply that to the examples.

I think that most people when it comes to science its just 'let me just do the problems, I don't even have time to understand what's going on' and that's where the problem comes in because if you don't understand then you're stuck.

We're supposed to do three pages for this and I tend to go over because I like re-asking questions and asking myself 'well, why is this?', 'why does this happen in this case, does it happen in some other case, or is it just, or is this a special case'

SUMMARY WRITING VERSUS REFLECTIVE WRITING:

Interviewer: If you had a choice, like if you had an hour a week and you had to do summary writing or reflective writing and you were preparing for an exam, would you do the summary writing or reflective writing ? What do you think helps you more?

Fiona: I think the reflective writing would be better because as I ask myself questions, I prove to myself that I know what I'm talking about

Interviewer: Do you see a real distinction between reflective writing and summary writing?

Diane: Reflective writing , what's really good is that you don't have to care about the way you write, you can make a mistake, you just leave it there, it's a lot quicker, and a lot stress free. A summary; you really have to stick to your topic, pretty much say what you read, and just kind of basically memorize it. But here [with reflective writing], because you're more free it sticks in your head easier.

Evgeny: I remember the concepts, but not everything that we've covered and I find that it [reflective writing] helps because if I was writing a summary, I'd probably be looking in the textbook all the time and copying out the facts just like in the textbook without really thinking about them but in the reflective writing assignments and in the reflective writing I actually have to think about it without looking in the textbook and putting it into my own words. For me it helps. I think that reflective writing really helps me understand the concepts,

Laurent: Well, first of all, I don't think it's the same thing as summary at all. If I were to write a summary: these are the most important points, write them down and you're done. When I do reflective writing , I'll read the text and I'll know some of the things and some of the things I won't know. When I freewrite I'll have mentioned the stuff I know already. For example: 'I know what force this is, that's no problem, next' type of thing and then, I'll focus on what I don't know. Then for reflective writing it's a kind of flow of thoughts: 'okay, what if I try doing this to solve this'. so for me it's very different from summary, I don't see it the same way.

Summary

Most students enter “gateway” courses with loosely organized course concepts in contrast to the web of interconnections perceived by their instructors.

In performing Reflective-Writing students employ a hermeneutical circle to reach out beyond the individual sections of the textbook and enable students to relate that material to other parts of the textbook.

The quintessential element in reflective writing is the self-dialogue between the student and each textual extract.

It is crucial, in this sense to get students to approach the textual extract with questions, for example ‘what do I understand?’, ‘what do I not understand?’

Thanks!!



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