

Enhancing students' conceptual understanding by engaging science text with reflective writing as a hermeneutical circle

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ABSTRACT: Students can have great difficulty reading scientific texts and trying to cope with the professor in the classroom. Part of the reason for students' difficulties is that for a student taking a science gateway course the language, ontology and epistemology of science are akin to a foreign culture. There is thus an analogy between such a student and an anthropologist spending time among a native group in some remote part of the globe. This brings us naturally to the subject of hermeneutics. It is through language that we attempt to understand an alien culture. The hermeneutical circle involves the interplay between our construct of the unfamiliar with our own outlook that deepens with each pass. It can be argued that for novice students to acquire a full understanding of scientific texts, they also need to pursue a recurrent construction of their comprehension of scientific concepts. In this paper it is shown how an activity, reflective-writing, can enhance students' understanding of concepts in their textbook by getting students to approach text in the manner of a hermeneutical circle. This is illustrated using studies made at three post-secondary institutions.

INTRODUCTION

During the 1980's and 1990's, a major focus of attention on improving students' success in science gateway courses was conceptual change theory. A brief discussion about the evolution of models developed within this theory is found in Kalman, Morris, Cottin & Gordon, (1999). Such an approach did not yield as great an increase in students' understanding as had been hoped.

Students do not conceive of science in terms of a coherent theoretical framework. The student's paradigm, in the Kuhnian sense, is that the subject consists of solving problems using a tool kit of assorted practices. "The professor classifies the problems in terms of physics concepts, while the students classify them by situations" (Hewitt, 1995). Research shows that most students have loosely organized course concepts in contrast to the web of interconnections perceived by their instructors. Huffman and Heller (1995) in a study of 750 university students in a calculus-based introductory physics course show that most students' personal (alternative) scientific conceptions "are best characterized as loosely organized, ill-defined bits and pieces of knowledge that are dependent upon the specific circumstances in question" (p.141). In a similar vein, Hammer (1989, 1994) shows some students view physics as weakly connected pieces of information to be separately learned, whereas others view physics as a coherent web of ideas to be tied together.

Chi and her collaborators (Chi, Feltovich, & Glaser, 1981) and Chi, Slotta, & de Leeuw (1994) theorize that the reason why novice learners have difficulty in grasping science concepts is that they tend to build explanations (mental models) based on surface features. Chi and collaborators assert

that the many underlying structural and process attributes required to understand scientific concepts are not consistent with the surface features that they generate. Slotta & Chi (1999) state, “once an ontological commitment is made with respect to a concept, it is difficult for this to be undone”. Recently (See for example Chi & Roscoe, 2002), Chi clarifies her stance on the structures of concepts as embedded in naïve theories. She explicitly claims that naïve theories and scientific theories are often incommensurate in the sense of Kuhn (1962) and Feyerabend (1962):

Each of us was centrally concerned to show that the meanings of scientific terms and concepts -- 'force' and 'mass', for example, or 'element' and 'compound' -- often changed with the theory in which they were deployed. And each of us claimed that when such changes occurred, it was impossible to define all the terms of one theory in the vocabulary of the other. The latter claim we independently embodied in talk about the incommensurability of scientific theories. (Kuhn 1982, p. 669)

Recently, it has been suggested that a holistic mode is required (Elby, 2001). Using such an approach I have had some success in putting together a variety of activities to change students' mindsets (Kalman, 2008). One element in this toolbox has been the developing of an instrument called Reflective-Writing to get students to metacognitively examine the material in their textbooks before it is discussed in class (Kalman, Aulls, Rohar, & Godley, 2008). In order to improve the effectiveness of this instrument, it is necessary to understand how it operates. In this paper, I will explore how it functions within the context of the hermeneutical circle and I will utilize studies of its use at three post-secondary institutions. (The earlier paper of Kalman, Aulls, Rohar, & Godley (2008) was based on a study at only one of these institutions.)

REFLECTIVE WRITING

Reflective writing is a part of the writing-to-learn movement (Connally, 1989), the aim of which is to incorporate informal writing into all disciplines. Bangert-Drowns, Hurley and Wilkinson (2004) conducted a meta-analysis of 48 school-based writing-to-learn programs. This analysis shows that writing can have a small, positive impact on conventional measures of academic achievement. In particular two factors predicted enhanced effects: the use of metacognitive prompts and increased treatment length. Specifically, reflective writing is based upon the notion of "freewriting" popularized by Elbow (1973). Freewriting in courses is generally associated with having students read assignments, discuss the content, and then engage in freewriting to help internalize the concepts and conceptual relationships. Countryman (1992) defines freewriting as writing rapidly for a short and fixed period of time. Freewriting falls within Britton and colleagues' (1975) notion of “expressive writing”; they use this term to refer to writing to oneself, as one would in diaries, journals and first-draft papers, or to writing to trusted people who are very close to the writer, as in personal letters. Since it is not intended for external audiences, it has few of the constraints of form and style. Expressive writing often looks like speech written down; usually it is characterized by first-person pronouns, informal style, and colloquial diction. Fulwiler (1987) notes that “Some writing activities promote independent thought more than others do. Expressive or self-sponsored writing, for example, seems to advance thought further than rote copying” (p. 21).

Expressive writing became popular in universities in the 1980s as part of a general movement to promote writing for understanding, and it included many formats such as freewriting (Martin 1982). Many examples of such writing are found in the works of Fulwiler (1987). In particular, there is a section on writing in College Physics by Verner Jensen in which Jensen proposes that

“understanding can be enhanced through a freewriting experience” (p. 330). Jensen also notes that “Physics students can use the writing process to clarify their thinking and understandings about physical phenomena through their written articulation of relationships. Learning physics requires many different mind processes including abstract thinking. Writing can assist the student with this process” (p.330).

Writing-to-learn strategies in the sciences have been addressed by a number of researchers (e.g., Countryman, 1992; Rivard, 1994; Holiday, Yore, & Alverman, 1994; Pugalee, 1997, Wallace, Hand, & Prain, 2004; Kalman, 2006, 2008). In particular it has been used as a way for students to pinpoint their difficulties in the solving of quantitative problems (Countryman, 1992; Mayer & Hillman, 1996; Kalman, 2001). Rivard (1994) notes that writing-to-learn has been used to enhance the learning of science content, and also that writing as a response is intimately connected to thinking. Indeed Bangert-Drowns, Hurley and Wilkinson (2004) point out that “Writing can prompt and support the use of cognitive learning strategies”. Ellis (2004) “confirmed the potential of writing to help students engage with the knowledge of their discipline, which in this case was the sciences”. McDermott and Hand (2010) conducted a secondary reanalysis to analyze and report student perceptions from a number of individual writing-in science experiences taking place in varied contexts. They note that “Writing was not being viewed as a knowledge telling process, where students may know the content, or a knowledge regurgitation process, where they give words back to the teacher without understanding them, but rather as a process whereby they were able to construct new knowledge”.

Early in the course, students participated in a one-hour in class “workshop” on how to use Reflective Writing (Kalman, 2008) to understand concepts. They are to begin by reading the textual extract (a section of the textbook). They are instructed to first read the extract very carefully trying to zero in on what they don’t understand, and all points that they would like to be clarified during the class using underlining, highlighting and/or summarizing the textual extract. They are then told to freewrite on the extract. “Write about what it means. Try and find out exactly what you don’t know, and try to understand through your writing the material you don’t know.”

During this workshop, it was also made clear to the students that the reflective writing activity involved their writing and not writing to please the instructors. They were told that the marker would only read the material to ensure that the students were on task (writing about the subject matter and doing reflective writing rather than for example summary writing) and that the students had written an adequate amount of material.

The reflective writing was not marked. Students do the reflective writing for themselves. If marked, students would write for the instructor, worrying about paragraphing and sentence structure. We believed that this would distract them from the purpose of the activity. In order to make the students accountable, so that they would do the reflective writing, they were also asked to hand in three sentences about three concepts that they had learnt about during their reading. The number of the sentences was chosen to be substantive but not threatening. The three sentences were marked, but only if the reflective writing had been done. The mark for each student’s nine best submissions was worth 15% of the total grade.

REFLECTIVE-WRITING AS AN HERMENEUTICAL CIRCLE

Eger (2006) has pointed out that for students to come to an understanding of scientific material, there needs to be some overlap between the students’ ontology and that of the professor:

If our horizon and the text's horizon do not overlap at all, there is no way for our projections to fall within the realm of the text's potential meanings, and the attempt to reach understanding fails—incommensurability. (p.17)

The problem faced by the students is as Bevilacqua & Giannetto(1995) point out:

Ordinary textbooks for high school and undergraduates do not offer a coherent scientific theory of the phenomena: they offer layers of scientific results, coming from competing interpretations, deposited during centuries. A quantitative correspondence between the layers cannot hide the general lack of a coherent meaning and the conflation of contrasting models. From one point of view textbooks are good for indoctrination, like catechisms, from another they offer a technical view of science, closer to operating manuals of modern artifacts than to science texts. (P. 119).

Students can have great difficulty reading scientific texts and trying to cope with the professor in the classroom. Part of the reason for student's difficulties is that for a student taking a science gateway course the language and epistemology of science are akin to a foreign culture. Textbooks seem to be written in students' native language and seemingly all that is required is to understand the meaning of the special scientific vocabulary. This works to the extent of going to France and being taught that chaise is the word for chair, maison is the word for house and so on, but nothing else. Without grammar, you have great difficulty communicating "where is my hotel; the Louis V?". For many students in the introductory gateway course, although individual words are understandable, the sentences appear to take the form of an unknown language.

Wittgenstein (1973) writes:

When one shews someone the king in chess and says: "This is the king". This does not tell him the use of the piece – unless he already knows the rules of the game up to this point: the shape of the king. You could imagine his having learnt the rules of the game without ever having been shewn an actual piece. The shape of the chessman corresponds here to the sound or shape of a word. ... Consider this further case: I am explaining chess to someone; and I begin by pointing to a chessman and saying: "This is the king; it can move like this, ... and so on." – In this case we shall say: the words "This is the king" (or "This is called the 'king'") are a definition only if the learner already 'knows what a piece in a game is' (#31 P. 15)

It is my contention that a student can use Reflective Writing to begin to analyze the material in the textbook in the manner of the modern theory of hermeneutics developed by Hans-Georg Gadamer (1976).

Understanding must be conceived as a part of the process of the coming into being of meaning, in which the significance of all statements – those of art and those of everything else that has been transmitted – is formed and made complete. (p.146)

The hermeneutic approach starts by having students initiate a self-dialogue about each textual extract. Within the framework of such a dialogue, there exists two "horizons". There is the horizon that contains everything that a student believes from the particular vantage point of encountering the textual extract. The second horizon encompasses the potential in the textual extract; the sense in which the words, in the textual extract, are related within the language game understood by the

author of the textbook. “To acquire a horizon means that one learns to look beyond what is close at hand- not in order to look away from it, but to see it better within a larger whole and in truer proportion.” (Gadamer P. 272). The student approaches the textual extract with preconceptions (misconceptions) about the material within the textual extract. The key quintessential experience occurs when the student is pulled up short by the textual extract. “Either it does not yield any meaning or it’s meaning is not compatible with what we had expected.” (Gadamer P. 237). At this point the 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).

METHODS

We followed methods used in an intrinsic case study as recommended by Stake (1988) and Merriam (1988). We consider this to be an intrinsic case study because the student’s perspective is of primary interest within the context of the particular course design used in this study. Repeated readings of the interviews for each student led to the identification of re-occurring general and specific themes that were common to all students, as well as themes that were unique to particular students. We compared the different student interviews with each student to see if students constructed reoccurring categories that might reveal underlying themes regarding their views towards reflective writing and its value to their deep understanding of the physics course content. In performing this qualitative analysis, we combine data from a previous study at Concordia university (Kalman, Aulls, Rohar & Godley, 2008) with data from two colleges (Marianopolis and Champlain) located in the Montreal area. The college data has not been published or presented previously. Certain questions cannot be easily addressed by quantitative methods. For example, what happens when students engage in the Reflective Writing activity? Part of the answer follows from examining the written products of the activity, and part of the answer can be obtained through semi-structured interviews. How do students actually go about doing the activity? Do they change the way that they perform the activity during the course?

At the outset of the study, two sets of data were collected. Firstly, students were asked to respond to a survey after two weeks of having used reflective-writing in order to assess their initial predispositions toward writing as a tool for conceptual learning. Secondly, samples of reflective-writing were acquired. This material helped to establish a baseline to examine the students’ use of reflective writing throughout the course. A series of semi-structured interviews were completed at three points throughout the course.

In order to promote the credibility of the study, Moschkovich & Brenner (2000) suggest that the researcher needs to carry out the research in ways that answers the question, “How well do the results capture the constructs used by participants in a context and the particular dynamics of that context?” In this study prolonged engagement occurred in the sense that the complete cycle of instruction across 13 weeks was observed by one researcher who also taught the class and was aware that no unusual or atypical events occurred.

Triangulation was also used to establish credibility. The study used three sources of data: Survey responses relating to students’ initial evaluations of the reflective writing activity, evaluative remarks in relation to the reflective writing activity that occurred during each of three interviews, and finally, students’ reflective writing products that were collected throughout the course. Moreover, the results of the analysis of reflective writing products were compared to the results of the interview analysis to assess whether they corresponded or conflicted with each other. Finally, member checking was used

by having students review a portion of the interview transcripts from each interview for accuracy and completeness.

Sample

The studies comprising this program of research consisted of three sets of five students, one set from each of three institutions. 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. 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 fifteen students were interviewed by the same person.

At Concordia University, the actual number of students from each discipline in the course, in the order given, was: 30% Science (mostly Biology), 20% Engineering, 20% Mathematics and Computer Sciences, and 30% other (Humanities and Commerce). Half the students were male and the other half female. At both colleges, all the students were in either the pure and applied sciences or the biological sciences concentration. The former included students who intend to go into engineering. Students were selected to match the discipline profile. In addition, at Champlain College and at Concordia University, students were purposively selected on the basis of a survey taken near the beginning of the course. At Marianopolis College, students were selected on the basis of the survey and also the results of the first midterm test. The language of instruction at all of these institutions is English.

Data Collection And Analysis

Interviews

All interviews were audio- and video-taped. Two sets of questions were used and these reoccurred in the three separate interviews. The purpose of the first set of questions was to open the interview and to direct students toward considering the meaningfulness of reflective writing in broad terms. Specifically, the interviewer asked: "What do you view as the purpose of reflective writing?" and then "How useful would you say the activity is?" Probes for each question attempted to be general but to determine if the student had said all he or she could say. For example: Does anything else come to mind? Anything else? Can you tell me more about that? A specific probe for the second question was; "So, in what ways was it helpful?"

The purpose of the second set of interview questions was to attempt to make specific the procedures used to carry out reflective writing and any changes that might have occurred in how students carried out reflective writing during the course. To get students to describe what they do as reflective writing in detail, a series of questions were asked that represented the number and order of procedures used to carry out reflective writing. The questions were: What do you do next? What happens next? What else do you do? So, what do you do first? Or, overall, what do you do from the time you start to the time you finish?

The same questions were asked in the series of three interviews that took place in the third, seventh, and thirteenth week of the course. A student cannot answer such questions without revealing his or her knowledge of how to execute reflective writing as process. We explicitly asked if the person

engaged in self-questioning, since this strategy represents preliminary evidence of the student entering into a self-dialogue about the physics content or how to make sense of it, while reading and writing. Such an action would fall within the notion of the hermeneutical circle (Heidegger, 1977). Self-dialogue contributes to an interplay between the parts and the whole of a text adding to the complexity and depth of its meaning. The initial reading of the text followed by such a self-dialogue permits the novice student to pursue a recurrent construction of their comprehension of scientific concepts so that they can acquire a full understanding of scientific texts.

Content Analysis

In the essays, we looked for responses that were logical, and that related directly to the subject matter that the student had read. Moreover, we tried to find explicit connections between properties and category, examples and claims and evidence of them. Analysis was done independently to code sentences from students' reflective writing. Inter-rating coding was carried out for 25% of students' reflective writing samples.

RESULTS

The Hermeneutical Circle

Students set up their horizons and relate their initial knowledge to prior text

Reflective writing escape's Suchter's critique (1995) that Eger's pieces (2006) lack serious substance. In performing reflective writing, students actually do set up their horizon and then attempt to relate their knowledge within this horizon to other parts of the textbook as we see in the following example:

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 textual extract by Lelana, a student in a gateway, calculus-based course on mechanics.)

The questioning takes the student from the part (projectile motion) to the whole (her knowledge about vectors; horizontal and vertical motion). The student then returns from the whole to a particular (constant velocity and acceleration in a straight line studied in a previous chapter). The hermeneutical circle begins with a textual extract. The student has some primitive conception that projects a meaning of the textual extract. The student's self-dialogue within her horizon of meaning yields a reinterpretation of the textual extract, which leads 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 student has learnt a difficult

concept often misunderstood by students before it has been discussed in class: In projectile motion, the vertical and horizontal motion are independent of each other.

An Ontological Structural Element In Understanding

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, a Concordia student.)

Clarification of concepts

In the earlier section “Reflective-Writing As An Hermeneutical Circle”, I had stated that “The key quintessential experience occurs when the student is pulled up short by the textual extract. ‘Either it does not yield any meaning or its’ meaning is not compatible with what we had expected.’ (Gadamer P. 237)”.

With this in mind, note that Lelana is at first puzzled by her reading. She thinks that it means that an object has a constant velocity and still accelerates. She has misread constant speed to be constant velocity. She then begins a self-dialogue relating the words back to the text. She recalls the definition of acceleration and remembers that velocity is a vector quantity. Acceleration occurs if either the magnitude or the direction of the velocity vector change. She then relates these to the

directions of the velocity and acceleration vectors. The concepts are now clarified enough that she will follow the later discussion in class.

Evidence for students approaching the textual material in the manner of a hermeneutical circle also emerged from the interviews

Laurent (Marianopolis student): I did find that it changed. I'm able to read it and I take down my notes, and then I review my notes and then I can write it. I try to find links to what makes it easier for me to understand.

Laurent's finding links echo Lelana's efforts found in her writing samples.

Alexei (a Concordia student): Now I am starting continuously just writing non-stop, so it improved a lot. Before I wouldn't write continuously while reading. ... Now if I don't understand it when reading when I write it, it just so happens that I do understand it for some reason. In order to do reflective writing you really have to understand first, or well, not understand, but know what you do not understand about a particular question. So you have to read carefully. I read the whole chapter at once, part by part, to see what I understand out of it. I'll try to summarize it in my head... Then afterwards I just try and write whatever comes to my mind.

Alexei's point echo Gadamer's idea (1976) that to understand a line of text you need to relate it to the whole text and then notes that it is not possible understand the whole text without relating it to the parts:

Fundamentally, understanding is always a movement in this kind of a circle, which is why the repeated return from the whole to the parts, and vice versa is essential. Moreover, this cycle is constantly expanding, in that the concept of the whole is relative, and when it is placed in ever larger contexts the understanding of the individual element is always affected. (p.167)

Interviewer: Would you say that you've changed how you do freewriting from the first time that we did the interview?

Fiona (a Champlain student) What I used to do is read a paragraph or even a couple of sentences at a time, and see what that was saying and then after, right away, say 'well okay, this is what's going on, that makes sense'. Recently I tried reading longer pieces of text and I tried to think about it and then just starting writing about that. I can't read too much, because then I'll forget everything that was said, so I try and focus on a couple of ideas and then just write about what I've read and I find that I can understand more because I'm not focused on the details.

Interviewer: Before when you did it, was it line-by-line or paragraph-by-paragraph?

Fiona: basically, it was harder to do also and longer because I was focused on the little details and it was hard because I couldn't understand, the big picture. I was usually stuck and I usually went 'I don't understand this, I don't know why' so now I feel I understand the general theories more than the little parts that can be cleared up once I understand.

Fiona's need to understand the big picture again relates well to the notion of the hermeneutical circle. Fiona couldn't make any progress as long as she concentrated on the parts.

Summary Writing Versus Reflective Writing:

After our experience at Concordia, we tried to elicit from the students at Marianopolis and Champlain colleges what their thoughts were on summary and reflective writing:

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

Fiona: I think the freewriting 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 it as being different from summarizing?

Carolyn: It's a more personal interpretation of the material.

Interviewer: How does that help you in your learning then, or does it?

Carolyn: It does, just to get the general idea before the teacher explains, to know which things you didn't understand, and to know to what things you should pay more attention in class when the teacher explains it

Marianopolis students

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

Diane: Freewriting, 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 freewriting], 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 [freewriting] 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 freewriting 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 freewriting 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 freewriting, 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 freewriting 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

Interviewer: Do you see it helping you understand it better, or grasp the material better by doing freewriting?

Laurent: It helps me come up with questions, or if I read something and if there's a loophole or there's something missing, it's not clicking in my head, I find that...because usually I don't do that, but when I'm freewriting I'm more aware of it. If I was summary writing I would just say it again in my own words. You're more honest in freewriting, You're saying 'I don't

understand this' 'but I do understand this but I don't see how they connect'. When I do summary writing I feel like I'm just regurgitating everything I just read. I don't like that.

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

Comments 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 saying...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'

Alexei: When I don't understand the material, I start asking myself questions and then I try to understand it, by writing it [the answers to the questions] down.

Interviewer: Do you ask any questions during reflective writing?

Solomon: Typically it would be I don't understand this concept, and then well, I guess maybe it works this way or that way and I'll actually ask myself questions about the material...for more clarification, typically it's because I don't understand a link...how two things fit in the puzzle.

Interviewer: When you're doing freewriting do you ask yourself any questions?

Evgeny: Sometimes when I'd freewrite I'd get stuck and I'd realize that I really don't understand what I'm writing about. In those cases I'd have to go back and reread the whole section asking questions. I ask questions in the sense that, 'what am I doing, I don't understand'.

Note the common reporting of self-dialogue. Alexei's comment about "You have to understand what you are reading enough to know something to write about." reminds us of Gadamer's view.

Also Fiona writes that she wants to "get a more global understanding as to what's going on, not just what the examples want us to do." Finally there is Solomon's point about asking questions of himself because "I don't understand a link...how two things fit in the puzzle." These remarks of Fiona and Solomon point to students' striving to go from the parts to the whole.

DISCUSSION

The studies comprising this program of research consisted of three sets of five students, one set from each of three institutions. All the students took essentially the same first course in calculus-based physics (mechanics). Early in the course, students participated in a one-hour in class "workshop" on how to use of reflective writing to understand concepts. During this workshop, it was also made clear to the students that the reflective writing activity involved their writing and not writing to please the instructors.

Students generally felt that there was a major difference between summary-writing and Reflective-Writing. They felt that summary-writing was basically just listing the important points without thinking about them. However, in doing the Reflective-Writing assignments they felt that they had to put the information into their own words, which really helped them to understand the concepts,

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 understand the material in the textbook reaching out beyond the individual sections of the textbook. They come to realize that they began to the course with pre understandings that are not aligned with the framework described in the textbook. In examining this dissonance, they seek to relate passages that they are studying to text found in previous chapters. In doing this they develop a more holistic approach to the course. At the same time they refine and come to a clear understanding of key concepts. The quintessential element in reflective writing is to get students to initiate a self-dialogue about 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?'.

REFERENCES

- Bangert-Drowns, R. L., Hurley M.M. & Wilkinson B. (2004). The Effects of School-Based Writing-to-Learn Interventions on Academic Achievement: A Meta-Analysis. *Review of Educational Research* 74: 29–58.
- Bevilacqua, F. & Giannetto, E. (1995). Hermeneutics and Science Education: The Role of History of Science. *Science & Education* 4: 115-126.
- Britton, J., Burgess, T., Martin, N., McLeod, A., & Rosen, H. (1975). The development of writing abilities (pp.11 - 18). London, UK: Macmillan.
- Chi, M.T.H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science* 5, 121-152.

- Chi, M.T.H. & Roscoe, R.D. (2002). The processes and challenges of conceptual change. In M. Limón & L. Mason (Eds.), *Reconsidering conceptual change. Issues in theory and practice*, Dordrecht, The Netherlands: Kluwer Academic Publishers, pp. 3-27.
- Chi, M.T.H., Slotta, J. D., & de Leeuw, N. (1994). From things to processes: a theory of conceptual change for learning science concepts, *Learning and instruction* 4, 27-43.
- Connally, P. (1989). Writing and the ecology of learning. In P. Connally & T. Vilardi (Eds.), *Writing to learn mathematics and science*. New York: Teachers College Press.
- Countryman, J. (1992). *Writing to learn mathematics: Strategies that work*. Portsmouth, NH: Heinemann.
- Eger, M. (2006). *Science, understanding, and Justice: The philosophical Essays of Martin Eger*, edited by Abner Shimony. Open Court Publishing Company, Chicago, IL, USA.
- Elbow, P. (1973). *Writing without teachers*. New York, NY: Oxford University Press.
- Elby, A. (2001). Helping Students Learn How to Learn, *American Journal of Physics: Physics Educational Research Supplement* 69, S454-S64.
- Ellis R. A. (2004). University Student Approaches To Learning Science Through Writing, *International Journal of Science Education*, 26: 15, 1835 — 1853.
- Feyerabend, P.K. (1962). Explanation, Reduction, and Empiricism. In H. Feigl and G. Maxwell. (Eds.), *Scientific Explanation, Space, and Time*, Minnesota Studies in the Philosophy of Science, Volume III. Minneapolis: University of Minnesota Press. Pages 28-97.
- Fulwiler, T. (1987). *The journal book*. Portsmouth, NH: Heinemann.
- Gadamer, H.-G. (1975/1960) *Truth and Method* (translated by G. Barden and J. Cumming, from the 2nd [1965] edition.) New York, NY, USA: Crossroads.
- Hammer, D. (1994). Epistemological Beliefs in introductory Physics, *Cognition and Instruction* , 12(2), 151-183.
- Hand, B., Prain, V. & Wallace, C. (2002). Influences of writing tasks on Students' answers to recall and higher-level test questions. *Research in Science Education*, 32, 19-34.
- Heidegger, M., (1977). *The question concerning technology and other essays* (translated by W. Lovitt.) (pp. 277-282). New York, NY, USA: Harper and Row.
- Hewitt, P. (1995). Lessons from Lily on the Introductory Course. *Physics Today* Sept., 85-87.
- Holiday, W. G., Yore, L. D., & Alverman, D. E. (1994). The reading-science learning-writing connection: Breakthrough barriers and promises. *The Journal of Research in Science Teaching*, 31(9),877-893.
- Huffman, D. and Heller, P. (1995). What does the force concept inventory really measure? *The Physics Teacher* 33(3), 138-143.
- Jensen, V. (1987). Writing in College Physics. In Fulwiler, T. (1987), *The Journal Book*. (pp. 330-336) Portsmouth, NH: Heinemann.
- Kalman, C. S., Morris, S., Cottin, C. and Gordon, R. (1999). Promoting conceptual change using collaborative groups in quantitative gateway courses, *American Journal of Physics: Physics Educational Research Supplement* 67, S45-S51.
- Kalman, C. (2001). Teaching students to solve quantitative problems in science courses by writing their way into the solution. *The Successful Professor* sample issue, 3-4.
- Kalman, C. S. (2006) *Successful Science And Engineering Teaching In Colleges And Universities* San Francisco, CA, USA: Jossey-Bass/Wiley Inc.
- Kalman, C. S. Aulls, M. W., Rohar, S. & Godley, J.: 2008 (March/April) Students Perceptions of Reflective Writing as a Tool for Exploring an Introductory Textbook. *Journal of College Science Teaching*. 37, 74-81

- Kalman, C. S. (2008) *Successful Science and Engineering Teaching: Theoretical and Learning Perspectives*. Dordrecht, The Netherlands: Springer.
- Kuhn, Thomas S. (1962). *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.
- Thomas S. Kuhn (1982) *Commensurability, Comparability, Communicability*. *Proceedings of the Biennial Meeting of the Philosophy of Science Association*, 2, 669-688.
- Martin, N. (1992) *Language Across The Curriculum: Here It Began and What It Promises*. In A. Herrington & C. Moran (Eds.), *Writing, Teaching, and Learning in the Disciplines* (pp. 6-21). New York, NY, USA: Modern Language Association.
- Mayer, J. & Hillman, S. (1996). *Assessing students' thinking through writing*. *The Mathematics Teacher* 89, 428-432.
- McDermott, M. A. & Hand, B., (2010). *A Secondary Reanalysis of Student Perceptions of Non-traditional Writing Tasks Over a Ten Year Period*. *Journal Of Research In Science Teaching* 47, 518-539.
- Merriam, S. B. (1988) *Case Study Research in Education: A Qualitative Approach*. San Francisco: Jossey-Bass.
- Moschkovich, J. N. & Brenner, M. E. (2000) *Integrating A Naturalistic Paradigm Into Research On Mathematics and Science Cognition and Learning*. In A. E. Kelley and R. A. Lesh (eds.). *Handbook of Research Design in Mathematics and Science Education*. (Chapter 17, pp 457-486) Lawrence Erlbaum, Mahwah, NJ.
- Pugalee, D. K. (1997). *Connecting writing to the mathematics Curriculum*. *The Mathematics Teacher*. 90, 308-310.
- Rivard, L. P. (1994). *A review of writing to learn in science: Implications for practice and research*. *Journal of Research in Science Teaching*. 31, 969-983.
- Slotta, J.D. & Chi, M.T.H. (1999). *Overcoming robust misconceptions through ontological training*, Paper presented at the Annual meeting of the American Educational Research Association, Montreal, Canada.
- Stake, R. E. (1998). *Case studies*, in N. K. Denison and Y. S. Lincoln (eds.) *Handbook of Qualitative Research in Education*., New York: Prentice Hall.
- Suchting, W.A. (1995), *Much Ado about Nothing: Science and Hermeneutics*, *Science & Education* 4(2), 161-171.
- Wallace, C. S. Hand, P. & Prain, V. (2004). *Writing and Learning in the Science Classroom*. Dordrecht, Holland: Kluwer Academic Publishers.
- Wittgenstein, L. (1973) *Philosophical Investigations* 3rd edition. Upper Saddle River, New Jersey, USA: Prentice Hall;.