Changing the Way Students Learn in Physics Gateway Courses

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A Thesis

In the Department

of

Physics

Presented in Partial Fulfillment of the Requirements

For the Degree of

Doctor of Philosophy (Physics) at

Concordia University

Montreal, Quebec, Canada

April, 2012

CONCORDIA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

This is to certify that the thesis prepared

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Entitled: Changing the Way Students Learn in Physics Gateway Courses

and submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (Physics)

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ABSTRACT

Providing a constructive environment through implementation of certain activities to encourage students to take an active role in their learning is very important in physics gateway courses.

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Concordia University, 2012

Under the umbrella of physics educational research, scholars are looking at teaching physics using different methods: philosophy of science, epistemology, or hermeneutics. In each approach it is found that it is essential to create a constructive teaching and learning environment for students to learn actively. When students' ways of acquiring knowledge change from being conveyed by authority to constructing their own understanding, their role changes from being a passive acceptor to being a more active constructor.

Research shows that only helping students to change from their personal views of concepts to scientific conceptions is not enough and does not contribute much to students' science learning. To develop a scientific mindset in science courses also requires a change in attitude from a view that study in science is a matter of solving problems using an independent set of tools, classified according to problem type, to a view that a science subject consists of a web of interconnected concepts. Elby pointed out that students' epistemological beliefs in physics will affect how they approach physics courses. This means that we need a more holistic theory to focus not only on subject content, but also on students' scientific reasoning and epistemological beliefs.

In this dissertation, a set of activities is applied in Physics gateway courses to create a constructive environment. Through these activities we hope to help students to gradually become aware of a constructive procedure of learning. The effectiveness of these activities is examined in terms of helping students change their ways of learning and epistemological beliefs.

Acknowledgements

The completion of my PhD thesis was made possible by the great support from my husband, Guoqi, and that from my daughter, Tianyuan. Without my husband's devotion, understanding and spiritual support, I could not even have started my PhD study. Great thanks to my daughter for her having such a joyful soul and being such a confident girl, which has actually lighted up each of my day and made it easier for me to study while taking care of her.

I would like to express my deepest gratitude to my supervisor, Dr. Calvin S. Kalman and his wife Marilyn Cooperman. My supervisor has been very supportive and encouraging throughout my PhD study and the time of development of this thesis. He and his wife also gave me much care and help in both my study and my life.

I wish to extend my thanks to Dr. Bruce Shore for his comments on giving presentations and other academic support. I would like to give my special thanks to Dr. Mark Aulls for his precious and stimulating suggestions on developing questionnaires.

I am heartily thankful to my friends Teresa Cai and Xihui Wang for their always being with me and help me in my life!

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INTRODUCTION

In chapter 1 and 2, a comparison between the evolution of science philosophy and that of hermeneutics is made as part of an argument for the utility of hermeneutics in science education. We can see how constructivism entered science philosophy and hermeneutics at the same time and in the same way. The hermeneutic method is a general way of learning when people are faced with new concepts in, both human and natural science. When people approach new concepts using the hermeneutic method, they would construct their own understanding through their own reasoning. The question of reasoning is embedded within a broader conception of epistemology [Hand, Lawrence & Yore, 1999]. In chapter 3, different epistemology models show a common theme on the progression of students' personal epistemology and way of learning.

Evolution of science philosophy, evolution of hermeneutics and development of personal epistemology were compared in chapter 4. Here we find that they are all parallel. The discussion shows that providing a constructive environment to encourage students to take an active role in their learning is very important. Then a set of activities were introduced which could help students reach this goal.

A series of studies from chapter 5 to chapter 9 begins with reflective writing and then incorporates a larger set of activities. The effectiveness of each separate activity in terms of helping students to make conceptual change has already been reported (Kalman et al., 1999; Kalman et al, 2004; Kalman et al, 2008; Kalman & Rohar, 2010). In this thesis, effectiveness in terms of helping students to change their way of

learning and epistemological beliefs is studied, first on the reflective activity, and then in terms of the whole set of activities.

In chapter 5, three cases in a course, where students did both reflective writing and summary writing is discussed to explore students' ideas and compare and contrast these two activities. Chapter 6 and 7 are two case studies, one on reflective writing and the other on summary writing. Some common themes are found from the two studies. Chapter 8 is based on chapter 6 and 7 and concerns further comparison and contrasting between the two activities.

In chapter 9, the whole set of activities are utilized by an experimental group. Comparison was made between this group and the control group in which students only did summary writing. Pre- and post- interviews were done to try to find changes in students' epistemology and way of learning through the semester.

CHAPTER 1: EVOLUTION OF SCIENCE PHILOSOPHY

Under the umbrella of physics educational research, scholars are looking at teaching physics from different angles: science philosophy, epistemology, or hermeneutics. Research shows that it is essential to create a constructive teaching and learning environment (Hand, Lawrence, Yore, 1999) for students to learn actively. In this chapter, we are starting from the evolution of science philosophy which will give us some directions for teaching science.

1.1 Bacon

The philosophy of Francis Bacon dominated science from the seventeenth to the nineteenth century and Bacon's philosophy was the corner stone of the success of natural science in the 19th century. "During the eighteenth century, the name of Isaac Newton became coupled with that of Bacon in the genealogy of the chosen people of British science. Bacon… the lawgiver of the Novum Organum of the new inductive philosophy, but a man who failed to put that philosophy successfully into practice… Newton fulfilled the promise of the Baconian laws and took possession of the world of nature in its widest sense…" (Smith, 1994, p. 12)

In the seventeenth century, an attack on Aristotelian philosophy was brought by Galileo, Bacon and Descartes (Losee, 1993). Though Bacon accepted the Aristotelian inductive-deductive theory of scientific procedure, Bacon's theory is different from that of Aristotle in an emphasis on gradual, progressive inductions and a method of exclusion (Losee, 1993). Progress in Science according to Bacon is viewed as going from observations to general principles and then back to observations. The starting

point is observation and experiment; from this we go to general principles by induction, and then by deduction, scientists designed new experiments to confirm the inductive generalizations. “It is true that Bacon emphasized the inductive stage of scientific procedure. But he did assign to deductive arguments an important role in the confirmation of inductive generalizations.” (Losee, 1993, p. 66) Galileo and Newton also emphasized the experimental confirmation of deductive consequences. (Losee, 1987)

During the seventeenth and nineteenth centuries, inductivism and objectivity were the most important features of natural science. Any human element played a negative role in natural science as it would destroy the precision of natural science which made it successful. In the famous book *Novum Organum,* Bacon developed what is well-known as Baconian induction. The two important elements of Baconian method are “First, the idea of unbiased observation: the scientist should collect information without prior conjectures or presumptions, the interference and subjectivity of the scientist ought to be eliminated… the second is the idea of a continuing collection and inductive systematization of information”. (Sahlin, 1991, p. 431) Thus in Bacon’s theory of induction, scientific activities should be interpretation of nature rather than anticipation of mind. (Sahlin, 1991) The Baconian method was so dominant at that time that even Newton, despite his prestige, said that he did not use any hypotheses at all by saying “Hypotheses non Fingo” (Newton, 1726, p. 943). Newton “was concerned about accusations of making theoretical pronouncements that did not fit in with Bacon’s accepted views on the Scientific method.” (Kalman, 2008, p. 75).

1.2 Popper

Many philosophers including Popper (1963, 1972), Kuhn (1962, 1977), Lakatos (1970), Feyerabend (1981), and Laudan (1977), though they have different views of philosophy of science, all criticized Baconian inductivism.

Bacon criticizes Aristotle's theory in bringing about his rules of induction, but Popper in turn brought about a radical change in science philosophy by saying "The success of science is not based upon rules of induction, but depends upon luck, ingenuity, and the purely deductive rules of critical argument" (1963, p. 53) in his book 'Conjectures and Refutations'. In this book, Popper discussed the impossibility of purging our minds of all anticipations or conjectures or guesses: "Thus we are split into a human part, we ourselves, the part which is the source of our fallible opinions, of our errors, and of our ignorance; and a super-human part, such as the senses or the intellect, the part which is the source of real knowledge, and which has an almost divine authority over us. But this will not do." (p. 17) Popper's scientific method still claims science activities as a search of objective truth. But he asserts that this truth is obtained through the hypothetical-deductive method. Human's anticipation, conjecture, imagination and creativity are highly valued and do not play a negative role any more. Popper defined a scientific hypothesis as being "both logically possible and physically possible to falsify it" (1987, p. 59). Any scientific hypothesis must always be open to falsification and the "present technical inability to design suitable tests need not disqualify a hypothesis." (Popper, 1987, p. 59)

It was Popper who brought about the concept of falsification of hypothesis whereby

framing hypotheses stopped being regarded as bias and began to be an important step in scientific progress. Instead of being an obstacle on our way to truth, hypothesis is a starting point. “We may seek for truth, for objective truth, though more often than not we may miss it by a wide margin. And it implies that if we respect truth, we must search for it by persistently searching for our errors: by indefatigable rational criticism, and self-criticism.” (Popper, 1963, p. 16) As we can not purge our minds of anticipations or prejudices, there is not objective observation without any human perspective from which we can infer objective theories. Observation is already selective when the observer chooses a problem, defines a task, and to describe the observation, we need to choose a language with a set of terms developed by scientists, which in its turn presupposes their interests, and points of views. We should “give up the idea of ultimate sources of knowledge, and admit that all knowledge is human; that it is mixed with our errors, our prejudices, our dreams, and our hopes; that all we can do is to grope for truth even though it be beyond our reach”. (Popper, 1963, p. 29) So we cannot verify any knowledge to be truth. Instead of verification, we can only falsify. Any hypothesis is acceptable as long as the hypothesis withstands tests designed to discredit it. In Popper’s philosophy, observation, reasoning, intuition and imagination, all these things are to “help us in the critical examination of those bold conjectures which are the means by which we probe into the unknown”. (Popper, 1963, p. 28)

In the book “Objective knowledge: An Evolutionary Approach”, (1972) Popper broke with the tradition of common sense theory of knowledge which can be traced

back to Aristotle. He was not trying to exclude common sense in science, but actually he admired common sense which is “essentially self-critical” (1972, Preface). He viewed a commonsense theory of knowledge as a subjectivist blunder. Common sense is not the foundation of a secure system of human beliefs; instead it is the starting point, the only starting point of science, philosophy or rational thoughts. Common sense can be adequate or inadequate, true or false instincts or opinions of humans “from which we start can be challenged and criticized at any time”. (Popper, 1972, p. 33) The assumptions from our common sense will be either modified or transcended and replaced. Though we begin with “a vague starting-point, and we build on insecure foundations, we can make progress” (Popper, 1972, p. 34) through criticism. In the sense of better approximation, from our common sense, we are getting closer and closer to the truth by criticism and learning from our mistakes. In the book, Popper also criticized inductivism by a philosophical question of “What is the justification for the belief that the future will be (largely) like the past?” (p. 2) Based on past experiments, we expect and believe in certain regularities where science theories come from in inductivism and this is the problem of common sense that it is simply taken for granted that our beliefs in regularities is justified by those repeated observations. The inductivists emphasize positive instances and from which they draw non-demonstrative inferences (Hempel, 1966). But the reliability of the conclusion from limited positive instances can not be guaranteed. In the opposite way, Popper emphasizes the negative instances through falsification.

1.3 Kuhn

There are some common points between Kuhn's and Popper's philosophy of science. They both doubt neutral observation without prejudice and do not believe that there are objective rules for inducing objective theories from facts. Kuhn (1962) brought about the concept of 'paradigm' of science and opposed the concept of 'development-by-accumulation' held by Bacon and Popper. That means the changes of paradigm in science never carry us nearer and nearer to the truth. According to Kuhn, changes in Science are more like oscillation rather than better and better approximation. As for Popper, the progress of science is directed to the goal of truth though it is beyond our reach. But for Kuhn, the word "truth" only means 'a source for the scientist's conviction that incompatible rules for doing science cannot coexist' (p. 169) in the period of normal science. There is no objective truth that can be the goal of science. Human elements are much more valued by Kuhn than Popper. Kuhn includes sociological elements in his paradigm. Kuhn and Polanyi (1974) even credit scientific passions a logical function that contributes an indispensable element to science.

The following figure (Figue 1) (Kalman, 2008, p. 85) stands for the scientific revolution described by Kuhn as a paradigm is replaced by another. During normal science, scientists follow only one paradigm which is an accepted model or scheme including theory, experimental techniques and methods. The paradigm guides scientists to solve new problems, theoretical or experimental. When more and more insoluble theoretical problems or experimental anomalies come up, a crisis is

triggered and leads to a scientific revolution. During this time, the old paradigm and the new one can coexist, but eventually, the competitive new one will be dominant and replace the old one and scientists return to normal science again.

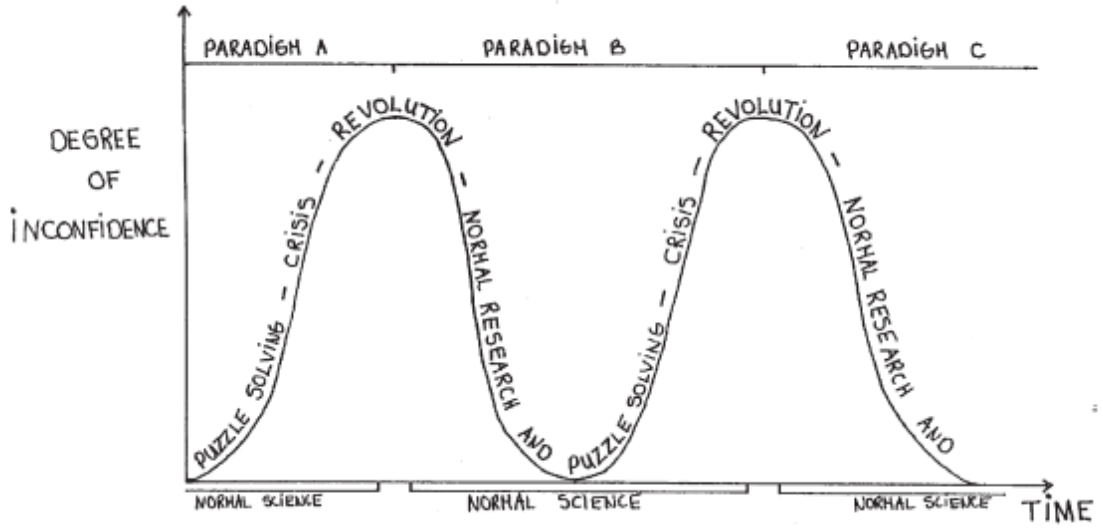


Figure 1: Kuhn's Paradigm

1.4 Lakatos

Both Popper and Kuhn, feel that sequential changes occur in science; a theory is replaced by another because of being falsified, or a paradigm replaced by another because of a crisis triggered by many anomalies in the old paradigm. Lakatos rejected the notion of sequential changes and absolute refutation. Instead of a theory, Lakatos proposes that a succession of slightly different theories and experimental techniques correspond to a research programme. Like Kuhn, besides theory and experimental techniques and methods, Lakatos includes scientific culture in his research programme. In this research programme, (Losee, 1987) there is a static component called the 'hard core' and a dynamic component called 'auxiliary hypotheses'. (Figure 2. Losee, 1987, p. 92) The hard core tells us what paths of research to avoid (negative

heuristic) and the auxiliary hypothesis tells us what paths to pursue (positive heuristic) (Lakatos, 1970). The hard core includes essential laws and assumptions that are not exposed to falsification (Losee, 1987), that is why it is negative heuristic. The auxiliary hypothesis is a protective belt which suggests what types of theory-change are appropriate in response to anomalies (Losee, 1987). That is why it is positive heuristic.

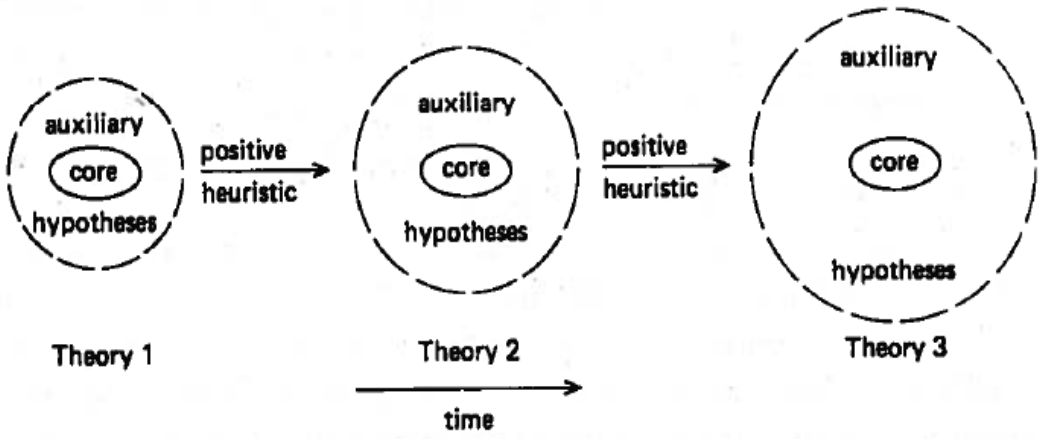


Figure 2: Lakatos' progressive research programme

If a scientist accepts a research programme, it means accepting the hard core as an inviolable part and all the anomalies and tests are to be directed to the protective belt where auxiliary hypothesis are open to change. If a new theory developed in response to experimental challenges has new predictions, then the research programme is progressive. If the addition of new hypothesis to the protective belt only accounts for existing data and cannot be used to predict new results, then the programme is labeled as a degenerative programme. Instead of the notion of sequential changes, in Lakatos' philosophy, competing research programs can coexist and it is the coexistence and competition of programmess that brings about major progress in science.

CHAPTER 2: EVOLUTION OF HERMENEUTICS

Hermeneutics has been used as a methodology for human science. Some people such as Eger (1993), Borda (2007) and Schulz (2010) argue for the use of hermeneutics in science and science education. In this chapter, we will start from the evolution of hermeneutics and exhibit its similarity to the evolution of philosophy of science. Then we will focus on ontological hermeneutics which provides us with more possibilities of using hermeneutics in science education.

2.1 Hermeneutics as a demarcation between natural sciences and human sciences

Hermeneutics comes to us from the 19th century as a by-product of repeated efforts to improve the interpretation of ancient texts. For a long time, hermeneutics has been restricted to the human sciences and used to differentiate human science from natural science (Gadamer, 1975). Before philosophical hermeneutics, positivism and scientism governed natural science in the 19th century because of the "prosperity' of positive science. Within this framework, knowledge of natural science is considered to be objective and neutral. The task of scientists is just to find the causal explanation of nature. It seems impossible to find any place for hermeneutics which is connected with 'understanding of meaning' and 'freedom of understanding'. Moreover, the work of Dilthey, an important philosopher in hermeneutics, deepened the gap between explanation and understanding, natural and human science, philosophy of science and hermeneutics. Positivism had great influence on philosophy resulting from the considerable success of the natural sciences. "The methodical spirit of science permeates everywhere" (Gadamer, 1975 p. xvii). For the rise of positivism put

pressure on all human activities, including arts and social science, implying that all such activities can only become strict, accurate and real science and make vast progress by following the method of natural science; all those things in the world work according to the law of cause and effect. To prevent such a methodical spirit of science from interfering in human science, Dilthey tried 'to justify epistemologically the particular methodological character of the human sciences and hence place them on the same level as the natural sciences' (Gadamer, 1975 p. 229).

2.2 Arguments for hermeneutics in science and science education

Ancient hermeneutics is about interpretation of signs and symbols that is in a very universal way. Georg Friedrich Meier discussed the universality of symbols in his book 'Versuch einer allgemeinen Auslegungskunst' (1757) which represents the last instance of rationalist hermeneutics. 'In Meier's title, Versuch einer allgemeinen Auslegungskunst, the word allgemeinen (universal) indicates that now all the signs of the world fall within its domain. The hermeneutics of human discourse, then, is merely part of the universal hermeneutics that includes signs of all kinds.' 'The interpretation of verbal objects constitutes only one sphere within the universal art of interpretation that is applicable to all signs, natural as well as artificial.' (Grondin 1994. p. 56) Hermeneutics is interpretation theory concerning signs. 'Signs, however, are not specifically verbal. Each thing in the world is a sign, a signum or a character, insofar as it is a means whereby the reality of something else can be known.' (Grondin 1994 p. 56) In terms of Meier's universality of signs, verbal objects, graphs and equations in science textbook are signs whereby students know science; all signs in

nature are means whereby scientists know nature. Interpretation of these signs is Meier's semiotic hermeneutics.

For a long time, hermeneutics was treated as the theory of method for human science, in the same way as philosophy of science is the theory of method for natural science. In Dilthey's opinion, we should explain nature, while understand the spirit. In this way, philosophers like Dilthey suggested that the method of natural science should not be used in human science to justify human science epistemologically; 'Hermeneutics, so it is believed, through its attention to meanings, bestows on the human sciences their humanness, and marks them off from disciplines where elimination of the specifically human perspective has become a principle.' (Eger, 1992, p. 340) In terms of positivism and scientism, hermeneutics could not find any place in natural science. But isn't there any humanistic character in natural science?

Husserl (1970) criticized positivism in his book "the crisis of European sciences and transcendental phenomenology". For some people, Husserl's book is a reaction against science as he emphasizes the humanistic characteristic in natural science by bringing about the crisis of science in general—that is, also of the positive sciences, including pure mathematics and the exact natural sciences and claiming transcendental phenomenology in natural science. Actually, this is a misunderstanding as Husserl never denies the exact science. 'Physics, whether represented by a Newton or a Planck or an Einstein, or whomever else in the future, was always and remains exact science.' (Husserl, 1970, p. 4) He wants to bring awareness of the 'crisis' of science as the loss of its meaning for life. Science is not mere factual science. 'Merely

fact-minded sciences make merely fact-minded people.' (Husserl, 1970, p. 6) People only care for the physical world, neglecting the spiritual world. Science is reduced to instruments by separating the 'prosperity' of science from their significance concerning human beings and the world. Husserl's 'crisis' is not only of science, but also of philosophy. 'It was not always the case that science understood its demand for rigorously grounded truth in the sense of that sort of objectivity which dominates our positive sciences in respect to method and which, having its effect far beyond the sciences themselves, is the basis for the support and widespread acceptance of a philosophical and ideological positivism.' (Husserl, 1970, p. 7) The human questions are intrinsically in the realm of science and related to all science—even to those of which man is not the subject matter, such as natural science. In his opinion, the positivistic concept of science in his time was a historically residual concept (Husserl, 1970) as it excludes human questions.

Actually, there have been several famous philosophers of science, who applied 'understanding' and 'hermeneutics' to science. Popper gives an in-depth discussion of 'understanding' and 'hermeneutics' in natural science in his book 'objective knowledge' with his theory of three worlds. In his theory, the physical world is 'world 1', the world of our conscious experiences is 'world 2' and the world of the logical contents of books, libraries, computer memories and suchlike is 'world 3'. 'I have given here some reasons for the autonomous existence of an objective third world because I hope to make a contribution to the theory of understanding ('hermeneutics'), which has been much discussed by students of the humanities.'(Popper, 1972. p. 162)

The objective third world, including theories in science books, is the final state of understanding, though 'the activities or processes covered by the umbrella term understanding are subjective or personal or psychological activities'. (Popper, 1972 p. 162) 'The activity of understanding consists, essentially, in *operating with* third-world objects'(Popper, 1972 p. 164). Though the notion of 'understanding' in natural science is different from that in human science, 'yet there is no sharp division here' (Popper, 1972). In a letter by Einstein to Born: 'You believe in the dice-playing God, and I in the perfect rule of law within a world of some objective reality which I try to catch in a wildly speculative way.' Popper is sure that 'Einstein's wildly speculative attempts to *catch* reality are attempts to *understand* it.' (Popper, 1972) 'Thus I oppose the attempt to proclaim the method of understanding as the characteristic of the humanities, the mark by which we may distinguish them from the natural science.' So, we can say that scientists operate with the knowledge of nature (world 3) through understanding, and science students operate with knowledge in textbooks also through understanding. Though the result of understanding (world 3) is objective and autonomous, the process of understanding to get it is subjective or personal. Part of the framework of my research is hermeneutics in Physics education. The definition of understanding by Popper, *operating with* the third-world object, implies that understanding is not a one-way procedure. The word, 'operating', indicates that students can not get results at once; they cannot just 'run to' the third-world object immediately. They have to operate with the object in back-and-forth processes of understanding which is similar to the back-and-forth movement of the hermeneutical

circle.

In the book ‘The Essential Tension’, Kuhn (1977) talks about ‘text’ and ‘hermeneutics’. To understand Aristotle’s enterprise, he does not need to be an Aristotelian physicist, actually he cannot exactly be one, but he has to learn to think like one to some extent. When talking about historians and physicists, Kuhn says, ‘Consciously or not, they are all practitioners of the hermeneutic method. In my case, however, the discovery of hermeneutics did more than make history seem consequential. Its most immediate and decisive effect was instead on my view of science.’ (Kuhn, 1977. p. xiii) Kuhn is the person, who coined the concept of paradigm in science. When he explains where this word comes from, he uses the similarity between language, which is the central concept of Gadamer’s ontological hermeneutics, and physics terms and standard ways. Scientists are taught definitions and standard ways to solve selected problems in which certain terms like ‘force’ or ‘acceleration’ figured. When they accepted a sufficient set of these standard examples, ‘they could model their own subsequent research on them without needing to agree about which set of characteristics of these examples made them standard, justified their acceptance.’ (Kuhn, 1977. p. xix) This procedure is very close to the one by which language students learn to conjugate verbs and to decline nouns and adjectives. The word ‘paradigm’ comes from the English word for the standard examples employed in language teaching. (Kuhn, 1977)

2.3 Evolution of hermeneutics

In this section, we will see how hermeneutics evolved in a similar manner to the evolution of science philosophy which provides us another way of arguing for hermeneutics as an approach to science and science education (Eger, 1993)

Chladenius

In the eighteenth century, 'hermeneutics' was the word used by many people who tried to understand and interpret historical books. Chladenius is one of them and his hermeneutics is in the form of historical methodology. 'The whole problem of interpretation appears to him basically as pedagogical and occasional.' (Gadamer, 1975, p. 161) For him, immediate and unimpeded understanding of historical books is the normal situation. 'Hermeneutics arises as a pedagogical aid in exceptional cases where our understanding of what the text says is blocked for some reason.' (Gadamer, 1976, p. xiii) Hermeneutics is used as a method to remove obscurities in texts. In terms of Chladenius' hermeneutics, the situation is either understanding or not understanding depending on whether there are obscurities.

Schleiermacher

Since Schleiermacher, the point is no longer of 'not understanding', but rather of 'the natural priority of misunderstanding'. (Gadamer, 1976, p. xiii) 'Misunderstanding arises naturally, and that understanding must be intended and sought at each point.' (Schleiermacher, 1959, p. 86) This natural misunderstanding comes from 'the changes in word meanings, world views, and so on that have taken place in the time separating the author from the interpreter.' (Gadamer, 1976, p. xiii) Because the interpreter's

situation is separated from the author's, what follows automatically is always misunderstanding because of prejudice. The interpreter's present situation and prejudices are virtually in existence and act as a negative role in understanding. 'As the source of prejudices and distortions that block valid understanding, it is precisely what the interpreter must transcend.' (Gadamer, 1976, p. xiv) Schleiermacher defines hermeneutics as 'the art of avoiding misunderstandings'. In his theory, to understand is to purge all prejudices, 'and it is achieved in direct proportion to the knower's ability to set aside his own horizons by means of an effective historical method. Schleiermacher tried to develop a critical methodologically controlled way of understanding instead of 'aggregate of observations' (Gadamer, 1975, p. 163). The efforts of trying to justify the methodology of human science and to make it as rigorous as natural science can be seen more in the work of Dilthey. For Schleiermacher and Dilthey, 'the task of understanding is to recover the original life-world' in which the author understood himself. This implies that the autonomous subject 'extricates himself from the immediate entanglements of history and the prejudices that come with that entanglement' (Gadamer, 1976, p. xiv) To achieve objective understanding, the interpreter has to have a neutral prejudice-free consciousness. Understanding here is a duplication of a past intention.

Heidegger

Heidegger saw hermeneutics in an ontological way and the interpreter's fore-having, fore-sight, and fore-conception stopped to be a negative role in hermeneutics by being worked out 'in terms of the things themselves'. (Heidegger,

1962, p. 153) Gadamer developed these ideas into a systemic theory in his book 'Truth and method' (1975). The interpreter is projecting a meaning for the text with particular expectations and the fore-project is open to be revised. 'Interpretation begins with fore-conceptions that are replaced by more suitable ones.' (Gadamer, 1975, p. 236) We have to admit that 'all understanding inevitably involves some prejudice' (Gadamer, 1975, p. 239) Besides the conformation of a fore-project in its being worked out, there is no other objectivity here. The word 'prejudice' is not equal to false judgment, it can have a positive or negative value. Because of human finitude of being in our present horizon, our prejudices are the productive ground of our understanding that can start. 'In fact, the historicity of our existence entails that prejudices, in the literal sense of the word, constitute the initial directedness of our whole ability to experience. Prejudices are biases of our openness to the world.' (Gadamer, 1975, p. 239)

2.4 Similarity between the evolution of science philosophy and that of hermeneutics

The following table (Table 1) shows the similarity between the evolution of science philosophy and the evolution of hermeneutics. In the table, we can see that though the evolution of science philosophy was ahead of the evolution of hermeneutics at first, philosophers of science started an attack on subjectivism in natural science and users of hermeneutics started an attack on subjectivism in the human sciences almost at the same time.

Table 1: Similarity between the evolution of science philosophy and that of hermeneutics

Science philosophy		Hermeneutics	
Aristotle (BC)	Common sense theory of knowledge	Aggregate of observations	Chladenius (18^{th} century)
Bacon (17^{th}—19^{th} century)	The existence of observer's prejudice.	Natural priority of misunderstanding	Schleiermache; Dilthey (19^{th} century)
	Scientists' prejudice is a negative role.	The knower's own present situation can have only a negative value.	
	Scientists should purge their minds of anticipations or prejudices; should not make any hypothesis.	Interpreter's present situation is what the interpreter must transcend.	
	Gradual, progressive inductions and a method of exclusion.	A critical, methodologically controlled interpretation is needed.	
	Scientists have a super-human part inside which is the source of real knowledge and has an almost divine authority over us.	There is an autonomous subject who successfully extricates himself from the immediate entanglements of history and the prejudices that come with that entanglement.	
Popper; Lakatos (20^{th} century)	Attack on subjectivism	Attack on subjectivism	Heidegger; Gadamer: (20^{th} century)
	Can we purge our minds of anticipations or prejudices? Is there objective observation?	Can the knower leave his immediate situation in the present merely by adopting an attitude?	

	Instead of being an obstacle on our way to truth, hypothesis is a starting point.	Our prejudices do not cut us off from the past, but initially open it up to us.	
	Hypothesis is open to falsification. Auxiliary hypothesis are open to change.	Fore-project is open to be revised.	
	We should admit that all knowledge is human; that it is mixed with our errors, our prejudices, our dreams, and our hopes.	The present situation is the given in which understanding is rooted, and which reflection can never entirely hold at a critical distance and objectify.	

During the seventeenth and nineteenth century, philosophers of science realized the preexistence of observer's prejudice which should be purged by scientists. In the nineteenth century, philosophers in hermeneutics thought that the interpreter's present situation is what the interpreter must transcend, although it had natural priority. Then in the twentieth century, philosophers in science and those using hermeneutics in the human sciences started to value people's prejudices.

From the above discussion, we can see that constructivism entered science philosophy and hermeneutics at the same time and in the same way. Considering the universality of symbols given by Meier (1757), the hermeneutic method not only can be applied in the human sciences, but also can be used in the natural sciences. In the following section, we can see that ontological hermeneutics removes the subject/object dichotomy between human and nature sciences, and this gives us a stronger argument that hermeneutics can be used as a general way of learning in both

human and natural sciences.

2.5 Ontological hermeneutics

Ontological hermeneutics brings further possibilities for us to apply hermeneutics to science and science education. Heidegger brought a radical change to hermeneutics—from epistemological to ontological, and his student, Gadamer, developed it into a systemic theory in his book 'Truth and Method'. In this book, we can find ideas that can be used to apply hermeneutics to science and science education. 'To this Heidegger gave a new and radical turn in the light of the question of being revived by him. He follows Husserl in that historical being is not to be distinguished from natural being.' (Gadamer, 1975) 'I cannot agree with those who maintain that the limits of the hermeneutical aspect are revealed in confrontation with extra-historical modes of being, such as the mathematical or aesthetic.' 'There are other respects in which the universality of the hermeneutical aspect cannot be arbitrarily restricted or curtailed.' (Gadamer, 1975) The truth designed by Gadamer is neither the truth of natural science given by Newton, or Descartes, or Kant, nor the methodical work within the human science. It is the truth of the whole experience of the world and human living, including nature and spirit, the truth of philosophical hermeneutics. How is understanding possible? 'Understanding is not just one of the various possible behaviours of the subject, but the mode of being if There-being itself.' (Gadamer, 1975) In his next book, 'Philosophical Hermeneutics', Gadamer (1976) discusses the universality of hermeneutics furthering more detail. 'The hermeneutical question, as I have characterized it, is not restricted to the areas from which I began in my own

investigations. My only concern there was to secure a theoretical basis that would enable us to deal with the basic factor of contemporary culture, namely, science and its industrial, technological utilization. Statistics provide us with a useful example of how the hermeneutical dimension encompasses the entire procedure of science.'

In an epistemological sense, natural science is an objective explanation of the object given by the subject. While as for human science, spirit is both subject and object. Understanding in human science is always labelled by 'subjective', sharply different from natural science. In an ontological sense, understanding is not activities of the subject, but the mode of being and hermeneutics is the universal way of being in the world. In terms of this, it's meaningless to discuss the subject/object dichotomy between human and nature science.

The ontological shift of hermeneutics proposed by Gadamer (1975) is guided by language, by which the text 'speaks'. But the text usually speaks in a language that is different from our own. People may think about translation when considering a new language. But does this mean to translate the text word-by-word? Translation is always related to understanding. 'Since it must be understood within a new linguistic world, it must be expressed within it in a new way' (Gadamer, 1975, p. 346) Even when the text is written in a person's native language, it does not speak to the person directly without the process of understanding. 'The meaning of a text is not to be compared with an immovably and obstinately fixed point of view.' (Gadamer, 1975, p. 350) In this sense, understanding is not 'reconstructing the way in which the text has come into being. Rather, one is understanding the text itself.' (Gadamer, 1975, p. 350)

2.6 Hermeneutics in science education

Eger (1992, 1993) argued for the use of hermeneutics in science and science education. He related science to hermeneutics through language which is a main concept in ontological hermeneutics. Through this language, the "book of nature" (Eger, 1992) speaks to us. This definition of science as language is in accordance with Meier's universality of symbols.

When university students take science courses, they are not dealing with the book of nature, but the book of science (Eger, 1993), a world delimited by language that scientists use to talk about nature (Gregory, 1988). Students can have great difficulty reading scientific texts because the language and epistemology of science are akin to a foreign culture (Kalman & Rohar, 2010). "All of science including discovery takes place in a social and cultural milieu"(Cobern, 1995). Whenever one is trying to understand something new, for example, when students are faced with subjects written in scientific language, s/he will achieve a deeper understanding if s/he approaches it in the manner of a hermeneutical circle as developed by Gadamer (1975). "the parts, that are determined by the whole, themselves also determine this whole." "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." Gadamer used the term *horizon* as 'the range of vision that includes everything that can be seen from a particular vantage point'. Students come into science classes with their own preconceptions and beliefs which make sense in explaining observations in

their life world and are reasonable to some extent. Thus horizon A of a student includes both their life experience and former theoretical knowledge. There is another horizon, horizon B, which is understood by the author of the textbook and described in scientific language. If the two horizons overlap to some extent, students may use the overlap as a starting point to get into a hermeneutical circle and try to understand the text. Students enter the process of understanding with their own horizon which is always open to change and in constant formation insofar as the projection of the textbook from the students' horizon. When students begin to learn Newton's law, they first try to find all those experiences related to 'force' or 'movement', part of horizon A which may overlap horizon B. From this starting point, they project the whole, Newton's law, and then go back to check if the parts add up to support the whole. If not, they may modify their preconceptions—starting point and therefore the projection of the whole, and then go back to check again. This is the back-and-forth movement of the hermeneutical circle. Every circle brings students closer to horizon B—the scientific mindset. Students' process of understanding consists of constructing a new horizon instead of reconstructing the pre-existed meaning. Students are truly making their own understanding of what the textbook says. Understanding is a process of fusion of the two horizons. 'This process of fusion is continually going on, for there old and new continually grow together to make something of living value, without either being explicitly distinguished from the other.' (Gadamer, 1975, p. 273). To help this fusion happen, educators are expected to create a constructive environment which encourages students to take an active part in their learning instead

of being a passive acceptor of the pre-existed meaning of textbooks. During this active back-and-forth movement, students are examining the consistency between parts and the whole. This procedure is helpful for them to improve their critical thinking skills. Halpern (1997) gave the definition of critical thinking as 'the use of those skills or strategies that increase the probability of a desirable outcome. It is used to describe thinking that is purposeful, reasoned, and goal directed'. It is also called directed thinking because it focuses on a desired outcome—horizon B. Halpern elaborates that the 'critical' part of critical thinking denotes an evaluation component, 'when we think critically, we are evaluating the outcomes of our thought processes'. When students 'go back to check if the parts add up to support the whole', they are actually 'evaluating the outcomes of their thought processes' and rethinking about what they thought through checking internal consistency.

CHAPTER 3: STUDENTS' PERSONAL EPISTEMOLOGY

From the last two chapters, we can see that constructivism entered science philosophy and hermeneutics at the same time and in the same way. The hermeneutic method is a general way of learning when people are faced with new concepts in, both human and natural science. When people approach new concepts using the hermeneutic method, they would construct their own understanding through own reasoning. The question of reasoning is embedded within a broader conception of epistemology [Hand, Lawrence & Yore, 1999].

Given the viewpoints of science as seen by different philosophers, we can see that the view of science is changed from a static collection of fixed information pieces to more relativistic paradigms that are always open to change. The evolution of science philosophy is parallel to the development of personal epistemology way of learning. When students come into science classes, their understanding of the textbook (projection of the textbook from horizon A) is mixed with errors and prejudices. Those who think that science knowledge is fixed and transmitted from authority would prefer to take a passive role in their learning; while those who think science knowledge is evolving and tentative are more likely to be active in their learning and their projection of textbook is open to be revised and replaced by another one. But how do they revise their understanding? That is through a hermeneutical circle. From the overlap of a students' horizon A and the horizon B of the textbook, the student can project the whole. From the student's subsequent understanding of the whole, the student can go back to the particular text to see if the whole and the parts [particular

texts] support each other. In this way, students move and change their horizon A to be more like the horizon B projected by the textbook. As students check for consistency between the parts and the whole, they need scientific thinking and reasoning skills to evaluate the outcomes of their thoughts, to rethink their thoughts.

These considerations are carrying us to the theme of epistemology—the nature of knowledge and the nature of knowing in science education.

3.1 One-dimensional models of epistemology

The research on epistemology can be traced back to Piaget (1977) who used the term 'genetic epistemology' (Hofer & Pintrich, 1997). He described a series of stages to portray children's intellectual development.

Perry continued Piaget's work and developed a scheme of intellectual and ethical development of students in college, but used the word 'position' instead of 'stage' (Hofer & Pintrich, 1997). Perry's model describes students' epistemological responses to the college environment. The nine positions are descriptive of the nature of knowledge and truth (Hofer & Pintrich, 1997) that are categorized as follows: dualism; multiplicity; contextual relativism; commitment within relativism. (Perry, 1970) Perry suggests that how college students response to the college environment is an evolving developmental process which is brought about through cognitive disequilibrium. 'Individuals interact with the environment and respond to new experiences by either assimilating to existing cognitive frameworks or accommodating the framework itself.' (Hofer & Pintrich, 1997, p. 91) Position 1 and 2 are characterized as dualism when students view knowledge as absolute, right or

wrong and being conveyed by the authority. Multiplicity refers to position 3 and 4 when students start to recognize the diversity and uncertainty of the world and realize that each person can has different opinions. When students reach relativism (position 5 and 6), they take on an active role to make meaning and they need to choose and affirm their own commitments. Finally, the student progresses to commitment within relativism (position 7, 8 and 9) that focuses on responsibility. From position 1 to 5, the main focus is on students' intellectual development while after position 5 the focus shifts to ethical considerations. (Moore, 2002)

Perry's male sample brought it under attack in the late 1970s (Hofer & Pintrich, 1997). Belenky et al. (1986) decided to study women's ways of knowing. Though this model is different from Perry's model by focusing more on the source of knowledge and truth, it can be lined up to Perry's positions. In this model, we have five positions starting from *silence* where women listen silently to external authority, then go to *received knowledge* which is similar to Perry's dualism, where all answers are either true or false. The third position is *subjective knowledge* which is interchangeable with Perry's multiplicity, but truth is a more intuitive reaction for women (Hofer & Pintrich, 1997). When women reach *procedural knowledge*, they demonstrate reflection and analysis of procedure of knowledge. At the final position of *constructed knowledge*, women construct their knowledge and they are an intimate part of the known (Belenky et al., 1986, p. 137).

Since 1986, Baxter Magolda started a longitudinal study (1992) on college students. The sample included both male and female. Her epistemological reflection model

contains four different ‘ways of learning’ (Hofer & Pintrinch, 1997). The research did not directly probe students’ perspective of knowledge itself, but focused more on the nature of learning in the college classroom and each way of learning corresponds to particular epistemic assumptions. With four ‘ways of learning’, we have four epistemic assumptions: absolute; transitional; independent and contextual. Absolute knowers believe absolute knowledge that comes from authority; transitional knowers start to doubt the certainty of knowledge and authority; independent knowers begin to value their own opinions and contextual knowers begin to construct their own perspective.

King and Kitchener’s reflective judgment model (1994, 2002) concerns students’ epistemic assumptions behind reasoning. The model has seven reflective judgment stages that are categorized at three levels: pre-reflective; quasi-reflective and reflective. Pre-reflective is parallel to Perry’s dualism and quasi-reflective is parallel to Perry’s multiplicity and contextual relativism. The highest level of reflection is similar to Perry’s commitment within relativism. Throughout the seven stages, the focus is on ‘both the individual’s conception of the nature of knowledge and the nature or process of justification for knowledge’ (Hofer and Pintrich, 1997, p. 98).

Kuhn’s research model (Kuhn, 1991; Kuhn et al, 2000) of argumentative reasoning focuses on individual’s responses to everyday life. Through interviews on how college students’ reason and make judgment in everyday life, Kuhn studied the evidence for their epistemological thoughts. She reported three categories of

Table 2: Alignment across different epistemology models

Intellectual and ethical development (Perry)	Women's ways of knowing (Belenky et al.)	Epistemological reflection (Baxter Magolda)	Reflective judgement (King and Kitchener)	Argumentative reasoning (Kuhn)
Positions	Epistemological perspectives	Ways of knowing	Reflective judgement stages	Epistemological views
Dualism	Silence	Absolute knowing	Pre-reflective thinking	Absolutists
	Received knowledge			
Multiplicity	Subjective knowledge	Transitional knowing		Multiplists
			Quasi-reflective thinking	
Relativism	Procedural knowledge	Independent knowing		Evaluatists
Commitment within relativism	Constructed knowledge	Contextual knowing	Refletive thinking	

epistemological views: absolutist, multiplist and evaluativist that are aligned with Perry's four categories.

The research models above tapped into college students' epistemic assumptions from different angles: nature of knowledge, source of knowledge, way of learning, and reasoning. Though they have different focuses, all the models can be aligned as shown in table 2 (Hofer & Pintrich, 1997, p. 92).

Though all of these models have different foci, we can see the similarity across the models: students progress through stages where they experience more and more uncertainty, and simultaneously, their way of acquiring knowledge changes from being passive to being more active and constructive.

3.2 Multiple-dimensional models

As different dimensions in those one-dimension models are not necessarily developing at the same rate (Schommer, 1990), it is valuable to develop multiple dimension models. Concerning the number of dimensions, no agreement has been reached. We have three-dimension models (Qian & Alvermann, 1995); four dimension models (Schommer, 1990; Hofer & Pintrich, 1997); and even indefinite numbers (Hammer & Elby, 2002).

Schommer's (1990) model includes 4 dimensions. Two of them are about students' way of learning: *fixed ability* and *quick learning*. The other two, *simple knowledge* and *certain knowledge* are about nature of knowledge.

Based on a review of all those one-dimension models and Schommer's four-dimension model, Hofer and Pintrich (1997) proposed two areas of

epistemological theories: nature of knowledge and nature of knowing, each of them has two dimensions. For nature of knowledge, these dimensions are *certainty of knowledge* and *simplicity of knowledge*. For nature of knowing, these are *source of knowledge* and *justification for knowing*. Each dimension is a continuum: *Certainty of knowledge*: can take on values between being fixed to being tentative and evolving; *simplicity of knowledge*: between being discrete and concrete to being relative and contextual; *source of* knowledge: from being transmitted by external authority to being constructed during interaction with others by the knower; *justification for knowing*: between accepting knowledge claims without evaluation to justifying claims with self-reasoning.

To compare all the dimensions in those one-dimension models above with Hofer and Pintrich's four-dimension model, there is still something excluded in this multiple dimension model. For this reason, besides the four core dimensions, Hofer and Pintrich also proposed "peripheral dimensions": beliefs about learning, instruction and intelligence.

3.3 Epistemology in Physics

Much of the work on personal epistemology presumes that epistemological beliefs are domain general (Hofer, 2002). But some researches (Schommer & Walker, 1995; Hofer, 2000) show that beliefs are likely to vary depending on different subject domains. There is some research in this vein being done in mathematics (Schoenfeld, 1992) and physics (Redish, et al, 1998; Adams, et al, 2006; Redish & Hammer, 2009). The widely used surveys on students' epistemologies in physics are *Maryland Physics*

Expectations survey (MPEX) (Redish, et al, 1998), *Epistemological Beliefs Assessment for Physical Sciences* (EBAPS) (www2.physics.umd.edu/~elby/EBAPS/home.htm) and *Colorado Learning Attitudes about Science Survey* (C-LASS) (Adams, et al, 2006). MPEX is a 34-item Likert-scale survey questionnaire that ranges from agree to disagree. It probes students' attitudes and beliefs in physics. C-LASS includes 42 statements and is also based on a Likert-scale. This survey focuses on students' beliefs about physics and their way of learning physics. The EBAPS survey has 5 subscales and consists of two parts: one part including 17 statements is like MPEX and C-LASS items, but scored on a scale of 0 to 4; the second part including 13 scenario items that are not scored linearly.

In chapter 6 and 7, a survey questionnaire on students' expectation about physics and their way of learning physics is developed. It was used in a case study through two semesters in two institutions. The later version B including 12 items was evolved from version A which includes 13 items. Both of them use Likert-scales.

All these survey questionnaires on epistemology in physics mentioned above focus on both some core dimensions and peripheral dimensions according to Hofer and Pintrich's model of knowledge and knowing. Hammer (1994) described a three dimensional model: beliefs about the structure of physics knowledge; beliefs about the content of physics knowledge and beliefs about leaning physics. The survey questionnaire of MPEX developed by Redish, et al. (1998) tries to probe students' understanding of what science is about, how it is done, and students' expectations about physics. EBAPS (Elby, et al. 2001) includes five subscales: structure of knowledge;

evolving knowledge; nature of learning; source of ability to learn and real-life applicability. The two survey questionnaires are widely used in the physics educational research community (Elby, 2001; Redish & Hammer 2009). Elby (2001) defined students epistemological beliefs as students' views about the nature of knowledge and learning. Redish and Hammer (2009) defined epistemology as how students understand knowledge and learning in physics. The C-LASS survey was developed by Adams, et al. (2006) based on the above two widely used surveys (Perkins, 2004) to probe students' beliefs about physics and learning physics.

From all the discussions on surveys in physics educational research above, we can see that they all include learning which is considered to be a peripheral dimension by Hofer and Pintrich. Though students' beliefs on the four core dimensions about knowledge and knowing are tangled with students' way of learning, the two may develop differently. In the following chapters, when I talk about epistemology, I am referring to the four core dimensions as set out by Hofer and Pintrich. In chapter 6, 7 and 8, students' epistemological beliefs and way of learning are analyzed and compared. The relationship between the hermeneutical circle which is a general way of learning and students' score on survey questionnaire about students' way of learning in Physics is also explored.

Hammer and Elby (2002) argued that students' epistemologies revealed by survey questionnaires might not be reliable as students' responses to questions did not necessarily represent their epistemologies in the contexts of learning. Instead of using the standard questionnaire developed by Hofer and Pintrich, I try to find out

information indicating students' epistemology from interviews trying to put students in the environment of learning.

CHAPTER 4: A SET OF ACTIVITIES TO CREATE CONSTRUCTIVE ENVIRONMENT FOR STUDENTS

From the last chapter on different epistemological models, we can see that though they have different foci: nature of knowledge, nature of knowing, students' way of reasoning or way of learning, students' reflection models etc, there is a common theme among these models. Students' perspective of knowledge changes from being fixed, certain or absolute to relativistic and tentative. Students' ways of acquiring knowledge changes from being conveyed by authority to constructing their own understanding. And starting from trust in authority, they gradually have reservations about authority and value their own opinions. From this progressive change, we can see that students' role is changing from passive to more active. If knowledge is fixed and conveyed from authority, the goal of education is to transmit information from one end (teacher) to the other (students); students just need to accept these facts passively. If knowledge is relativistic, and tentative, science theories are satisfactory within certain limits, and students' opinions are also valued, we should not neglect learner's active and constructive role.

4.1 Relationship between evolution of science philosophy and hermeneutics and the progressive procedure of students' epistemology

If we put the previous three chapters together, we can see some relationships between a student's progress on epistemological beliefs, the evolution of science philosophy and the evolution of hermeneutics (see Table 3)

Table 3: Relationship among students' epistemological beliefs and the evolution of science philosophy and hermenuetics

Epistemological beliefs			Philosophy of science	Hermeneutics
knowledge	Source of knowledge	Way of learning		
Absolute, right or wrong	Being conveyed by authority	Accept facts silently	Accumulation of facts from observation	Aggregate of observations
Uncertain and tentative	Different people may have different opinions.	Start to doubt authority	There is no objective observation	Natural priority of knower's misuderstanding
Evolving and needs evaluation and limits	Students' own opinions are also valued	Take responsibility for their own active role; to construct their own understanding	Hypothesis are always open to change and revision	Fore-project is open to be revised. Interpreters construct their understanding starting from prejudices.

From Table 2 and Table 3, we can see that constructivism entered science philosophy and hermeneutics almost at the same time. In the realm of epistemology, we find that at a certain point, students start to take on an active role as a learner and construct their understanding.

4.2 Constructivism

Constructivism has had significant influence on science teaching and learning (Matthews, 1998; Matthews, 2000). In this thesis, I will only consider cognitive constructivism derived from Piaget (1953) and social constructivism derived from Vygotsky (1962).

Cognitive constructivism

The idea of cognitive constructivism is that 'knowledge is actively constructed by the learner, not passively received from the environment'. (Von Glasersfeld, 1990) Piaget focuses on an individual's personal process-how individuals construct their own knowledge. Piaget (1953) proposes that students cannot passively accept information and then understand and make use of it. Instead, students need to construct their own understanding. Students' individual process of constructing their own schemas is assimilation and accommodation. When the new information that students encounter can be brought into their schemas, students just assimilate it. Accommodation occurs when new information is in conflict with students' preexisting ideas and they have to change their schemas to resolve the conflicts (Powell, 2006) so that the new information can be accommodated in their own knowledge system.

Social constructivism

Vygotsky's social constructivism focuses on students' interaction with the environment (teacher and other students) instead of Piaget's notion of a personal process in cognitive constructivism (Powell & kalian, 2009), students construct their knowledge through interaction with others. Teachers should create a teaching and learning environment so that students can be scaffolded through this interaction. In collaboration with more capable peers, students can be scaffolded to a higher developmental level compared to the level determined by independent problem solving (Vygotsky, 1978). Whether it is through personal process or interaction with others, the common point between cognitive constructivism and social constructivism is that knowledge is constructed, not transmitted.

People may ask the question 'what is it that is constructed?' 'A modest proposal is that what is constructed is mental representations' (Irzik, 2000). In this way, the concept of constructing of knowledge can be accepted even in the most conservative way as even Popper (1963, p. 95) said, 'we are not passive receptors of sense data, but their active digesters'.

4.3 Problems in physics education

The traditional way of teaching is teacher-centered and students take on the passive role of acceptor. It implies an assumption of absolute, fixed knowledge and students are required to passively accept information conveyed to them by teachers. In terms of hermeneutics, it reflects Schleiermacher's opinion of understanding to be a neutral duplication.

Scholars are looking at science educational research from different angles: nature of

science, science philosophy, epistemology, and some are working on hermeneutics. From these different angles, we can see that learners are individual constructors of their understanding. In terms of hermeneutics, this is in accordance with Gadamer's idea that understanding is not reconstructing pre-existed things neutrally, but understanding is a mediation between pre-understanding and text.

Hewitt (1995) pointed out "The professors classify problems in terms of physics concepts, while the students classify them by situations." Students entering gateway courses have their own viewpoints that differ significantly from theories understood by experts or professors. As Posner et al. (1982) point out these students will cling to these viewpoints because their beliefs make sense in their physical life world. They have constructed their private understanding that they will not easily relinquish. In science education, much effort has been expended within the framework of conceptual change theory (Kalman, C. S., Morris, S., Cottin, C. and Gordon, R. 1999, Kalman, C. S. 2008), but such efforts did not yield as great an increase in students' understanding as had been hoped. Only helping students to change from their personal conception to scientific conception is not enough and doesn't contribute much to students' science learning. Haaften (2007) suggested paradigm change rather than conceptual change. Certainly, we need a more holistic theory to focus not only on subject content, but also on students' scientific reasoning, epistemology and educational psychology.

It has been shown that some students view physics and science subjects as weakly connected pieces of information to be separately learned in contrast to the web

of interconnections perceived by their instructors (Hammer 1989, 1994). Based on this, Kalman pointed out that developing a scientific mindset may not simply be a conceptual change from personal scientific concepts to scientifically accepted concepts, it may also require a change in attitude from a view that study in science is a matter of solving problems using an independent set of tools, classified according to problem type, to a view that a science subject consists of a web of interconnected concepts (Kalman 2009).

Elby (2001) pointed out that students' epistemological beliefs—their views about physics knowledge and how to learn physics will affect how they approach physics courses. Again, this means a more holistic model is required than conceptual change theory. "Students who have difficulties often view physics knowledge as a collection of facts, formulas, and problem solving methods, mostly disconnected from everyday thinking, and they view learning as primarily a matter of memorization. By contrast, successful learners tend to see physics as a coherent system of ideas…and learning as a matter of reconstructing and refining one's current understanding." (Hammer, D & Elby, A, 2003) Vosniadou (1994) argues that concepts are entrenched and constrained within a larger theoretical structure. She postulates that students' viewpoints about nature are contained in framework theories in addition to various specific theories. Vosniadou suggests that students' difficulties in making a conceptual change are not only because framework theories are coherent systems of explanations that are based on everyday experiences and grounded in years of confirmation, but additionally, because these are ontologically and epistemologically based. Thus a shift in any of

students' beliefs will create a shift in the entire system of the framework theory and all the other knowledge built upon it.

4.4 A set of activities to create constructive environment for students

We implement a set of activities in physics class and through these activities we hope to help students gradually get aware of the constructive procedure of learning and approach their textbook in the way of a hermeneutical circle so that teaching and learning can be more effective.

Reflective Writing activity

Writing-to-learn strategies have become increasingly valued in science teaching (Mullin, 1989; Rice, 1998; McDermott, 2010). Research has shown these strategies to be helpful for students in confronting and becoming aware of misconceptions and consolidating their conceptual knowledge (Sutton, 1992; Hein, 1999; Hand, Hohenshell & Prain, 2004). Hand (2004) also found that students' performance on conceptual questions was improved by engaging in a series of writing tasks. However, success depends upon the nature of the writing task. If the writing tasks mainly require students to hit the replay button, then it is not surprising that they do not perceive writing to be a way of developing knowledge (Prain & Hand, 1999). To get students to actively construct their new knowledge, the emphasis of writing tasks should be based more on reflection about their knowledge (Hand, Prain & Wallace 2002) and on epistemology and scientific reasoning (Hand, Lawrence, & Yore, 1999; Hand, Prain & Wallace 2002). Reflective writing (Kalman 2007) comes from writing-to-learn, but it emphasizes the active learning on the student's part.

In order to scaffold students to become active learners, we ask students to do reflective writing (Kalman, Aulls, Rohar & Godley, 2008) before going to classes. This writing task emphasizes reflective thinking about what they have read. In performing reflective writing, students construct their own understanding of the material. It is not simply a recall of points in the science textbooks that students usually do in summary writing. Keys et al. (1999) noted "encouraging students to write is to encourage them to negotiate meaning and construct knowledge."

The following are the instructions for reflective writing:

> Many of you may have experience that during discussion with others, you can clarify your ideas. Speaking to others is always helpful to obtain a better understanding. The idea of doing reflective writing is to construct a self-dialogue about what you have read. The main difference between summary and reflective writing is that in a summary you write down what you already have in your mind during your reading, while in doing reflective writing you question what you read and relate it to other concerns. DON'T just pick up important sentences or ideas from the textbook and give me a list!
>
> To do it, first finish reading the material, at the same time, you may underline, highlight, or even do summarization. Then close your book, and rethink about what your have in your brain, at the same time, write down your rethinking rapidly. Don't pay attention to grammar, it's not formal writing, but jotting. Write down your own understanding of concepts, relationship among those concepts, or even relationship of the material to former chapters and

your former knowledge from other disciplines and life experience.

Don't worry if what you are writing is right or not. Marking is not based on that.

Students' reflective writing was not marked for content. Students do the reflective writing for themselves. If marked, students would write for the instructor, worrying about paragraphing and sentence structure. It is checked to see if the student is on task - that is writing about the section and freewriting. As long as this is the case and the student produces a reasonable amount of material, the student receives 100%. If not, marks are taken off.

The philosophy behind reflective writing is cognitive constructivism. Students construct their own understanding through the personal process of self-dialogue. People always have inertia to stick to what they thought and it is the dialogue that pushes them to move back-and-forth hermeneutically to check internal consistency and practice critical thinking. In this activity, students are asked to get into dialogue with themselves. They are encouraged to rethink about their thinking and show their reasoning instead of summarizing separated pieces of information from the textbook. To do reflective writing, students should actively search the meaning of the material in the textbook and construct their own understanding of it through interaction between their pre-understanding and the textbook. In terms of hermeneutics, the interaction is in the way of a hermeneutical circle.

Research on this activity (Kalman et al, 2008) shows that this activity helps students prepare for classes.

Collaborative Group activity

Collaborative group (CG) is another important activity designed by Kalman (2007) to help students to develop a scientific mindset. Students are asked to work within a group which usually consists of three or four students on certain topics. Each student in the group is assigned to a particular role: reporter, scribe, timekeeper or contrarian. Details in this activity can be found in Kalman (2007). In an experiment, Kalman picked four typical personal scientific concepts in Mechanics widely held by students entering an introductory mechanics course. Correspondingly, there are four group activities in the Mechanics course. Students stay in the same group throughout the course but switch roles. Before the first activity, there is a warm-up activity for students to get to know each other and learn how to get an agreement in performing a group task. Students have 8 minutes to discuss on a given topic before presentation. We get two groups holding different opinions to present their result to the whole class. After presentation, discussion is open to the whole class, then the professor takes over and explains the concepts on the basis of experimental knowledge. After the group activity in class, each student is asked to write a "critique" which is a writing product based on the collaborative group activity. The critique activity was introduced to promote critical examination of the alternatives produced in the collaborative group exercise. It is basically an argumentative essay in which students have to put forward as many possible arguments in favour of all the conceptual viewpoints raised in class and then point out which viewpoint is correct from an experimental point of view. The philosophy behind this activity is social constructivism. Students construct their

understanding through interaction with environment (other group members). In class, students are presented different opinions and they are asked to argue for all possibilities in the critique instead of just stating the 'right' one. In this way, students develop scientific thinking and reasoning to evaluate different possibilities and realize that physics knowledge is evaluative.

Most of us have the experience that we may understand things better during a discussion with other people, though it may be that 'the partner supplied nothing but verbal affirmative sounds' (Kalman, 2007). This activity provides students a possibility of studying in a hermeneutical circle through dialogue with others.

This activity has been compared with Peer Instruction (Kalman et al, 2010). The result shows that "over all, the Collaborative Group method seems to be more effective that the Modified Peer Instruction method" (p. 330)

Write-Pair-Share

This activity can be seen as a combination of free-writing and a small group activity. Students are presented with a particular topic and asked to free-write on it for 3 minutes. Then they discuss with their neighbour and then go to a whole class discussion. Teachers can ask students to vote before and after discussion with their neighbour.

These three activities are different processes of dialogue that scaffold students to engage in a hermeneutical circle. We are trying to provide students with an environment in which students can change from being passive acceptors to viewing learning as an exploratory, constructive and active adventure.

CHAPTER 5: A CASE STUDY ON STUDENTS' PERSPECITVE OF HERMENEUTICS AND DIFFERENCE BETWEEN REFLECITVE WRITING AND SUMMARY WRITING

5.1 Introduction

This chapter is about a case study (Creswell, 2007) on reflective writing and summary writing done in fall 2009 at Concordia University. We tried to find out students' perspective of pre-understanding and difference between reflective writing and summary writing. When I contacted the professor for his permission to do research in his class, he had already posted the course outline including the distribution of final grades. He asked students to do summary writing which contributed fifteen percent to the final grade. In order to incorporate the reflective writing activity into his class, students were asked to do reflective writing as a bonus. So in this study, students were doing both summary writing and reflective writing. Instructions for reflective writing are found in chapter 4.

The following are the instructions for summary writing as developed by the professor.

> The **"summary"** of each chapter **must** contain simply-drawn **illustrative graphs and pictures** that are necessary for the understanding the concepts lying behind them (**do not draw photographic-quality pictures**; they are too difficult to draw. However, you need to understand them and to be able to relate them to their corresponding concepts). The summary must also contain all **derivations of formulae, laws, and principles**, as well as a

summarization of the concepts and laws in your own words. The purpose of doing the summary before coming to the lecture is to allow students to benefit the most from the class time during which we discuss the important and difficult parts of the chapter at hand and try to solve as many problems as possible; also to try keeping you up to date with the material.

5.2 Methodology

This is a multiple case study on students' perspective of pre-understanding and the difference between summary writing and reflective writing in a calculus-based Mechanics course. The class size is of 73 students with the majority studying engineering and the rest being science students. Summary writing was a course requirement, but reflective writing was totally voluntary and students got a maximum bonus of 10 for participating in reflective writing depending on how many assignments they did and how they accomplished it.

In this study, we collected and analyzed two kinds of qualitative data: students' reflective writing products and interview transcripts (see Appendix A for interview questions). As the professor asked students to do summary writing on chapters, the reflective writing is also done chapter by chapter. In all 19 students who participated in reflective writing, four of them did all the 7 assignments on 7 chapters. We didn't collect summary writing products.

The interview questions are on three topics: general way of learning this course, perspective of pre-understanding and ideas about the difference between summary writing and reflective writing. Students' perspective of pre-understanding and how

they use it reflects students' awareness of hermeneutics. In the interview, instead of using the term 'hermeneutics' itself which is difficult for an interviewee to understand, we used the plain word of 'pre-understanding' and asked them how they used it. In a hermeneutical circle, the overlap between students' pre-understanding (horizon) and the textbook is the starting point for them to construct their understanding of assigned material in the textbook. If there is no conflict between their pre-understanding and the textbook, they just need to assimilate the new knowledge as it can be fit into their own system. What if the two conflict? Ideally, students should go back-and-forth between the two using some form of scientific thinking and reasoning and in the process accommodate the new knowledge with a revision of their pre-understanding resulting in a new horizon which has a greater overlap with the horizon projected by the textbook. Three students participated in the interviews, which were done towards the end of the semester. So this study consists of three cases.

5.3 Data analysis

Case 1: A

Student's background and way of learning:

This student came from outside Canada and she had been taught the same material as was taught in this physics course before in her country. When she was asked about her general way of learning this course, she first talked about writing assignments and studying material before classes. She read the assigned material, thought about it and did writing assignments. After classes, she tried to do problems. In the process of doing problems, she tried to relate them to daily life, to see what was happening in

reality to get a better understanding of concepts.

Perspective on pre-understanding

As she had studied all the same material as this course previously, she thought that she had more pre-understanding and it was definitely helpful. She thought that she had already experienced all the difficulties that might occur in this course and she said she knew 'what is going on'. Those same difficulties would not happen again this time and she had a greater priority to get something more out of physics compared to other students.

She thought that pre-understanding is also helpful *even if it was not true*. Generally, we have something in our mind about everything, when we study about something in classes we go through it again and understand better what the reality is. She thought that her pre-understanding was not really incorrect, but it was not complete. She gave an example of this: everybody knows that we are on the earth, we do not fall down, but only a few people really know how that happens and what gravity is. The belief is not incorrect for those who do not know why we are standing on the earth and do not fall down. They are correct, but just incomplete. If they go through it and study a physics course, they will understand more. In her opinion, she saw the world correctly, but did not know the reason behind observed phenomena, so her per-understanding was incomplete. She thought that physics law was "something from life" and was normal belief. So when she had some belief before, she could go through it and understand what was really going on by taking physics courses. Pre-understanding was really important for her and she could not imagine going into class and having

nothing in her mind as physics is “from life”. Her pre-understanding was a projection of the reality from her horizon and by taking physics course she continued to revise her pre-understanding using new information derived from the course to enhance her understanding. For this student, studying a physics course is not to replace her old ideas of new content in the textbook as her pre-understanding is just incomplete, but the studying process starts from her pre-understanding. To try to understand new information in the textbook, she accommodates new ideas. She said that she tried to get a better understanding of new ideas by using her previous concepts or beliefs. If she just memorized the textbook and took whatever it is, it was not helpful for her.

Perspective on summary writing and reflective writing

She thought that the idea of reading chapters before going to class is truly helpful even if students do not understand everything. Reflective writing helped her to think about both sides: the textbook and her previous concepts and beliefs. In performing reflective writing, she combined them (the textbook and her own beliefs) together. She really liked doing that.

For this student, summary writing is just to summarize whatever she understood from the textbook. During summary writing, she just put what was in the textbook and what she understood from the textbook. But reflective writing included what she understood from the textbook and her own beliefs and the corresponding combination. So reflective writing included her own ideas. She first did summary writing to understand what was going on in the textbook, and then combined it with her own ideas in performing reflective writing.

Writing products:

The following is an example of her reflective writing:

> When we are in the car and the car goes straight line with high speed, we also go straight line, but when we suddenly decide to take ramp the exit with that high speed, we all felt if that we move to the right, but why? We know because of the inertial when car goes straight we prefer to continue to go straight but when the car takes ramp we prefer to go straight and car goes left so we have collision to the door of the car. But there is no force to the right to push us. Also there is a force to the left which is friction of the seat but because it's not great it can't keep us at the rest. That force which we think it might be push us is fictitious force so it's real. But it has effect on us.

In this piece of writing product, she was trying to relate concepts in the textbook to her pre-understanding, her life experience in this case, by discussing the situation of "When we are in the car and the car…" She was raising questions and elaborated her discussion on it, "…we all felt if that we move to the right, but why? We know because of the inertial when car goes straight we prefer to continue to go straight..." The projection from her pre-understanding is the starting point for her to construct own understanding.

Case 2: S

Student's background and way of learning:

This student did not come to university directly from high school. His high school

education was 7 years before. When he was asked about his way of learning this course, he said usually to do the problems in the book. It was only when he was asked about what he did before class, he mentioned summarization and reflective writing.

Perspective on pre-understanding

For this student, his pre-understanding was like background information that would give him general ideas about physics concepts. He based his study on this pre-understanding. When he tried to understand concepts, he would automatically try to relate it to something that he already knew. His pre-understanding from his life experience was also helpful when he tended to visualize physics concepts. Studying physics to him was mainly using new information, to modify his pre-understanding to get an enhanced understanding. And the procedure of the modification depended on what his pre-understanding was and what he found in the textbook. When his pre-understanding consisted of a general idea and it was not completely in conflict with the textbook, then he just needed to make a little bit of change in definition. But when his pre-understanding was in total conflict with the textbook, he said that he would replace it. He made a comparison between what he learned and what was in conflict so that he knew what he had to replace.

Perspective on summary writing and reflective writing

He thought the reflective activity helped. During his doing reflective writing, he rethought about what was in the book and then put the new information into his own words. To save time, he did summarization on odd sections and did reflective writing on even sections so that he covered everything. In performing summary writing, he

took notes on whatever he felt was important in the book and wrote it down. To do summary writing, he tried to make sure he had written down everything and said that it was more like to write down what was in the book rather than to write down what you were thinking. But he still thought about what he was writing, such as where the formula comes from because he really wanted to understand. When he performed reflective writing, he wrote down his understanding and tried to think about what it means in a more general sense; how it relates to everything else.

Writing products:

The following is an example of his reflective writing. He was trying to relate concepts to his life experience as the student did in case 1.

> There are reference frames that can be used to look at an object like being on a train and watching something on the train vs watching something on a train from a position off the train. You can identify an inertial frame of reference for an object where it has 0 acceleration if it is not being acted on by other objects. Like papers falling off the dash when you accelerate in the car. If you are in the car the papers look like they accelerate backwards but from outside the car the paper are at rest and it is the car that accelerates. The papers will stay at rest with respect to the outside inertial frame of reference unless acted on by a force. The object will have constant velocity.

Case 3: C

Student's background and way of learning:

This is a girl majoring in Psychology and she felt that she never really thought

about Physics concepts such as acceleration or speed or anything. She did not think that she was interested enough in physics to be eager to know the details. Generally, her way of learning physics is to listen in classes and to solve problems from the textbook. If she could not solve the problems, she knew that there was some information missing and would review the material. Her main focus was the problem assignments.

Perspective on pre-understanding

At first, she said that she did not use her pre-understanding in learning the material in this course at all. Later on, she said "maybe not consciously" and it could happen that something made sense to her and was actually physically sensible. She thought that her pre-understanding could be helpful or unhelpful and it depended on if her own understanding had the same physical meaning as that given in her physics classes. When her pre-understanding is "wrong", it would make her study more difficult. She gave an example that if you believed in something in your mind and then somebody tried to tell you something different and they are similar and there were subtle differences, then it would be very difficult for her to "replace" her pre-understanding with the new one. In this case, her pre-understanding was making her study more difficult.

She said that she did not trust herself with her pre-understanding as sometimes there was one thing that seemed to be making sense to her but actually it worked in the other way. Also sometimes, there was no relationship between her pre-understanding and what was discussed in the textbook. So, since she was a first

year university student, she thought that sometimes it was wiser to take what is given instead of trying to match it with what she already knew. When her previous knowledge and knowledge in textbook did not match at all, she knew that she would be running into difficulty if she did not accept the book. So mainly, she just accepted what the textbook says.

Perspective on summary writing and reflective writing

This student was not sure how effective the reflective writing was. But the activity definitely made her to think about the material more. In the instructions for reflective writing, we asked students to show how they constructed their understanding and not to worry about whether or not what they wrote was right or not. This was to help ensure that students would not copy from the textbook to make sure it was right. Also marking was not based on whether or not the reflective writing was right or not. This is the reason that the student doubted the effectiveness of the activity. She thought that she was just writing down what she believed and it could be incorrect. When she tried to remember something, she was just remembering what's incorrect. Students were asked to reflectively think about the assigned material, she thought that she might reflect in a wrong way which makes things more confusing.

Though the student doubted the effectiveness of reflective writing, she viewed it differently from summary writing. As she understood, summarization was basically to make a copy of the book and follow the outline of the book. "It was almost like I was reading the book". When she did reflective writing, she would think of physics concepts. She usually did summarization first, and then did reflective writing.

Writing products:

Though this student does not value reflective writing very much and said that she did not use her pre-understanding in her study as she did not trust it, she did some of her assignments in the way of reflective writing. The following is an example:

> Concept of momentum initially makes me think of Newton's first law that an object at rest will stay at rest and an object in motion will stay in motion in the absence of any external forces. This is sort of my preconceived notions of what momentum is. So it must relate somewhat to this as in the concept of inertia because of the nature of this equation which deals with mass and velocity. Mass is the resistance to change its velocity and inertia is also the tendency of an object to resist any tempt to change its velocity.

The student was trying to relate new concepts to previous chapters by tracing "momentum" back to "force" and inertia. Her knowledge of the previous chapter was in her horizon at that time and she was trying to get a projection of new concepts from it. Though her thoughts were not very clear, she did try to explore her own understanding.

5.4 Results and discussion

I created the following table (Table 4) that consists of 3 cases and those main pieces of information from the interview transcriptions are categorized.

In table 5, information from the interviews and from the writing products was categorized by themes and sub-themes.

Student A constructed her own knowledge through thinking about "both sides":

Table 4: A case study in 2009 fall at Concordia

		A (F)	S (M)	C (F)
Generally, how do you study the course?		study all the chapters before the professor starts; think about the problems; try to see that what is in reality	Exercises in the book	solve problems
Pre-understanding	Bring your pre-understanding into studying the course?	I studied all the lessons before in my country. Helpful.	it's background of information that you can get general idea;	No. not consciously No. I don't trust myself with my pre-understanding
	How did you go from the pre-understanding to your present ideas?	So my belief wasn't really incorrect…but wasn't complete. So now I …think about everything, Now I know more, and understand better. I coupled what is correct and what is wrong.	You have pre-understanding, and then take some new information, and then modify it; If what I was thinking was wrong and I guess you will replace it… So I know what I thought previously was wrong.	It's sometimes more wise to take what's given instead of trying to match it with what you know;
Reflective writing	How does reflective writing help you to engage into your study	It helps to think about both sides, textbook and your belief and compare it. Combine them together, put together, see what comes.	Helps to new information and put it into your own words.	it make me think about more; I don't know how effective it is…

	the difference between the two activities	Summarization, it's just to summarize whatever we understand from the textbook; Reflective writing includes what we understand from the textbook, and our belief, and combination that stand up. first do summarization to understand what the exactly is the textbook and what's going on in the textbook, and after combine with my own idea to do reflective writing.	Summary writing: make sure writing down everything, …you don't write down what you are thinking, you write down what's in the book… Reflective writing: writing down my understanding… Try to think about what it means in more general, how it relate to everything else;	Summarization's like much… that copy the book; Reflective writing, I just think of concept…
Other comments		studied all the lessons before in her country.		I'm not majoring in physics, I don't think of engineering, I don't think of Physics.

Table 5: Themes and sub-themes of the case study in 2009 fall at Concordia

		A(F)	S(M)	C(F)
General way of learning		Writing on chapters; doing problems	Doing problems	Doing problems
Reflective writing	helpfulness	Helpful	Helpful	Not sure
	Different from Summary writing?	Yes	Yes	Yes
	Writing products	Relate to pre-understanding; Raising questions and discussion on it	Relate to pre-understanding	Relate to pre-understanding
Hermeneutical circle		Pre-understanding is open to revision	Pre-understanding is open to revision; When conflict is hard to be solved, just to replace pre-understanding with textbook.	Accept textbook
Personal epistemology	Certainty of knowledge	Evolving	Evolving	Not mentioned
	Source of knowledge	Constructed	Somewhere between transmitted and constructed	Transmitted

textbook and her beliefs, and compare them. She thought that her beliefs are not incorrect but incomplete as she saw the world correctly and just did not know the reason behind what she observed. She valued her pre-understanding highly. Her comments on reflective writing 'includes what we understand from the textbook, and our belief, and combination that stand up' shows that through reflective writing, she was evaluating both sides to change her pre-understanding (horizon A). She use the word 'couple' to describe her thinking process which is similar to Gadamer's 'mediate'. This student is approaching the textbook in the manner of a hermeneutical circle to construct her own understanding.

In her writing products, she was not only relating new concepts to her pre-understanding, but raising questions and elaborate discussion on it also.

In the interview, there is information of her personal epistemology on two dimensions based on Hofer and Pintrich's model. Her physics knowledge keeps evolving and is open to revision. She constructs her own understanding by comparing and evaluating "both sides", pre-understanding and textbook. It is not helpful for her just to memorize and take what the textbook says.

Student S thought that pre-understanding was the background of information and it was valued by him. He started from pre-understanding and then 'take some new information, and then modify it (pre-understanding)'. From this comment, we can see his assimilation ('take') and accommodation ('modify') procedure. But when he can not resolve the conflict between pre-understanding and new information by 'modifying' it, he would just 'replace' it (pre-understanding). At some point in this

case, he would stop constructing his own knowledge. There is no strong indication of a hermeneutical circle for his study.

In his writing products, he was relating new concepts to his life experience to get deeper understanding. But there was no indication of raising questions and discussion of these questions.

From the interview transcription, we can see that though his physics knowledge is evolving (modification of pre-understanding), his source of knowledge is between being constructed and transmitted. When he can quickly solve the conflict between pre-understanding and textbook, he would make "a little bit of change" and construct his knowledge; but when he cannot quickly solve it, he would just accept the authority.

Student C did not credit her pre-understanding and reflective writing activity. She did not use pre-understanding consciously as she did not "trust" herself. We can see that this student's way of learning is really passive by her comments of 'it's sometimes more wise to take what's given'. From the interview, there is not any indication of hermeneutical circle or constructive way of learning for this student. But in her writing products, we find that she was trying to relate new concepts to former chapters by "…it must relate somewhat to…" though she did not explore what the relation is.

She did not mention information about certainty of knowledge. Her source of knowledge is transmitted from authority.

Table 5 provides us with a strong indication of positive relationship between

students' perspective of hermeneutical circle and source of knowledge. The three students' attitude to pre-understanding is changing from being positive to being negative; and students' source of knowledge is going from constructed to transmitted. The first student A's reflective writing products were better accomplished than the other two. The first two students, A and S, thought reflective writing was helpful and their knowledge was evolving. The last student who is on the lowest stage was not sure whether the reflective writing was helpful and did not provide information about certainty of knowledge.

All three students viewed summary writing (SW) and reflective writing (RW) differently. Whether their way of learning is active or passive, they think reflective writing gets them to think more about concepts. In table 6, we can see their perspective of the difference between two activities in detail. Though all of them think the two writing activities are different, it might be because they are instructed to do both at the same time. They can see some difference from the instructions anyway. From Table 6, we can see that students S and C's view of reflective writing have

Table 6: Students' perspective of difference between RW and SW

	A(F)	S(M)	C(F)
RW	includes what we understand from the textbook, and our belief, and combination that stand up.	writing down my understanding …	I just think of concept…
SW	summarize whatever we understand from the textbook	write down what's in the book…	copy the book

nothing to do with pre-understanding and have no indication of a hermeneutical circle. And their view of summary writing is to copy the book without any mention of

understanding. We find it interesting that student S and C's view of reflective writing is almost the same as student A' view of summary writing. This raises a question: though students view reflective writing differently than summary writing, how do they actually accomplish it (reflective writing) and benefit from it?

This study gives us a strong indication of a positive relationship between students' perspective of hermeneutical circle and personal epistemology in terms of source of knowledge. In the following two chapters, we present two separate case studies on reflective writing and summary writing to answer the above question.

Appendix A: Interview questions

1. Generally, how do you study the course PHYS 204?
2. Before the second question, let me first give the definition of pre-understanding. You may already have some ideas about physical concepts, such as force, velocity, mass, and so on. These ideas may come from your former educational experience, or from your experience of life world. Let's say, all those ideas in your mind before you entering this course are called pre-understanding. How do you think the role of this pre-understanding?

   Do you bring your pre-understanding into studying the course?
3. What was your understanding of the relationship between force and motion before your entering the course PHYS 204 (pre-understanding)?
4. How do you think the role of this pre-understanding in your study? (in terms of usefulness)

5. What is your understanding of the relationship between force and motion?
6. How did you go from the pre-understanding to your present ideas?

   Discard the old one and accept the new one (which is described in the textbook) directly? Or went back-and-forth between the two, to compare, or try to find the relationship, or try to understand the new one based on your pre-understanding?
7. Based on the procedure you described just now, how does reflective writing help you to engage into the procedure?
8. Within this course, you do both summarization and reflective writing, what do you think of the difference between the two activities?

CHAPTER 6: A CASE STUDY ON REFLECTIVE WRITING

6.1 Methodology

In this multiple case study (Creswell, 2007), we integrated data collected at Concordia University (institution A) in Montreal in the 2009 winter semester and at Langara college (institution B) in Vancouver in the 2010 fall semester. In institution A, we collected data in an introductory calculus-based Mechanics course taken by 75 students. The majority of these students were studying engineering with the rest being science students. All the students in the class were asked to do reflective writing on each chapter of the course textbook with the exception of the first chapter. This assignment accounted for 15% of their final grades. In institution B, we collected data in an introductory algebra-based course that covered both Mechanics and Electromagnetism. The class contained 31 students, the majority of whom were majoring in science. The students were provided with the same instructions for reflective writing as was given in institution A. This assignment accounted for 5% of their final grade.

We collected and analyzed three kinds of data: quantitative scores on a survey; interview transcripts and students' writing products. In this way, we are trying to explore relationship among students' personal epistemology, way of learning and how they accomplish reflective writing. In order to explore students' attitude to and way of learning physics and science courses, we developed a Likert-scale questionnaire (Appendix A) with7 positive statements: 3, 5, 6, 9, 11, 12 and 13. The answers were arranged as: *1.strongly disagree, 2. disagree, 3.undecided, 4.agree and 5. strongly*

agree. For the remaining negative statements, we arranged the answers in the opposite way. Each statement is assigned 5 points: 1 point for choice 1 and 5 points for choice 5 accordingly. In data analysis, we converted the total points into a percentage score. In institution A, we had 16 out of 75 students participating in the survey with percentage scores ranging from 46.2 to 86.2. The average score was 68.9 with a standard deviation of 9.8. As the switching of scales in this version is not normal and students might discover what are positive and negative ones to achieve high scores, we developed version B in institution B. In this version, we arranged answers from 'strongly agree' to 'strongly disagree' to all the statements. Also, we deleted statement 6 as it reflects students' attitude to the writing activity, not their way of learning. The percentage scores of nineteen participants ranged from 48.3 to 88.3. The average score was 68.2 with a standard deviation of 9.4. Higher percentage scores on the questionnaire should indicate a more positive epistemological belief in physics and science. We administered the survey in the middle of the semester outside the class in institution A and at the end of semester in the class in institution B.

Throughout the semester we collected writing products of the 5 students who participated in interviews in institution A and all those students who signed consent forms in institution B. There were 8 writing assignments on calculus-based Mechanics in institution A and 7 on algebra-based Mechanics in institution B. The course in institution B covered Mechanics and Electromagnetism. Though students did reflective writing on both topics, in order to integrate data with that in institution A, we analyzed only the writing products on Mechanics in this paper. Analysis of these

writing products was conducted to determine if students completed the writing assignment in the way of reflective writing or summary writing.

In institution A, a pre interview was conducted in the third week and a post interview was conducted towards the end of the semester to collect qualitative data on students' perspective of hermeneutics and reflective writing. In institution B, we conducted only one interview towards the end of semester.

6.2 Two students who finished some writing tasks in the way of reflective writing

Case A1[1]

This student got 76.9 on the survey which is higher than the average of 68.9. He handed in 5 assignments and two are reflective writing.

The student thought physics was not just in school, it was also in life. He liked to put concepts and problems together to get a deeper understanding. He thought pre-understanding was helpful for his study in this course as he could visualize concepts from his life experience.

In doing reflective writing, he first did a little summary, then went back and tried to understand each piece, and then put it in his own words. Reflective writing "helped a lot" for a couple of reasons: one is to prepare for the classes; the other is to help him understand more about physics.

When it was towards the end of the course, the student said that this is a hard course and a little bit too complicated for an entrance course. Sometimes, it happened to him that he could not always go by what he had seen and what he thought made

[1] Cases A1, A2 and A3 refer to students 1, 2 and 3 in institution A.

sense to him. He thought it would be in one way, but the maths proved the other way. So he had to “let’s go with the maths”. When this situation happened, he would not argue with the book. But he was still “trying to understand it” and wrote down his understanding.

Though this student got the highest score on the survey questionnaire within the three cases in institution A, he was “not really gonna say something different than in the book” when his pre-understanding conflicted with textbook. This indicates that the level of his ideas about source of knowledge was not very high.

The following is an example of his reflective writing:

> Field forces do not require contact, they act over space. The book says empty space which I think is an oxymoronic description since the space would need something in it. I wonder if even a magnetic field should be labelled as something. And the term empty in this case should mean space without mass in it.

This student was doing the concept assignment in a different way than others. Most of the students were trying to make connections between new material and their experience from their life world (horizon A), that is trying to understand the new material through examples around them, while this student was trying to construct his own understanding at a more theoretical level, trying to fit the new concepts into his own theoretical system about physics (horizon A) and arguing about the fitness.

Case B1[2]

This student got 74.2 on the epistemological survey which is higher than the average of 68.2. He handed in 7 assignments and three of them are in the manner of reflective writing trying to relate new concepts to life experience.

This student referred to himself as "a textbook person" as he would rather read a textbook and learn from it than learning from other people. Besides reading the textbook, he also liked to look at online videos. When he started this course, he thought it was a matter of learning directly from teachers and through examples and he would just need to learn formulas and variables to pass the exam. But later on, he realized that studying this course was more of understanding physics ideas. And it helped him to understand things in real life in relation to physics, to do application to real life.

Pre-understanding was a little helpful for him as he thought if he was taught and understood physics ideas in a wrong way before, then it might be unhelpful. Nonetheless, he tried to put his pre-understanding and the textbook together. He said that his learning was much like "mixing up" his pre-understanding and what he just learnt and this made it simple for him to understand better. If the two things did not match, he would take a note.

Reflective writing was helpful and a new useful learning strategy for him. It not only motivated him to read the textbook, but also helped him to understand physics. The reflective writing itself was helpful to him, but he though this kind of writing was

[2] Cases B1, B2 and B3 refer to students 1, 2 and 3 in institution B.

for personal purposes, not for teachers to see how you do it. So because of this emotional reason, he tried to do the reflective writing more like note-taking to make sure what he wrote is right.

When his pre-understanding and the textbook were in conflict, he would not try to argue because "the new concept" in the textbook "is the truth". He would just stick with the new one and try to understand. This students' level of source of knowledge is very similar to the case A1.

The following is an example of his reflective writing trying to relate new concepts to his real life:

> Mass also shows it's proportionate to inertia. Bigger dudes have greater inertia than skinnier dudes. I guess that's why bullies in high school were fat or big and those who get bullied were skinny as hell because they can just get pushed off…

6.3 Four students who finished all writing tasks in the way of summary writing

Case A2:

This is a part-time student. She got 72.3 on the survey which is higher than the average of 68.9 but lower than the students in cases A1 and B1. This student did all the writing assignments in the manner of summary writing. Also she valued problem-solving more than "to get those concepts".

This student thought that pre-understanding was important and used it as a "reference". She said that it would be hard for someone to go into the course without pre-understanding. When people relate physics to life experience, "it makes sense".

She thought that her study in this course was a combination of pre-understanding and new concepts.

This students thought the reflective writing activity was extremely helpful. First it motivated her to study; secondly, it got her to start thinking about physics. She thought that doing reflective writing was a useful learning strategy.

Though the interview transcription does not indicate a clear perspective of her certainty or source of knowledge, there is a piece of information indicating the level of her idea of simplicity of knowledge was high as she said "everything is connected to everything else" when she talked about her thoughts during doing reflective writing. She thought knowledge was not separated pieces of facts but interrelated.

Case A3:

This student got 63.1 on survey which is lower than the average of 68.9. All of her concept assignments handed in were done in the way of summary writing. This student valued problem assignments more that reflective writing.

She did not use her pre-understanding much as she said that she was not so used to be in science. During that semester, she had a lot of science courses and she was really confused and overwhelmed. She said that she did try to bring her pre-understanding into her study but it was difficult for her.

She was not sure how helpful the reflective writing was. In terms of preparing her for classes, it was helpful. She tried to understand the content when doing reflective writing and if she could not understand it, at least she had some directions before going to lectures. But in terms of understanding, she thought practicing problems was

more helpful.

There is no indication of any dimension of her personal epistemology based on Hofer and Pintrich's model in the interview.

Case B2

This student got 68.3 on the survey which is very close to the average of 68.2. She handed in the 6 assignments and she did all the assignments in the way of summary writing.

This student's way of learning was mainly going to classes, taking notes and doing homework assignments as much as she could. And she did not think that her view of learning physics was changed through the course.

She thought that pre-understanding was helpful because if she already had exposure to it, the second time she could learn the material faster as it was already somewhere in her brain. When there was a conflict between her pre-understanding and the textbook and she was confused, she would move on to something else and then go ask the professor. If the conflict was "like insignificant detail", then she would ignore it.

Though the student said that this activity was definitely useful, she also said that it was a waste of paper and time. If she wanted to reflect on something to help her understand she would do it mentally without writing it down.

From her attitude to the conflict between her pre-understanding and the textbook, she would move on to something else. Her level of source of knowledge is very low.

Case B3

This student also got 68.3 on the survey which is very close to the average of 68.2 and handed in 6 assignments that are all summary writing. She studied the course by doing questions and problems over and over again.

As she took a physics course before in which she had trouble with a couple of concepts, now she was trying not to bring them into this course. But most of her pre-understanding was helpful and it was a kind of foundation for her to build more on it.

Reflective writing was helpful for her as it made her think about the material so that she would be clear what she understood and what she did not understood.

There is no direct indication of her personal epistemology based on Hofer and Pintrich's model.

6.4 Triangulation of evidence

Based on the six cases shown in Table 7, we found that the higher scores students got on the survey, the more likely they were to be doing reflective writing rather than summary writing. To triangulate such a hypothesis based on only six cases, we integrated the survey scores and students' writing products in institution B of all the nineteen students who participated in the survey. There is a statistically significant, positive relationship between percentage scores on the survey and the number of writing assignments indicating reflective thinking, $r=0.530$, $p=0.020$ (table 8). It supports the relationship that we find between students' survey scores and writing products based on the six cases. We did not do this statistical analysis in institution A

as we only collected writing products of the 5 students who participated in interviews and two of them did not do the epistemological survey.

Table 7: Themes for the case study on reflective writing

	Score/average on epistemology survey	Pre-understanding	Reflective writing	
			Helpfulness	Writing products
A1	76.9/68.9	Helpful	Helpful	To make connection at theoretical level
B1	74.2/68.2	A little helpful	Helpful	To make connection to life experience
A2	72.3/68.9	Helpful	Helpful	Summary writing
A3	63.1/68.9	Do not use it much	Not sure	Summary writing
B2	68.3/68.2	Helpful	Helpful; Also a waste of time	Summary writing
B3	68.3/68.2	Most of it was helpful	Helpful	Summary writing

Table 8: percentage scores on survey (a), number of writing assignments indicating reflective thinking(b) and number of writing assignments completed (c).

a	48.3	58.3	60.0	63.3	65.0	66.7	66.7	66.7	66.7	66.7	66.7	68.3	68.3	71.7	73.3	73.3	80.0	81.7	83.3	88.3
b	0	0	0	0	1	1	1	0	0	0	2	0	2	1	3	1	0	2	2
c	1	6	7	2	3	7	6	6	4	6	3	5	4	2	7	3	4	6	6

6.5 Results and discussion

In the interview transcripts, we attempted to identify students' awareness of a hermeneutical circle through their attitude to pre-understanding. If they are approaching the material in the manner of a hermeneutical circle, they would consider their pre-understanding (horizon A), and when they find some conflicts between their pre-understanding and the textbook (horizon B), they should argue about it, going

back-and-forth between the two horizons instead of ignoring their own pre-understanding and trying to remember what the textbook says.

From the data, we found that students with higher survey scores tended to perform reflective writing in the manner of a hermeneutical circle.

In institution A, regarding the two students who did all the assignments as summary writing, one of them (case 2) said that she liked reflective writing and exhibited a positive attitude to pre-understanding. The other one (case 3) showed a negative attitude to examining her pre-understanding and this student said that she was not used to being in science and felt overwhelmed. She also said that she couldn't really say reflective writing was helpful. Also, this student got very low points on the survey, exhibiting a negative attitude to way of learning physics and science.

In institution B, the two students who completed their writing tasks in a summary writing manner both indicated that reflective writing was helpful. Both of them exhibited a positive attitude to bringing their pre-understanding into studying the course, but not in a hermeneutical way as the student in case 2 mentioned ignoring conflicts and the student in case 3 said, "There's a couple of concepts that I had trouble with in the last physics course that I took before this, so I try not to bring that into this one."

In institution A, towards the end of the semester two students stated that the course was difficult. The reason for this might be that as the course progressed, students went from concepts that are easier for them to visualize, such as mass, force, velocity and acceleration, to concepts that are more abstract, such as momentum and energy. For

the same reason, in both institutions, most of the writing products that utilized a reflective writing style were in kinematics and there were many less reflective writing products in dynamics. In kinematics, students appeared to relate concepts to their everyday life experience. When they wrote about dynamics, which emphasizes abstract concepts such as momentum and energy, few of them could relate the concepts to each other at a theoretical level.

As we found that there were some students doing the writing task in a summary writing manner, even though they liked the idea of reflective writing and showed a positive attitude to examining their pre-understanding, we realized that it is important to improve the instructions for reflective writing to help students take more advantage of this activity.

In doing reflective writing, we found that students approached science textbooks in the manner of a hermeneutical circle, going back-and-forth between their horizon and that of the textbook, making comparisons, constructing arguments, and checking the internal consistency of their understanding. In case A1, the student did this at a theoretical level and the student B1 related new concepts with his life experience.

Appendix A: Questionnaire on students' way of learning physics (version A).

1. During my reading the textbook, I mostly focus on the equations.
2. When I do my problem assignments in this course, I usually first try to find similar problems and then follow the steps.
3. I find it's very helpful for conceptual understanding of physics to relate new

concepts and principals to former chapters or sections that I have learned.

4. When I am faced with a problem, I usually first go to find the equations that may be suitable to solve it
5. I think that concept understanding is crucial to solve physics problems.
6. I understand physics concepts and principals best through the writing I do in this course.
7. The goal of Physics course is to learn to solve problems.
8. In my science courses, I mostly study equations that might be used in exam.
9. Physics concepts and principals are related to each other to some extent as opposed to be separated.
10. All professors in science courses should mostly focus on problem solving as the means of learning Physics.
11. In my science courses, I try to understand science concepts before solving problems.
12. Learning Physics means to develop an understanding of the relationships between major concepts underlying Physics problems.
13. The intent of learning in science courses should be to develop an understanding of how the key concepts and principals are related to each other.

Appendix B: Pre-interview questions in institution A

1. Generally, how do you study this Physics course?

   Probe: Your experience in the course?

2．What do you expect out of the course?

Probe: What do you think you should get after finishing the course?

3．Before the third question, let me first give the definition of pre-understanding. You may already have some ideas about physical concepts, such as mass, force, velocity and acceleration. These ideas may come from your former educational experience, or from your life world. Let's say, all these ideas in your mind before you entering this course are called pre-understanding. How do you think the role of this pre-understanding?

Do you bring your pre-understanding into studying the course?

Yes—how do you use your pre-understanding?

No—how do you try to understand the material in the textbook?

4．How do you do your reflective writing assignment?

Probe: General steps?

5．How helpful is the reflective writing for you during your studying the course?

6．If answer to Q3 is yes, how does RW help you to engage into your studying process?

Appendix C: Post-interview questions in institution A

1．Could you please tell me something about your experience in the course PHYS 204？

2．What have you got out of the course?

3．How did the concept assignments fit into your experience of the course?

Probe: How useful have the concept assignments been for you during the course?

What do you mean when you say helpful or unhelpful?

4. a. Do you bring your pre-understanding into studying the course?

   b. Do you bring your pre-understanding into doing reflective writing?

5. When the course goes on, is there any change in your perspective of reflective writing?

   Probe: In terms of how you think of it and how you do it.

6. Could you tell me something about problem-solving vs. understanding of physics concepts?

Appendix D: Interview questions in institution B

1. Generally, how do you study this course?

   Probe: Your experience in the course?

2. Do you think your view of learning Physics has been changed through this semester?

3. What have you got out of the course?

   Probe: Physics knowledge? Learning strategies?

4. Before this question, let me first give the definition of pre-understanding (or your previous knowledge). You may already have some ideas about physical concepts, such as mass, force, velocity and acceleration. These ideas may come from your former educational experience, or from your life experience. Let's say, all these ideas in your mind before you entering this course are called pre-understanding.

How do you think the role of this pre-understanding?

Do you bring your pre-understanding into studying the course?

Yes—how do you use your pre-understanding?

No—how do you try to understand the material in the textbook?

5. How do you approach the reflective writing task?

   Probe: General steps?

6. During you doing reflective writing, you are instructed to relate new concepts to your previous knowledge, what do you usually do when you find the two conflicts with each other?

   Probe: Do you try to argue about the confliction or just memorize what the book tells you?

7. How do you perceive the activity in relation to your own learning?

   Probe: Is reflective writing helpful for you to engage into your studying process?

CHAPTER 7: A CASE STUDY ON SUMMARY WRITING

In chapter 6, we discuss six cases on reflective writing, three at Concordia University (institution A) in Montreal in the 2009 winter semester and another three at Langara College (institution B) in Vancouver in the 2010 fall semester. To compare reflective writing with summary writing, we had another group with the size of 30 students doing summary writing at Langara at the same time and taught by the same instructor. The instructor did not give student any instruction about how to do summary writing. As the two sections had the same course outline, the only different component was the writing activity.

7.1 Methodology

In this multiple case study, we collected quantitative data (way of learning in physics survey questionnaire, version B) and qualitative data (interview, see Appendix A for interview questions) to find a relationship between students' way of learning and their personal epistemology and their perspective of summary writing. The survey was done towards the end of the semester and the percentage survey scores of seventeen participants ranged from 58.3 to 93.3. The average score on the survey was 70.5 with a standard deviation of 8.6. We also conducted interview at the end of semester and five students participated in. Writing products were not collected. All the five cases are included in this chapter.

7.2 Data analysis

Student T

This student got a survey score of 92.5 which is much higher than the average of

70.5. He had left school for a long time and was coming back for engineering. This was his first physics course in fourteen years. This course was one of his favorite classes and he thought it was easy to follow.

Though he said that pre-understanding was helpful as long as it was correct, he also said that in his case, he did not feel that his pre-understanding was incorrect. Even if it conflicts with textbook, he did not think that his pre-understanding was wrong, it was just "not complete". In this case, he would try to find a way to make it work with what he knew. Anything that can be related to a new concept, whether it is from life or from knowledge studied in class before, made it easier for him to understand the new concept.

Summary writing was a good way of learning for him as it was "a reference point" for him to start. This activity was in line with what he would do anyway. Every time when he went into a new class, he knew about the material. To do a summary, he read the book, when he found anything that he was not sure about or "a key piece of information" he would stop reading and write it down. Whenever he found something that did not make sense to him, he would read the whole section and put it into context. He tried to figure out the whole picture and write it down in his own words.

Simplicity of knowledge: if he came across something that did not make sense immediately, he would read the whole section again and "put it into context". This indicates that he viewed knowledge as contextual instead of being discrete.

Source of knowledge: for him, memorizing something from textbook was effective, also he thought the textbook was "probably right". When he went to professors with

problems, he would not directly accept what professors said, but tried to “talk it through and figure it out”. Knowledge for him was not being transmitted by external authority. He would like to construct his own knowledge during interaction with authorities.

Justification for knowing: he would not just accept claims without evaluation by himself. If he was not satisfied with claims by other people, he would keep talking about it until it reached his satisfaction. During this process, he kept evaluating claims.

Student A

This student got a survey score of 73.3 and his way of learning is a combination of reading, practicing problems and discussion.

He studied a physics course before and he thought this pre-understanding was very helpful as he did not need to think about what he knew already. When his pre-understanding conflicted with the textbook, he would try to “say goodbye to it (pre-understanding)”, he would try to take the new knowledge on the textbook that he would be tested on. He might talk or argue about the conflict with the teacher, but would like to save the discussion for after. He also talked about his experience of learning physics for the first time when he did questioned the conflicts, but he found that did not really help. So this time he decided not to do so and just “believe them”. He made an interesting statement that his serious ideas are separated from his school ideas which are open to change. But it would take years to change his “serious” or “big” ideas.

When he did summary writing, he took the things that he understood well and wrote them down. As for what he did not understand, he would think about it but not put them on the paper. He thought this was really a good activity that helped him.

Source of knowledge: he decided to "believe" what was in the textbook because that was what he would be tested on. And later, he said that "maybe not believe", but "keep" for the test because the "teacher is the boss". From here, we can see that his source of knowledge is at low level of accepting things transmitted from the authorities.

Justification for knowing: when there was conflict between his pre-understanding and the textbook, he would "shut up" and "accept" new things without evaluation by himself. This is also at very low level.

Student M

This student also got 73.3 on the survey and her way of learning the course is mainly practicing exercises, sometimes she repeated the homework. If she could not understand something, she would read it in the book or go to the teacher.

She thought her pre-understanding from her life world was helpful for her to visualize and find examples. But if sometimes people conveyed faulty knowledge to her, that would make it harder for her in physics to get rid of what she was told. If there was conflict between her pre-understanding and the textbook, she would not argue about it. She would just go to the teacher and accept how it is.

When she did summary writing, she wrote down those things that she thought were important or would be asked in class or be tested in exams. This writing assignment

was helpful for her in two ways: first it prepared her for the classes better; secondly, she got better understanding through writing it down.

Source of knowledge: when she went to the teacher with questions, she would just "believe the teacher" and "accept it at first" as she thought the teacher had the experience and the whole picture of it and she even did not have a little glimpse of it. It needs time to get the whole picture and she would first accept it and give the time.

Student N

This student got 68.3 on the survey which is a little lower than the average of 70.5. She was in high school around seventeen years ago and she thought she was coming back to school with "little-to-no" about physics. She enjoyed the class and her way of leaning was an integrated process of reading, writing, doing all the practice tests and going to the teacher.

Her pre-understanding from her life world and calculus courses was helpful for her. When her pre-understanding conflicted with the textbook, she would go right to the teacher as she did not have time to sit and ponder it.

She thought that summary writing was helpful for her as it was a foundation of her integrated learning process. She thought this was a new learning strategy that she learned from this course. To do summary writing, she went through the textbook and wrote down anything bold or in italics to make sure understanding what she was writing. If she could not understand, she would write it down and go to ask the teacher.

Source of knowledge: when there was a conflict, she would bring out her points. But

she said that she “don’t necessary argue it” and “don’t have to believe it”. She would talk about it and accept what was explained in the way that she could understood.

Student J

This student got 61.7 which is the lowest survey score within the five cases. She studied physics “mostly by doing problems”. This course was hard for her and she studied hard but it was not something that she enjoyed very much.

Pre-understanding from her life world was helpful for her studying the course, but “it is hard to relate every topic in physics to actual story or real life occurrence”. It was better than “having no idea”. If her pre-understanding conflicted with the textbook, she would compare the two. If she could not solve it, she would go with the textbook, “ignore” or “forget” her pre-understanding.

Summary writing was helpful, but not the most helpful compared to problems and quizzes. Writing down everything she learned from reading, it gave her an idea of what the next topic was going to be, but not necessarily help her understand it better.

Source of knowledge: when there was conflict, she went by what she read from the book and ignore her previous knowledge as she thought “this (pre-understanding) must be wrong”. This indicates her accepting knowledge from authority.

7.3 Results and discussion

From table 9, we can see that student T got a much higher score on the survey about ways of learning physics. Also, his perspective about pre-understanding and the summary writing activity is much more positive than the other four students. Even when his pre-understanding conflicts with the textbook, he did not think that his

pre-understanding was wrong, it was just "not complete". In this case, he would try to find a way to make them work with each other. Though the other four students also commented that they found their pre-understanding was helpful, none of them would try to actively work on the conflict between their pre-understanding and the textbook if such a conflict were to occur.

Table 9: results for the five cases in summary writing

	Survey score: Average =70.5	Pre-understanding	Summary writing	Core dimensions of epistemology
T (M)	92.5	Helpful; He didn't feel that his pre-understanding was incorrect.	Helpful; Try to figure out the whole picture	Contextual; Constructed; To evaluate claims.
A (M)	73.3	Helpful as he didn't have to think about what he already knew; When there was conflict, say goodbye to pre-understanding.	Helpful; Write down what he understood and think about it in his mind if he had problem with it.	Transmitted; Without evaluation.
M (F)	73.3	Helpful as for those from her life world. Conlict: would not argue about it.	Helpful; Write down important things.	Transmitted.
N (F)	68.3	Helpful as for those from her life world and calculus courses. Conflict: go right to teacher, don't have time to think about it.	Helpful; a foundation of her integrated learning process.	Don't have to believe it (authority); Accept what she understood
J (F)	61.7	Helpful as for those from her life world. Conflict: ignore; forget.	Helpful, but not the most helpful; Not necessarily help her understand it better.	Transmitted.

From his comments on summary writing, we can see that "T" was trying to make a

connection between his pre-understanding and the textbook. He was also trying to put new concepts in contextual situations. These are exactly what we expect to see in reflective writing! The other four students were just writing down what they understood, important things in the textbook. The student J who got the lowest score on the survey was just making a list for summary writing and she said that this activity was helpful but not necessarily helped improve her understanding.

In examining table 9, we see that students' survey scores do not always correspond to their epistemological level. Student T's epistemological level and survey score are both the highest among the five students. Student N's epistemological belief is higher than the other three students, but she also got low scores on the survey. This indicates that students' epistemological beliefs and their way of learning are not developing at the same rate. When comparing T and N, we find that both of them were older students coming back to school after more than ten years of work experience, while the other three are much younger than them. This shows that change in epistemological beliefs might occur over a long time period and might be age related.

Appendix A: Interview questions for summary writing group

1. Generally, how do you study this course?

   Your experience in the course?
2. Do you think your view of learning Physics has been changed through this semester?
3. What have you got out of the course?

Physics knowledge?

Learning strategies?

4. Before this question, let me first give the definition of pre-understanding (or your previous knowledge). You may already have some ideas about physical concepts, such as mass, force, velocity and acceleration. These ideas may come from your former educational experience, or from your life experience. Let's say, all these ideas in your mind before you entering this course are called pre-understanding.

   How do you think the role of this pre-understanding?

   Do you bring your pre-understanding into studying the course?

   Yes—how do you use your pre-understanding?

   No—how do you try to understand the material in the textbook?

5. How do you approach the summary writing task?

   Probe: General steps?

6. During you doing reflective writing, you may find you previous knowledge conflicts with what the textbook tells you, what will you in this case?

   Do you try to argue about the confliction or just memorize what the book tells you?

7. How do you perceive the activity in relation to your own learning?

   Is it helpful for you to engage into your studying process?

CHAPTER 8: COMPARISON BETWEEN REFLECTIVE WRITING AND SUMMARY WRITING

The two chapters 6 and 7 are separately on reflective writing and summary writing. In this chapter, we are comparing and contrasting the results from the two chapters

8.1 Common themes

In chapter 6, the case study on reflective writing shows us that those students got higher scores on survey questionnaires tend to have more positive perspective on pre-understanding and are more likely to do reflective writing rather than summary writing. In chapter 7, we find that the student T, who got a much higher score on the survey questionnaire, has a much more positive attitude to pre-understanding and actively dealt with the conflict between his pre-understanding and the textbook. In contrast, none of the other four students would try to actively work on the conflict between their pre-understanding and the textbook. When a conflict occurred, they would go directly to their teacher or just say ‘goodbye’ to their pre-understanding.

Student T in the summary group was actually doing reflective writing as he was trying to make a connection between his pre-understanding and the textbook and to put new concepts in contextual situations, though he was not instructed to do so. In the reflective writing group, the four cases: A2, A3, B2 and B3 who got lower survey scores compared to the other two cases were actually doing summary writing, though they are instructed to do reflective writing.

These studies about writing activities (reflective writing and summary writing) show that those students got higher scores on survey questionnaires, which means

they have a more positive way of learning, they tend to have a more positive attitude to pre-understanding and they are more likely to do reflective writing rather than summary writing. Students who have higher level of personal epistemology also tend to accomplish reflective writing assignments better. But the correlation between way of learning and how they accomplish writing assignment is stronger than the correlation between personal epistemology and how they accomplish writing assignment.

8.2 Difference between reflective writing and summary writing

In this section, all the students from the same institution B are taken into account; they are B1, B2 and B3 in chapter 6 and all the five students in chapter 7. These students were in two different classes, but were in exactly the same course and taught by the same instructor. The only difference is their writing task: one class doing reflective writing and the other doing summary writing. The instruction for reflective writing was introduced in chapter 5 and there was no instruction about how to do summary writing.

Though all the three cases in reflective writing said that this activity was helpful and all the five cases in summary writing also commented that it was helpful, there are differences in terms of why the activity was helpful.

B1 said that the reflective writing not only motivated him to read the textbook, but also helped him to understand physics. B2 said that it was “definitely” helpful but also a waste of time. Though it sounds like negative, let us look into details about why it was a waste of time: she would like to “reflect” on a concept mentally without writing

it down. This shows that she did reflectively think about physics. B3 thought the reflective writing made her think about the material.

In the summary writing section, student T was older that all the other seven students in institution B and got a much higher survey score than the others. He said that he tried to figure out the whole picture and as we noted previously he was actually doing reflective writing. So in the following, this case would be considered as an exceptional student.

Let us look at the other four students who were in the summary writing section. Student A wrote down what he understood in summary writing and he would think about what he did not understand but not put them on the paper. Student M thought she got better understanding through writing important things down. Student N wrote down anything bold or in italics for summary writing and tried to understand them. Student J said that the summary writing was helpful, but not necessary helped her understand better.

From the above, we can see that reflective writing helped B1 to understand more and B2 talked about reflective thinking. B3's comments on reflective writing is similar to A and N's comments on summary writing. M thought writing things down for summary writing helped her to understand more, while J though it did not.

Overall, considering the older student T as an exceptional case (his survey score and epistemology are much higher than others), the reflective writing activity has a closer relation to helping students achieve a better understanding than the summary writing activity.

CHAPTER 9: A PHENOMENOLOGICAL STUDY ON THE WHOLE SET OF ACTIVITIES

In chapter 4, I introduced the whole set of activities (Kalman, 2010) designed to help students develop a holist and scientific mindset in light of hermeneutics and constructivism. This chapter is about a phenomenological study (Creswell, 2007) trying to find out if the whole set of activities help students to change their epistemology and way of learning physics.

9.1 Methodology

This study was done in the 2011 winter semester at Concordia University. It was in the same course as that in chapter 5: a gateway calculus-based Mechanics course. There were two sections taught by the same professor. One is the experimental group doing the whole set of activities: reflective writing on chapters, group activities followed by critique and write-pair-share. The other is the control group only doing summary writing on chapters. The experimental group is of the size of 74 students and the control group is of 98 students. Students' marks on all the writing products: reflective writing, summary writing and critique, are treated as a bonus. Students in the experimental group got a maximum bonus of 10 based on their reflective writing and critique; students in the control group got a maximum bonus of 10 based on their summary writing.

In the experimental group, the reflective writing activity was based on chapters. We performed two group activities (Appendix A) on two physics concepts: independency between horizontal motion and vertical motion and potential energy.

These two group activities were followed by two critiques as homework for each student to hand in individually one week after each in-class group activity. There was one write-pair-share (Appendix B) on rotation. Students free-write on this topic for three minutes, and then discuss with their neighbour. Professor asked students to vote before and after the discussion. This activity was followed by a review as a homework to be handed in individually.

To find out students' change in epistemology and way of learning physics, pre and post interview questions were designed (Appendix C). Of the students who were interviewed, one student in the experimental section and one student in the control group participated in both pre and post interviews so that we were able to do a comparison between pre and post to find out changes.

9.2 Data analysis

Student R in experimental group

This case in the experimental group is an Engineering student. He had work experience in electricity and was working while studying.

Pre-interview

Knowledge and how to acquire knowledge

He thought knowledge might be an understanding of how something works and a collection of ideas that could be explained and followed some logic. This student thought knowledge was complicated and uncertain and he also realized the difference between personal knowledge and knowledge of society as a whole. He talked about knowledge of society that he thought was traditionally passed down and sometimes it

was only for a certain class to know. He also talked about human elements in knowledge by saying that knowledge is something that people can use to improve things but it also had negative aspects.

He talked about acquiring knowledge in two aspects: as general and specifically for him. As general, he thought knowledge was acquired through osmosis. People take in information and then categorize or integrate different ideas to create new knowledge. He talked about people acquiring knowledge through different experiences. As for himself, he thought that he learned more through experiencing things than through theory. He did not pay attention to the lecturers if the professor just poured out information. He did not learn in the way of going over many slides in class, it might reinforce things, but he would like to do things on his own. He relied more on his own experience and reasoning. Doing problems and trying to reason through it were helpful when he applied concepts in the textbook to problems.

Physics knowledge

He thought physics knowledge was both discovered and created. As for anything visual, it was discoverable. But for anything theoretical, it was creative knowledge. He talked about subatomic particles and space that he thought nobody really knew what was going on there and people could only find the best explanation. This kind of knowledge was created in some way in his opinion.

He acquired physics knowledge during the day in real life situations and he thought that the reason why this worked for him was that it helped him to keep an interest in physics. He also liked to learn physics through solving problems and trying to reason

through them.

He thought that people were always discovering or thinking of new theories and things were changing. It is definitely possible that those laws of physics do not apply in some situations so that people have to change it. He was sure that the way physics research was carried out would change because technology would improve.

Good learner and bad learner in physics

He thought that to be a good learner in physics, a student had to have enough money to not worry about bills and stress, and have enough rest and time to spend on it. A good learner should be interested and excited about physics, and 'live physics all day'. A person who had a curiosity to engage and challenge professors would be a good learner.

To be a good learner in physics, a student had to have the ability to visualize in three dimensions and high math ability; should also pay lot of attention into details and explain things clearly.

A good learner was someone who did all the homework and listened and did not speak in class; who should also spend time in discussions with the professor.

He thought a bad learner in physics was a person who was arrogant and not interested; a person did not have imagination and had poor math skills; a person who did not complete assignments, did not care and did not listen in the class but talked during the lecturers.

About the course

For this student, the reflective writing assignments were really helpful as it forced

him to pay better attention to theory. Without the writing assignment, he would just read words and it would not be until he had to do problems that he would pay attention to equations and theories.

He was expecting better understanding of physics and applying it to what he did as an electrician.

Though he really liked physics and physics course, he felt crushed and frustrated and anxious everyday because of lack of time. It was kind of nerve racking for him because of not being able to put his best effort due to time constraints and stress.

Post-interview

Knowledge and how to acquire knowledge

The student thought that knowledge was information that could be collectively known and retrieved from books. Knowledge was explanations about phenomena. There was another kind of knowledge-emotional knowledge, which was about relationships or people.

In general, he thought people acquired knowledge by reading or being taught. Learning at school, reading books, more mathematical or problem solving and lectures helped with getting ideas and reinforcing ideas. He relied on what the teacher says and what he read in books. As for his own reasoning, he said that he did not have a lot of trust in it. He though that he was whimsical and doing things on impulse without reason during his formative years when he was younger. Now, he had to explain things in a kind of a logical manner and there has to be reasoning for them. Instead of relying on his own reasoning, he relied more on being taught how to reason

and that was exactly what he was doing.

About the course

He thought that physics was really interesting because it developed new ideas and ways of seeing things. He hoped that he could have enough time to focus on it but he did not. He was suffering in other classes too because of lack of time. He also felt isolated from other people because he did not have time to work collaboratively and get feedback. He was anxious because the exam was soon, but not frustrated.

He came into the class without real understanding of calculus that made the course a struggle for him. The course demanded more logic and problem solving effort from him. He has developed the habit of doing something that he was used to do without thinking from his work, but now the course forced him to take steps to think.

For him, the biggest difficulties and challenges are time, calculus and understanding of some concepts. But he did enjoy trying to understand concepts and it was pleasant and exciting to see how people designed these systems of thought. Being faced with difficulties, he just humored himself and he was not so worried if he did not get it right away, because he thought that ideas developed over time and reinforced each other in a bigger picture form later on.

Way of learning physics

Studying the course helped him to see how it was important for all sorts of other disciplines and it broadened his ideas.

In the beginning of the course, he read chapters and relied on classes and assignments. He looked into books for direct examples of how to solve the particular

problems step by step rather than try to incorporate the concepts into solving problems.

In the middle of the course, he realized that he needed to do more note taking in the chapters. He tried to think of the points that he needed to take out of the chapters.

At the end of the course, as it was approaching the exam, he tried to do as much problem solving as possible to prepare for the exam.

For him, understanding of concepts was important to problem solving as it did not have any real meaning just working with numbers.

He thought that in the future he would take fewer classes and put more time into them to get more out of classes.

About activities

Reflective writing forced him to think about what he was learning and helped him to prepare for the classes. If he did not understand the textbook, then he could clarify points in the lecturers or at least ask questions about them. This activity helped him to relate concepts. Through reflective writing, he joined the concepts together; built concepts on other concepts; related the understanding of concepts to each other. This activity helped him to integrate ideas.

As he performed reflective writing, he thought of terms and it helped him to clarify concepts. Sometimes, when he read the writing back, it did not seem to match what he had been taught or other concepts, and this made that activity a struggle for him. The activity was time consuming for him as he found himself struggling with even just putting sentences down.

He thought it was good to have different views presented in the group activity because there was reflection. He was trying to think of how to disprove others' views and it helped with his thinking in a general way. But he thought the activity was kind of hard because some students just wanted to rush through it.

He thought that it was important to present as many reasons as possible to argue different viewpoints in the critique rather than just starting from the correct view point because without arguments, how do people know that the real view is real? It was important to disprove certain ideas instead of coping with some sort of authority.

He did not think that he looked at other concepts differently because of the group activity and critiques on certain concepts.

Student L in control group

This student is a girl majoring in history. She chose to take this physics course though she did not need to. She thought she started with nothing in physics.

Pre-interview

Knowledge and how to acquire knowledge

She thought that knowledge was something you learned over time; picked up from living life; different experiences and what you took from that. For her, knowledge could be also outside school and is connected as everything is connected.

Her opinion was that knowledge was acquired through doing something, accomplishing something or doing an action. To acquire knowledge, you had to put yourself out there.

For learning at school, a lot came from the teacher so you have to be in class. You also had to get all the resources possible to achieve your goal, such as books, internet and relating to other students in class. For her, everything together comprised the learning process.

Physics knowledge

She thought that physics was definitely a discovery process and it was discovering the physics part of everyday life. She thought that the way of learning physics was different from that of history or politics as it was not tangible but abstract. To learn physics, people had to reapply what you learned and conceptualize it.

She thought that physics laws changed all the time and everything changed. We might have a physics law that worked today, but in the future it did not. She said that she did not know enough whether the way scientific research being done today was right or not, but she guessed that it could change as there was always room for change, hopefully for good. She talked about the social part of scientific research and hoped that physics research could help humanity to gain a better life.

Good learner and bad learner in physics

She thought that to be a good learner in physics, a student had to have the mindset for it; can conceptualize things that were not tangible; have creativity and imagination. In her opinion, the best way to learn physics was to put yourself in a particular situation and try to understand what was going on.

A good learner should have discipline to achieve certain learning goals. She thought it was different for everybody, some people did not need to spend much time on study

and still get a good grade. But for her, it was definitely going to class, listening to the teacher, asking questions and doing homework.

A bad learner in physics was a person who could not grasp the conceptualization of physics; who had a lack of motivation; “not caring of knowledge that they were gaining”; taking something for granted and this kind of person could not take anything from what they are learning. For her, a poor learner does not go to class, does not work, does not do assignments and does not ask questions.

About the course

For this student, summary writing assignment was helpful in terms of helping her to see what she understood and what she did not understand; helping her to learn more effectively; and it also could help her prepare for the exam.

She was expecting that both the social part of life and the science part of life together would give her a better understanding of everything in life. It helped her open up her eyes to different things. It was the unknown part of it that gave her extra knowledge. Though it was difficult for her, she enjoyed looking at different things.

She thought studying the course was fun and interesting. Also she felt smart when she took science as in the past she was told that her marks were not high enough for science.

Post-interview

Knowledge and how to acquire knowledge

She thought knowledge was something about experience, whatever you did in life you took it with you, you learned from it and what you could do with it in the future.

Knowledge for her had both features of being facts, information, ways to solve problems and being a complicated system.

Knowledge was acquired through different activities: going to school, meeting people, going out of the house. For learning at school, she had to read, go to classes, learn from teachers and peers, do assignments and everything else.

About the course

She thought that the course fulfilled her expectations in terms of her learning new things that were different from what she had known. Though the course was difficult, she liked it.

This course was a different way of thinking for her and a different and difficult way of mindset was demanded.

The biggest difficulty for her was to conceptualize as it was very abstract. To cope with her difficulty, she practiced more questions and tried to understand problems. She also went online for tutorials to get help.

Way of learning physics

She said that her ideas of learning physics were different compared to how she thought that she had to learn physics before she had taken this course as before she did not know how the course would be, now she knew the systematic way of doing problems.

In the beginning of the course, her way of promoting her learning was to attend classes, to do summaries, to practice problems and to try to take every part of the class and take advantage of it.

In the middle of the course, her way of promoting learning was to utilize every little thing and to utilize them more specifically.

At the end of the course, she was doing whatever she was doing at the beginning, but more specifically and she had more direction now to utilize everything.

She thought that understanding of concepts definitely helped her in problem solving.

About activities

She thought that the summary writing assignment helped a lot and it was given to make students read material before going to class, summarize in their words, try to understand, so that they could ask questions of what they did not understand in class. During her summarizing, she tried to understand what she was trying to say. Summarizing concepts made her understood more and gave her a lot substance. The more she summarized, the more she could get through the concepts.

9.3 Results and discussion

In Table 10 and 11, we can see the comparison between the two students' about their perspective on epistemology and way of learning. Compare the pre (Table 10) and post (Table 11) interviews, we can also get the change in their perspectives.

From the comparison of the pre-interview between the two cases, we can see that R in the experimental group mentioned the uncertainty of knowledge and he thought that theoretical physics knowledge was created. Both of them thought that physics laws and way of doing physics research could change. Their ideas about acquiring physics knowledge and about being a good learner or a bad learner in physics were

Table 10: Comparison between the two pre interviews.

	R in experimental group	L in control group
Knowledge	Understanding of how something works; a collection of ideas.	Something that you learn over time, pick up from the living life; Different experiences and what you take from that.
	Complicated, uncertain.	Interconnected as everything is connected
How to acquire knowledge	Osmosis; taking in information; categorizing or integrating different ideas so that to create a new knowledge; different experience.	Doing something, accomplishing something or doing an action.
	Through experiencing thing; doing things on my own and less through theory;	Getting all the resources possible; everything together gave her that learning process.
Physics knowledge	Both discovered and created.	Definitely a discovery process
	Acquiring physics knowledge during the day in real life situation.	To reapply what you learned and conceptualize it.
	Physics laws would change.	Physics laws change all the time.
	The way physics research was carried out would change.	The way physics research was carried out could change.
Good learner in physics	Enough rest and time to spend on physics; being interested and excited about physics; a curiosity. The ability to visualize in three dimensions and high math ability.	The mindset for it; to conceptualize things that were not tangible; creativity and imagination.
	Doing all the homework and listening and not speaking in classes; direct association and time with professor.	To have discipline to achieve certain learning. For her, going to class, listening to the teacher, asking questions and doing homework.

Bad learner in physics	Being arrogant and not interested.	Being lack of motivation; not caring of knowledge that they were gaining.
	No imagination and poor math skills.	No conceptualization of physics.
	Do not complete assignments, do not listen in the class.	Not going to class, not doing work, not doing assignments and not asking questions.
About the course	Reflective writing assignment was helpful as it forced him to pay better attention to theory.	Summary writing assignment was helpful in terms of helping her to see what she understood and what she did not understand
	Expecting better understanding of physics.	To open up her eyes to different things
	Being crushed and frustrated and anxious everyday because of being lack of time.	The course was fun and interesting. Also she felt smart when she took science

Table 11: Comparison between the two post interviews.

	R in experimental group	L in control group
Knowledge	Information that could be collectively known and retrieved from books; explanations bout phenomena	Something about experience, whatever you did in life you took it with you, you learned from them and what you could do with it in the future.
How to acquire knowledge	By reading or being taught.	By different activities: going to school, meeting people, going out of the house.
	For learning at school, reading books, more mathematical or problem solving and lectures. Instead of relying on his own reasoning, he relied more on being taught how to reason	For learning at school, she had to read, go to classes, learn from teachers and peers, to do assignments and everything else.

About the course	General	The course was interesting because it developed new ideas and ways of seeing things.	The course fulfilled her expectations in terms of her learning new things that were different from her mind.
	Emotional feeling	He was anxious because exam was soon, but not frustrated.	Though the course was difficult but she liked it.
	Difficulties in the course	Difficulties for him are time, calculus and understanding of some concepts.	Difficulty for her was to conceptualize as it was very abstract.
	How to deal with difficulties	He just humored at himself and he was not so worried.	She practiced more questions and tried to understand problems and went online for tutorials to get help.
Way of learning physics	In the beginning of the course	He read chapters and relied on classes and assignments. He looked into books for direct examples of how to solve the particular problems step by step.	She tried to attend classes, to do summaries, to practice problems and to take every part of the class and utilize what she had.
	In the mid of the course	He tried to think of the points that he needed to take out of the chapters.	She utilized every little thing more specifically.
	At the end of the course	He tried to do as more problem solving as possible to prepare for the exam.	She was doing whatever she was doing at the beginning, but more specifically.
Writing assignment		Reflective writing forced him to think about what he was learning and helped him to prepare for the classes Through reflective writing, he joined the concepts together	Summarizing concepts made her understood more and gave her a lot substance.

similar. R's comments on reflective writing and L's comments on summary writing were not very different. R did not realize that he was required to make connection between concepts during doing reflective writing.

The most obvious difference between them was their emotional feeling. R's feeling was negative because of having lack of time. L's feeling was very positive as she said that she felt smart just because she was taking a science course as she was told she did not have good enough marks to take science courses. And L was very interested in learning different things.

Comparing the two students' epistemology, we can see that in the pre-interview R considered knowledge as complicated and uncertain, and L thought that knowledge was interconnected as everything was connected, this shows that on the dimension of simplicity of knowledge, they are at the same level. On the dimension of certainty of physics knowledge, both of them claimed it was evolving. Also both of them talked about undergoing different experiences in the life world to get knowledge.

From the comparison between the two post-interviews, there are two differences. The first is that R's way of learning changed in the middle of the course while L did not make much of change in her way of learning throughout the whole semester. In the beginning of the course, R relied on classes and assignments, looked into books for direct examples of problem solving rather than incorporating the concepts into problem solving; in the middle of the course, he tried to think of the points that he needed to take out of the chapters. L just "utilized every little thing more specifically" in the middle of the course. At the end, she was doing whatever she was doing at the

beginning, but more specifically. The second is that R's comments on reflective writing have changed as in the pre-interview he said that reflective writing forced him to pay attention to theory while in the post interview he said that the activity made him "join concepts together". L's comments on summary writing in the post-interview were similar to those that she made in the pre-interview.

In the post-interview, neither of them provided information about simplicity of knowledge and they gave similar answer to "how to acquire knowledge" to what they did in pre-interview.

So if we compare both students' pre- and post- interviews, we find that R in the experimental group changed his way of learning through the course and his perspective of reflective writing was changed. In the case of L, we do not find evidence for change.

In chapter 3, we discussed four core dimensions based on Hofer and Pintrich's model and some survey questionnaires widely used in physics educational research community that include both some of core dimensions and way of learning. We proposed that students beliefs about core epistemological dimensions and beliefs about way of learning are tangled together, but they may change differently. The result from this study approved this.

In pre interview, the two students' epistemologies were at the same level. In the post-interview, their answers to "how to acquire knowledge" were similar to what they did in pre-interview. There is no evidence for change in their epistemology.

While in the post interview, we can see that R changed his way of learning and L

did not. Also, R's perspective of reflective writing changed while L's perspective of summary writing remained the same through the semester.

The implementation of the whole set of activities in a single one semester Physics course does not change students' epistemological beliefs. This result supported Wood and Kardash's (2002) research which shows that epistemology develops slowly over a long period of time. We can not expect changes in a students' epistemology through one semester of intervention in a single course.

Referring back to chapter 7, where we have student T who is much older that the other students and got a much higher score on the survey about ways of learning physics, this student's epistemological beliefs is at much higher level than others. In the same chapter, we also have another older student N, whose epistemological beliefs is lower than T, but higher than all the other three students in the same group. And her survey score about ways of learning is only average which is lower that A and M in the same group. This also shows that students' epistemology and ways of learning develop at different level. Tracing back to Rousseau (1762) who brought up an age-related sequence of stages of getting maturity and then Inhelder and Piaget's (1958) age-related stages of intellectual development levels, there has been an age-related assumption about epistemological change for a long time. Bruner and Haste (1987. p88) find that students' epistemology is "both age and context or content matter". In our research, students are in the same contexts of physics learning and their epistemological beliefs are age-related.

The result from student R's change in his way of learning does not give us strong

evidence that this set of activities is effective to change the way of learning for all students. It does show us that though improving students' epistemological beliefs is a long process, it is possible to change their way of learning by intervention in a single course.

We hope the intervention of activities create a constructive environment encouraging them to construct their own understanding instead of be passive acceptors. From chapter 5 to chapter 8, the studies about writing activities show that those students got higher scores on survey questionnaires, which means they have a more positive way of learning, tend to have more positive perspective on pre-understanding and are more likely to do reflective writing rather than summary writing. Students who have a higher level of personal epistemology also tend to accomplish reflective writing assignments better. But the correlation between way of learning and how they accomplish writing assignment is stronger than the correlation between personal epistemology and how they accomplish writing assignment. We also found that the reflective writing activity has a closer relation to helping students achieve a better understanding than the summary writing activity.

This chapter includes pre and post interviews in which we try to compare changes in the control and experimental groups. The results show us that using the implementation of the full set of activities for one semester can change students' way of learning physics.

Appendix A: two group activities followed by two critiques.

Group activity # 1:

A bullet is fired horizontally.

a) Describe the motion of the bullet.
b) Compare its vertical motion with the motion of a penny dropped from the same height at the same time

Your group has 7 minutes to discuss and describe the problem. (using diagrams and words).

Two groups will report on their findings.

Group activity # 2:

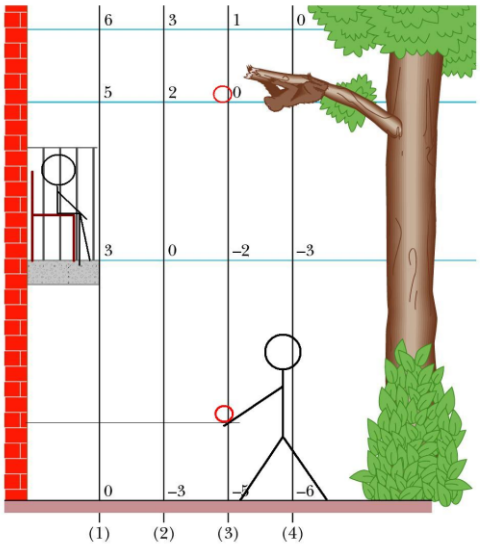
Person A: standing on the ground and throwing a ball upward from the height of 1m above the ground.

Person B: sitting on the balcony that is 3m above the ground.

The ball reaches it’s highest point that is 5m above the ground.

Take the point of view of person A, person B and the monkey on the tree [5m above the ground], to find out the potential energy of the ball-earth system when the ball is at person A’s hand and at the highest point. Also find out the change in the potential energy.

What do you learn from this?



Appendix B: Write-Pair-Share:

Step 1:

Consider a hoop and a solid disk released together at the top of the slope. If they roll without slipping, and the losses due to friction can be neglected, what is the velocity of each at any instant and which reaches the bottom first?

Conservation of Energy: $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$

Hoop:
$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}(mr^2)(\frac{v}{r})^2$$
$$= \frac{1}{2}mv^2 + \frac{1}{2}mv^2 = mv^2$$
$$v^2 = gh$$

Disk:
$$mgh = \frac{1}{2}mv^2 + \frac{1}{2}(\frac{1}{2}mr^2)(\frac{v}{r})^2$$
$$= \frac{1}{2}mv^2 + \frac{1}{4}mv^2$$
$$v^2 = \frac{4}{3}gh$$

The disk will reach the bottom first.

Step 2:

We have two tins, chicken gumbo and chicken broth of the same size, released from the top of a slope side by side. Which one will reach the bottom first?

Free write for 2 minutes

Step 3: Vote

Step 4: Experiment

Step 5: whole class discussion.

Step 6: A review after class.

Appendix C: interview questions

Pre-interview:

1. What comes to your mind when you use the word of knowledge? *(**PROBE:** Is it facts, information, ways to solve problems or a complicated system? Is knowledge interconnected?)*

2. How do you think knowledge is acquired? *(**PROBE:** what do you rely on most for learning in school: on your own reasoning, past experiences, what the teachers say, or what you read in books?)* Why?

3. How do you think physics knowledge is acquired? *(**PROBE:** Would you say physics knowledge is created or discovered?)* Why?

4. Do you think the laws of physics can change? Why?

5. Would you say that the way physics research is carried out today will change in the future? Why?

6a. What do you think is a good learner in physics?

What comes to your mind when you think of a good learner? Do you have a visual image?

6b.What do you think is a poor learner in physics?

What comes to your mind when you think of a poor learner? Do you have a visual image?

7. Do you expect that certain types of writing exercises could have an important role in learning physics?

8a.What is your expectation of this course?

8b. How do you feel right now about the course? (***PROBE***, are you curious, frustrated, excited, or anxious?) (***PROBE:*** *Could you tell me more?)*

Post-interview:

1. What comes to your mind when you use the word of knowledge? *(**PROBE:** Is it facts, information, ways to solve problems or a complicated system? Is knowledge interconnected?)*

2. How do you think knowledge is acquired? *(**PROBE:** what do you rely on most for learning in school: on your own reasoning, past experiences, what the teachers say, or what you read in books?)* Why?

3a. Now that the course is almost over, were your expectations fulfilled or did the course demand something different from you as a learner? *(**PROBE:** Could you tell me more? Why do you think you were (or were not) well prepared for taking this course*?)

3b. How do you feel right now about the course? ? (***PROBE***, are you curious,

frustrated, excited, or anxious?) (***PROBE:*** *Could you tell me more?)*

4a. What was the biggest difficulty or challenge you've faced in this course? Why?

4b. How did you feel about this difficulty of challenge? How did you try to cope with it? (***PROBE:*** *could you please tell me more?)*

5. Are your ideas about learning physics different now, compared to before you took this course? (IF YES) What experiences in this course had helped you shape them? *(**PROBE:** How did they influence you?)* (IF NO) Explain.

6.a) What exactly did you do at the beginning of the course to promote your learning of the content?

b) What exactly did you do in the middle of the course to promote your learning of the content?

c) What exactly did you do at the end of this course to promote your learning of the content?

7. Do you think that you are going to approach your studying differently because of this course?

8.Does an understanding of concepts help you with the solving of the problems? If yes probe why, if not probe Why not)?

For Experimental Group

Now I will ask you some specific questions about your views on reflective writing, conceptual group activities and critique activities.

1. Why do you think the professor has given you this activity RW? Do you think the instructions for RW are to get you to relate different concepts in different chapters? Why? What is it that you are relating? *(**HINTS:** ideas, concepts, theories?)*

2. When you are performing RW, describe what you are thinking about it. *(**PROBE:** Are you forming ideas? How?)*

3. Do you think it is important to have different views presented in the conceptual group activity? Why?

4. How important do you think it is to present as many reasons as possible to argue differing views in the critique rather than just stating the "correct" viewpoint?

5. The conceptual group activity and the critique deal with specific concepts. Have you looked at other concepts differently? *(**PROBE:** Have you developed any new learning strategies and applied them in your learning of new concepts?)*

For Control Group

Now I will ask you some specific questions about your views on summary writing.

1. Why do you think the professor has given you this activity SW? Do you think the instructions for SW are to get you to relate different concepts in different chapters? Why? What is it that you are relating? *(**HINTS:** ideas, concepts, theories?)*

2. When you are performing SW, describe what you are thinking about it. *(**PROBE:** Are you forming ideas? How?)*

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