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Implementation and Evaluation of the Course Dossier Methodology

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Abstract

It has been argued that for novice students to acquire a full understanding of scientific texts, they also need to pursue a recurrent construction of their comprehension of scientific concepts. The course dossier method has students examine concepts in multiple passes: (a) through reflective writing on text before it is considered in the classroom, (b) in a one-page essay at the end of the week, and (c) through a final essay at the end of the term. Students are encouraged to relate to the text in their reflective writing and critiques in the manner of a hermeneutical circle. Students are further scaffolded in writing their final essay by the use of student reviewers. This study explored how students in a humanities course perceived and accomplished the course dossier method. It was found that students' understanding of concepts improved as the course progressed.

D'aucuns ont fait valoir qu'afin que les étudiants novices comprennent pleinement les textes scientifiques, ils doivent également poursuivre une construction récurrente de leur compréhension des concepts scientifiques. La méthode qui consiste à tenir un dossier de cours requiert des étudiants qu'ils examinent les concepts en plusieurs passes : (a) par le biais de la rédaction réflexive sur le texte avant que celui-ci soit étudié en classe, (b) par un essai d'une page à la fin de la semaine et (c) par un essai final à la fin du trimestre. Les étudiants sont encouragés à mettre le texte en rapport avec leur rédaction réflexive et leurs critiques à la manière d'un cercle herméneutique. De plus, les étudiants sont davantage préparés à rédiger leur essai final par l'utilisation d'étudiants réviseurs. Cette étude explore la manière dont les étudiants d'un cours de sciences humaines perçoivent et accomplissent la méthode qui consiste à tenir un dossier de cours. On a découvert qu'au fur et à mesure que le cours a progressé, les étudiants ont davantage compris les concepts.

Keywords

writing-to-learn, hermeneutics, physics education, social constructivism

Reflective Writing

It is important to provide courses on science for humanities students because we need to have a public that has an understanding of how science functions so that the members of the general public can make intelligent decisions about government policy. A course for such students need not contain traditional problems and examinations. Students need to understand scientific concepts rather than have the ability to solve such traditional problems. The course dossier method uses writing procedures based upon Gadamer's (1975/1960) hermeneutical approach and scaffolding using student reviewers based upon social constructivism (Vygotsky, 1978, 1994) to assist students in the understanding of scientific concepts.

To get a clear understanding of these concepts, students need to compare their pre-understandings with the scientific theories presented in the textbook and by the teacher in the classroom. Kalman (2011) has shown that this can be achieved by having students engage with text utilizing reflective writing as a hermeneutical circle.

Reflective writing is a part of the writing-to-learn movement, the aim of which is to incorporate informal writing into all disciplines. Specifically, reflective writing is based upon the notion of "freewriting" popularized by Elbow (1973). Countryman (1992) defined freewriting as writing rapidly for a short and fixed period of time. Freewriting often looks like speech written down; usually, it is characterized by first-person pronouns, informal style, and colloquial diction. Fulwiler (1987) noted, "Some writing activities promote independent thought more than others do. Expressive or self-sponsored writing, for example, seems to advance thought further than rote copying" (p. 21).

Many examples of expressive writing are found in the works of Fulwiler. In particular, Fulwiler (1987) contains a section on writing in *College Physics* by Verner Jensen in which Jensen proposed that "understanding can be enhanced through a freewriting experience" (p. 330). Jensen also noted "Physics students can use the writing process to clarify their thinking and understandings about physical phenomena through their written articulation of relationships. Learning physics requires many different mind processes including abstract thinking. Writing can assist the student with this process" (p. 330).

Writing-to-learn strategies in the sciences have been addressed by a number of researchers (e.g., Countryman, 1992; Holiday, Yore, & Alverman, 1994; Kalman & Kalman, 1996; Pugalee, 1997; Rivard, 1994; Wallace, Hand, & Prain, 2004). Rivard (1994) noted that writing-to-learn has been used to enhance the learning of science content, and also that writing as a response is intimately connected to thinking.

Reflective writing is based upon hermeneutics. Schleiermacher was the first person to define hermeneutics as the study of interpretation in general, beyond the fields of law, religion, or aesthetics (Howell, 2012; Packer, 2010). Some people such as Eger (1993), Borda (2007), and Schulz (2014) argued for the use of hermeneutics in science and science education. Kuhn (1977) said, "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" (p. xiii).

Schleiermacher introduced the concept of the hermeneutic circle. He believed that "every extraordinary thing can only be understood in the context of the general of which it is a part, and vice versa" (as cited in Packer, 2010, p. 86). There are several related concepts of the hermeneutic circle. One involves the relationship between the parts and the whole in which understanding a text as a whole requires understanding its individual parts, but at the same time

understanding each individual part requires a sense of the whole. A circular relationship can also exist between a text and its context. Heidegger (1962) proposed a hermeneutic circle between understanding and interpretation. Following from the work of Schleiermacher, Dilthey explained the hermeneutic circle as a continual interaction between the implicit and explicit, and between the particular and the whole (as cited in Howell, 2013, p. 155). Gadamer (1975/1960) furthered Heidegger's work around pre-understanding, dialogue, the hermeneutic circle, and the theory of horizons. Gadamer explained the term "horizon" as "the range of vision that includes everything that can be seen from a particular vantage point" (p. 269). One's horizon is all that one can see which is defined by your pre-understandings. The interpretation must bring out this tension and when this happens there is a fusion between the interpreter's own horizon and the horizon of the text (Packer, 2010). When one's horizon encounters the horizon of a text or another person, a new horizon is formed, and a new understanding is created.

Students do not encounter the book of nature in science courses, but the book of science, which is written in a language that scientists use to talk about nature (Eger, 1993). Therefore, students can have great difficulty understanding scientific texts since the language and epistemology of science are not familiar to them (Kalman & Rohar, 2010). To understand a text, we must know the meaning of the phrases, and the meaning of each phrase depends on the paragraph and the whole text. On the other hand, to understand a text, we must know the individual parts. When we encounter a text, we start with some pre-understandings and projections. We use these pre-understandings to make sense of the small parts of the text that requires a sense of the whole text. There is a series of hermeneutic back-and-forth movements between the parts and the whole. Kalman (2011) believes that when students approach the textbook to provide their reflective writing assignments, they move between the parts and the whole. Further, a hermeneutical circle operates between their pre-understanding and their current understanding. Students in introductory physics courses have some ideas about physical concepts, such as force, velocity, mass, and so on. These ideas may come from their former educational experience or from their own experiences outside the traditional classroom. Students' pre-understandings and ideas make sense in explaining observations in their life world and are reasonable to some extent. Therefore, when a student comes to a text, two horizons are in view: the horizon of the student (horizon A) and the horizon of the textbook (horizon B). Horizon A as a whole contains students' parts such as the students' life experience, former theoretical knowledge, and the experience from the textbook. The textbook whole (horizon B) is a combination of its parts, too. If the two horizons overlap to some extent, students may use the overlap as a starting point to utilize a hermeneutical circle to try to understand the text. The students' horizon is dynamic and is always open to change. For example, when students begin to learn Newton's second law, their horizon A contains all those experiences and knowledge related to "force" or "motion." A part of their horizon may overlap horizon B of the teacher and textbook. From this starting point, students project the whole, Newton's second law, and then go back to check if the parts (their experiences and knowledge related to force and motion) add up to support the whole. If not, they may try to correct their understanding in reviewing the textbook again to create a new horizon (A), and then harmonize again the two horizons. This is the back-and-forth movement of the hermeneutical circle. The idea of reflective writing is to prod students into reflecting metacognitively on the material found in the textbook in the manner of a hermeneutical circle.

The student approaches the textual extract with pre-understandings about the material within the textual extract. The key quintessential experience occurs when the student is pulled up

short by the textual extract. “Either it does not yield any meaning or its meaning is not compatible with what we had expected” (Gadamer, 1975/1960, p. 237). When this happens, the dialogue begins. The student questions what is known within the entire horizon. The horizon may shift in the process. “A horizon is not a rigid frontier, but something that moves with one and invites one to advance further” (Gadamer, 1975/1960, p. 217).

The Course Dossier Method

Early in the course on science for humanities students, students participated in a one-hour in-class “workshop” on how to use reflective writing. Students were given a rubric (see Table 1), which is used to correct reflective writing. They were to begin by reading a textual extract (a section of the textbook). They were instructed to first read the extract very carefully trying to zero in on what they did not understand, and all points that they would like to be clarified during the class using underlining, highlighting, and/or summarizing the textual extract.

Students were asked to note as shown in the first row of Table 1, the reflective writing activity involved writing for themselves rather than writing to please their instructors. The second and third rows of Table 1 were designed to encourage students to engage the textual material in the manner of a hermeneutical circle. The last row was meant to encourage the students to critically examine the material and to encourage class discussion.

The course dossier method was described by Kalman (1999). Discussions about the material the students had read took place in class. After these discussions in class, at the end of the week, students wrote a one-page post-summary of the discussions, the “critique.” The critique could take various forms. In a course for humanities students, it would be a one-page essay, written in a manner that someone who does not know science could understand. This essay would begin with a short introductory paragraph concerning some particular concept presented in class that week. The rest of the essay would be a critical analysis of the concept. The critiques were done each week over a 13-week semester. Critiques provided a second opportunity to re-examine the concepts.

The course dossier method employs scaffolding in the manner of Vygotsky’s (1978, 1994) social constructivism. This approach is based on “a new and exceptionally important concept: the zone of proximal development” (ZPD) (p. 85). Vygotsky critiqued the assumption that a student’s developmental level is entirely given by a battery of tests of varying difficulties. Vygotsky believed that judging how well students solve the tests and at what level of difficulty is only one measure of the student’s developmental level. In his opinion, what the student can do “with the assistance of others might be in some sense even more indicative of their mental development than what they can do alone” (p. 85). As an example, suppose that two students in the introductory course are tested to be at the concrete operational stage of cognitive development (Inhelder & Piaget, 1958). This would mean that these students on their own could deal with tasks that have been standardized for the early concrete operational stage, but not beyond this. Suppose that you then propose a problem that requires a higher level of development and ask the students to complete it, or suppose that you offer leading questions. That is in some way the students are given some assistance in solving a higher-level problem. Suppose that in such a scenario, one student can deal with problems up to the early formal level of cognitive development (Inhelder & Piaget, 1958) and another student up to the late concrete level. Can we still say that the two students are at the same intellectual developmental level? Vygotsky argues that the two students are not actually at the same developmental level and that

“the subsequent course of their learning would obviously be different” (p. 85). This difference is called the ZPD. In Vygotsky’s view, whereas the tests show functions that have already matured and characterize the level of mental development *retrospectively*, the ZPD corresponds to functions “that have not yet matured but are in the process of maturation” (p. 85); that is, the ZPD characterizes mental development *prospectively*. Indeed, in his view, learning is ineffective, when the teaching is oriented towards developmental levels that have already been reached: “The only ‘good learning’ is that which is in advance of development” (p. 89).

Table 1
Marking Criteria for Reflective Writing

Features Present in the Reflective Writing Product	Meets Criteria Fully (100%)	Meets Most of the Criteria (65%)	Minimally Meets the Criteria (35%)	Does not Meet Criteria (0%)
Student presents the key concepts of the subject as s/he understands them.	Complete Does not copy the lesson.	Covers all concepts but not really in own words.	Partial coverage of concepts.	
Student describes the relationship between the various concepts.	Qualitative interpretation used to compose the relationship in the words of the student.	Surface description of qualitative interpretation used to compose the relationship.	Some attempt to compose the relationship.	Not able to interpret.
Student relates key concepts to his/her own life experiences.	Shows clear understanding of how the concepts occur in everyday situations.	Shows partial understanding of how the concepts occur in everyday situations.	Mention of everyday situations without any explanation of how they relate to concepts under study in current sections.	No relationships to his/her own life experiences are given.
Student formulates his/her own question(s).	Student realizes that there are concepts in the textbook that s/he does not understand and elaborates a clear question.	Student sets out a question that is not clearly formulated.	Student notes the difference between the students’ own ideas and the versions found in the textbooks without any discussion.	No questions given.

Wood, Bruner, and Ross (1976) use the term scaffolding to characterize the process by which students are assisted in the development of the functions found in their ZPD. The Vygotskian notion is that students can be scaffolded to successfully grapple with the concepts in a social setting involving the instructor and/or their peers. When they share their concepts with their classmates or peers they reconstruct their knowledge as an active learner, because they are not solely dependent on the instructor’s lectures.

Students review their critiques and are scaffolded with their peers in the following manner; at the end of the course, the students collect all or a sample of their critiques and write a single overview of the course using the following 6-step Course Dossier Method:

1. Two friends, who are not in the course, read the collected critiques and make comments.
2. The student rereads the collected critiques with the comments and writes reflectively on the collection.
3. The entries in step 2 are used to develop some common theme(s) that run through the work.
4. The themes are developed into a draft of an essay of ten pages. The essay must be a critical examination “covering” the entire course in terms of the themes based on material discussed in class.
5. The two friends read the draft and record their comments.
6. The draft is rewritten reflecting a reconsideration of the material especially in consideration of the remarks by the two friends.

Students are informed that if any step is missing from the dossier, the dossier will not be marked. The Course Dossier Method is summarized in Figure 1.

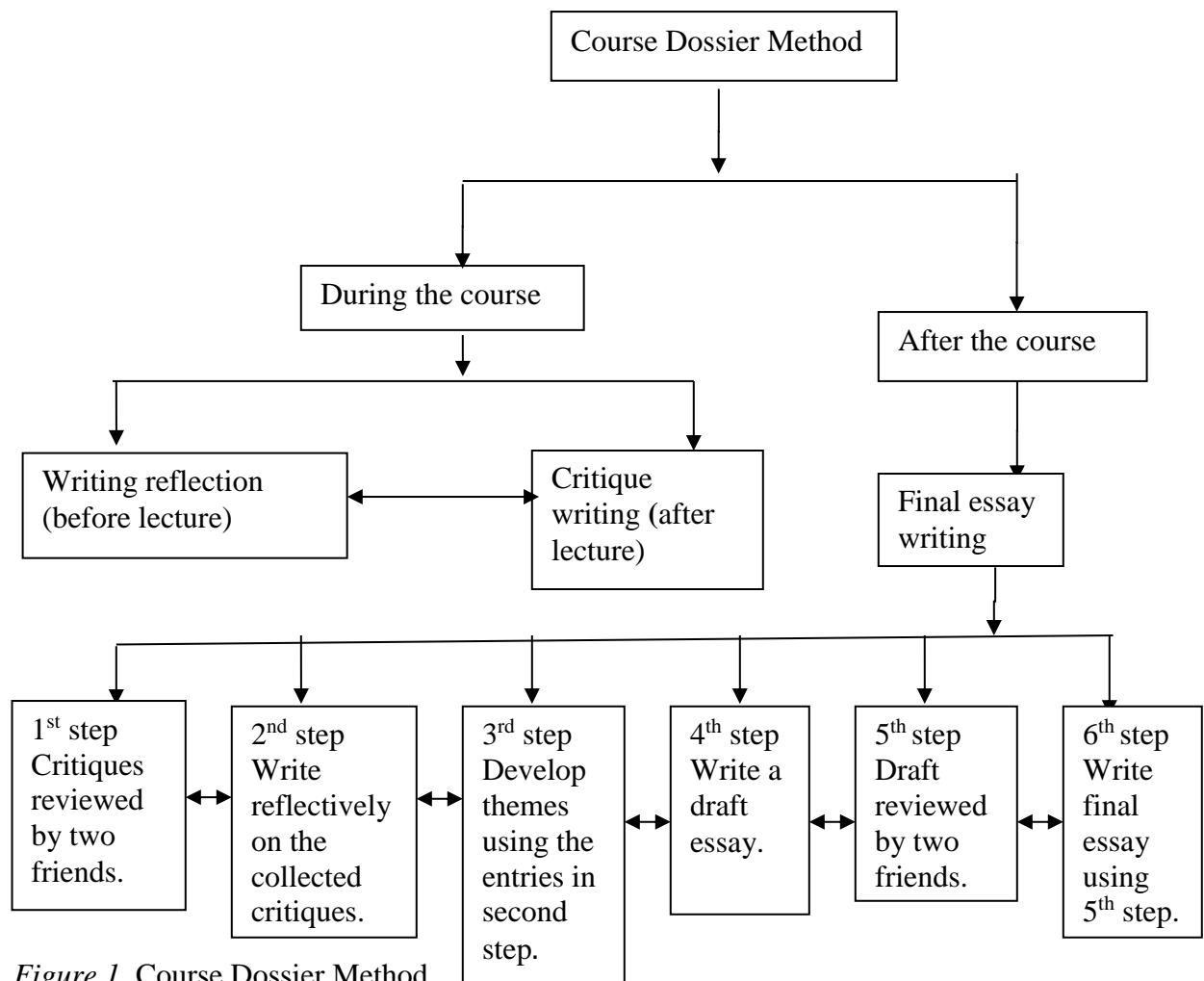


Figure 1. Course Dossier Method.

The audience for the critiques and the final essay is the student reviewers (two friends) and that is why they are written in a manner that someone who does not know science can understand. Because the two friends are not in the course, it impossible to ask them to undergo training. Students found it possible to find two fiends to undertake the task, and the friends always seemed to be helpful to the students.

During the course, the writing reflections before the class gave the students the opportunity to examine their pre-understanding. In critique writings after the class, they could re-examine their concepts. After the course, the students reviewed all of the critiques in writing the final essay. The students examined and re-examined their pre-understanding and combined the pre-understanding with new ideas through this method. These activities engaged the students in a hermeneutical movement.

Moreover, the course dossier method gave students the opportunity to share their thoughts with the reviewers. The students examined and re-examined their understanding of the subject matters with the aid of the reviewers' comments.

The Course

The initial enrolment in Physics 200: From Particles to Galaxies was 58 students who had not taken any post-secondary science courses. Ten students withdrew early in the course. The remaining 48 students comprised 34 male students and 14 female students. Students were enrolled in a wide number of humanities subjects and were from all three years of a BA program. The distribution of marks for the course were as follows: reflective writing – 20%, critiques – 20%, and course dossier – 60%.

The textbook for this course (Kalman, 2010) was written after one of the authors had taught this course for ten years. The book covers only those topics that are germane to the course. The course objectives are given in the course outline as: (a) to understand how science functions and (b) to develop the critical thinking skills needed to critically analyze ideas and compare them with observations of how nature functions. Students need to distinguish between concepts, hypotheses, and observations of nature.

It was thought that these objectives could be achieved by getting students in examine the modern theory of the creation and origin of the universe. To give students background for this examination, the course covers a rapid history of physics from Aristotle though quantum mechanics.

Method

The purpose of the present study was to assess student learning in the course. More specifically, students' conceptions of science and epistemological beliefs were assessed via interviews and student writing products. It was hypothesized that the specific pedagogical devices employed in this course would enable students to develop a rich, multi-faceted conception of science and to develop more complex epistemological beliefs. The authors believe that the insights gained from the present study would be widely applicable to the instructional design of other courses and would help reach a better understanding of desirable academic outcomes such as critical thinking, student engagement, and conceptual change.

We followed methods used in an intrinsic case study as recommended by Stake (1998) and Merriam (1988). We considered this to be an intrinsic case study because the students'

perspectives were of primary interest within the context of the particular course design used in this study. The course was examined in several ways. Firstly, a semi-structured pre-interview (Merriam, 1988) was conducted early in the semester, and a semi-structured post-interview was conducted when the classes were over with the four students who were willing to participate in this study. One of the students (JS) was majoring in Communication Studies, one (TS) in History, one (DC) in Religion, and the fourth student (LL) in Psychology. We also examined the writing products of eleven non-interviewed students to confirm that the interviewed students were representative of the whole class. All of these students signed an ethics agreement that had been vetted by the university ethics committee.

Students' code names for the interviewed (JS, TS, DC, LL) and the non-interviewed (AR, AV, BDS, CR, EW, JH, JL, KC, LGG, MF, RW) students were used because of ethical concerns. Interviews were conducted by a graduate student who was close in age to the interviewees. The interviewer did not share the contents of the interviews with the instructor until after all grades were submitted. Once the transcriptions were completed, the "within-case analysis" recommended by Stake (1998) was followed to analyze the interviewed data and the writing products that provided the detailed description of each case and the themes within the case (Creswell, 2007). (Software analysis packages were not used in the analysis.)

The interviews were audio- and videotaped and were later transcribed verbatim. The interview questions are in the appendix. The purpose of the interviews was to get an understanding of what the students were doing when they performed each stage of the course dossier process. It was also used to explore how the students used the various elements of the course dossier to understand the concepts presented in the course. The questions were also designed to explore in what way the students' understanding of concepts of physics improved and if there was any change of the students' views of physics after using this method.

To be clear on what the students did to carry out the activities, questions repeated similar themes: How did you prepare your preview sheets (reading reflections) before the lectures presented in the class? What did you do when you were preparing your preview sheets? How did these writing reflections influence you?

Triangulation was used to establish credibility. The results of an analysis of the students' writing products were compared to the results of the interview analysis to assess whether they corresponded or conflicted with each other. We compared the interviews and the writing products, what students said in the interviews, and if what they said is supported by what they did in their writing products.

It is obviously a limitation of this study that only four students were interviewed. To confirm that the interviewed students were representative of the whole class, the complete course dossiers including all the students' critiques of each of the interviewed students were compared to the dossiers of eleven non-interviewed students. This was particularly important because the students who had volunteered for the interviews were all male, whereas the additional students, who gave us permission to examine their writing products, comprised seven male students and four female students. The marks of the interviewed and non-interviewed students were typical of the whole class.

Data Analysis

Repeated readings of the interviews and the course dossiers led to the identification of re-occurring general and specific themes that were common to all students, as well as themes that

were unique to particular students. We have taken from the students' responses and the writing products the gist of what they say. We do not examine students' reflective writing products since reflective writing in and of itself, and as a hermeneutical circle, has been extensively examined elsewhere (Kalman, 2011).

Students in this study were generally successful in finding the important concepts covered in the class, but in the early critiques, the explanations about those concepts were unclear. For example:

Heisenberg's uncertainty principle appears to demonstrate that accepting probability is not opposed to being certain (or at least as certain as possible) about the given phenomenon. In an interesting paradox, this acceptance of probability instead of the old certainty led to a relief of the problem of the contradictions between Bohr's model and Maxwell's theory of electrodynamics. (JS)

Later, critiques were more understandable. In the eighth week, this same student's clarification about the expansion of the universe relating to red-shifting exemplified this:

the constant expansion of the universe (Hubble's law) means that the distance and speed at which other bodies are from earth changes, and thus so does our ability to observe those bodies. Red-shifting accounts for this. This is highly important because not only do we know that there is a changing special-temporal relationship between us and other bodies, but furthermore because we can quantify that relationship and represent it accurately. (JS)

Students also connected ideas from different parts of the course. In the second week, students learned about fruitful theories. At that time, AV's concern was the fruitfulness of a theory. But later, when the model of the solar system and the wave-particle nature of light was presented in the class, he understood that:

I think we could consider this (Einstein's photo electric effect) to be a fruitful theory in that it incorporates old facts (Lenard's idea) with new ones. Since light could be demonstrated as having particle and wave properties (being dispersed as 'quanta' but moving like a wave as demonstrated in previous experiments), Einstein's conception seems to provide the strongest case for the nature of light. (AV)

Further, he explained why a fruitful theory is more beneficial than other scientific methods, which may help us to formulate a realistic picture of science.

Rereading the critiques was helpful to students. Student AV made a very good comparison of the Baconian philosophical method of science and the Newtonian hypothetico-deductive method of science in the post writing (free writing) part of the second entry. This had not been explained well in his critique writing earlier in the semester. But after rereading the critiques, he noted:

this makes me realize that a fundamental difference between Bacon's and Newton's methods that I didn't consider in my critique is how Bacon's method seems more based on an individual's understanding of what is observed, while Newton's method involves

the responsibility of demonstrating to other scientists that what is being observed is explainable and that the explanation can be questioned, and if found to be lacking, it can be improved. (AV)

Reviewers asked many questions about the critiques. Consider a non interviewed student BDS, an English and Creative Writing major. One of the reviewers asked student BDS: “Do you think science is the pursuit of existing structures in nature or a means of organizing that which we observe or somewhat in between?” In the final essay, the student tried to answer those questions and explained his thoughts about of science in detail. He said,

We can now try to formulate a cohesive understanding of what the science of physics is, especially in regards to particles and galaxies. Sticking with our Aristotelian roots, we can do so through an understanding of its material and formal causes, its efficient causes and its final cause. Science as we’ve seen it, is comprised of thoughts, observations, evidence, data and analysis, and involves the process of applying abstracted, universal knowledge to particular events and phenomenon. . . . Science therefore is the forward ebb of our knowledge horizon concerning a relative objective truth about the natural world around us. Particles and galaxies, despite being on the opposite spectrums of the macroscopic and microscopic scales, can be syncretically studied when looked at in such a fashion. After all, both areas are concerned with building new knowledge on the foundation of older theories and laws, and it is this search for ultimate truth from within the unknown and through the use of the scientific method that reconciles these two, otherwise quite distinct, realms of knowledge (BDS).

Student DC said that one of the reviewers pointed out themes such as “experimentation, development of scientific method, opinion and biases of scientists are important to consider...”, “Determinism: how ideas have changed from the belief that everything in the universe” (1st entry). He used those themes in writing his essay. Based on the reviewers’ comments, TS found a theme “perception” of the course that made it easier for him to write the essay. Another non-interviewed student AR used particle physics as one theme of the course because he thought, “the sheer amount of knowledge I picked about particle physics is simply staggering that definitely has to go in there” (final essay). A large part of the final essay was a discussion of particle physics. Not only the concepts behind particle physics but also quantum mechanics were explained in more detail in the final essay. Student BDS stated that,

when I first signed up for this class on particles and galaxies I thought of how strange it was for distinct categories were to be presented alongside one another in a singular class and didactic process. After several weeks of the course, however, certain themes started to emerge and different general approaches to scientific knowledge became more apparent. And while the subject matter still seemed to contradict itself at times (by the end of the course it was clear the theories of general relativity and quantum mechanics are still somewhat non-syncretic) the underlying commonality of the nature of scientific development held the two domains closely together. (BDS)

In the final essay, student CR used “microcosm and macrocosm” as a theme of the course and explained it in a very logical manner:

In the past century or so, the world of physics has advanced to the point of being able to explain the microcosm and macrocosm of the universe from the tiniest to the grandest of scales we have yet observed. We move away from examining that which is immediately observable to us, whether with or without the aid of advanced technology, and into the dissection of the atom and the mapping of super-clusters. What is incredible seeing the reflection of the microcosm realm in the macroscopic realm? ‘Inflation’ is an excellent example of this idea (CR).

The analyzed data were tabulated based on the units- what was the change in students’ understanding of the subject matters at the end of the course compared to early in the semester, how helpful the reviewers’ comments were to discover the misconceptions or new ideas, in what way the course dossier method helped the students to improve their understanding of concepts of physics, and if there were any changes of the students’ views of physics after using this method. A short discussion was given for each case (four students who were interviewed) by comparing the interviews and the writing products, what they said in the interviews, and if what they said is supported by what they did in their writings products.

TS and DC mentioned that elements of the course dossier method helped them to come up with questions. As has been noted this is a key element in the hermeneutical circle. JS spoke about the critiques helping him to review the material. This is again evidence of a hermeneutical approach to the concepts. LL liked the method. There is evidence of scaffolding in their comments as well. JS spoke about the reviewers helping him explain things better and helping him to better understand the concepts. TS spoke about the interaction with the student reviewers as “opening up our minds about physics, not just memorizing.” DC said the basis of the course dossier method is just reflective. More details are found in Table 2.

Table 2
Responses to the Interviews

Research Questions	Student	Students' Approach
1. In what ways were the critique writings helpful to change students' understanding of concepts?	JS	The critique writings helped him to think about the course materials. Looking back at the critiques was very significant because he had to go back to the course materials.
	TS	He thought the critiques opened up his eyes about science because he found common themes after reviewing the critiques.
	DC	The critiques were challenging for him, because there were many concepts to understand and did not try to explain those concepts in a critical manner. In writing the critiques, he was just summarizing or paraphrasing the facts from the book in his own words.
	LL	He did not bring up physical things in his critiques writings, so his critiques were not clear to understand the subject matter.
2. In what ways were the reviewers' comments useful for students in analyzing the concepts?	JS	The reviewers found mistakes in his writing, and he was not able to use all of the reviewers' comments in explaining the concepts because of lack of time.
	TS	The reviewers' comments were very helpful because of their analysis of the critiques.
	DC	When he was reading the reviewers' comments, he discovered many questions about science, which motivated him to write something better.
	LL	His reviewers did not give him meaningful comments because they were very busy at that time.
3. How helpful was the course dossier method in improving the students' understanding of physics concepts?	JS	It was an interesting process for him and a very different learning method.
	TS	The overall course dossier opened up his eyes and his mind about physics because this method caused him to think about concepts rather than memorizing facts.
	DC	This learning method was a way for him to review the concepts and to learn something new by going over the course materials multiple times.
	LL	This method is really rare in educational system and can help students to think deeper and can help make links to real life.
4. How has the course dossier method changed the students' views on physics?	JS	This course has changed his perception about science, because before he thought science was straightforward. Now he realized science is two steps forward and one step backward. His perception about physics really changed after the course.
	TS	Before taking this course, he thought physics was basically related to speed, velocity, or force. After the course, he realized that physics is everything around us.
	DC	No indication
	LL	No indication

The four students who were interviewed looked at the course dossier method positively. Two students (JS and TS) followed the method properly except in using the reviewers' comments (due to lack of time). JS and TS alone used the reviewers' comments for themes. It would have been possible for JS and TS to have a higher grade if they had followed the reviewers' comments properly; nonetheless, their perceptions of physics changed. Every step of the course dossier method engaged JS and TS with the materials of the course because they reviewed the materials again and again. This process helped them to discover misconceptions and to reach a level of insightful understanding. DC missed five critiques and was more of a passive learner; he summarized the facts in writing the critiques and did not use the reviewers' comments. Not using these comments impacted on his final grade negatively. LL was a very different case than the others. His course dossier was not related to the course material. He did not follow the method at all and did not take the course seriously, so he received a failing grade. In Table 3, we give an overall comparison of the students' writing products with their interviews. We analyzed the students' writing products to compare what they did to what they said they found (as noted in Table 2).

Table 3
A Summary of the Analyzed data (Interviewed Students)

Case	Earlier Critiques	Later Critiques	Reviewers Comments	Final Essay	Final Grade ¹
JS	found the important concepts, explanations were unclear discovered the very important concepts, but the explanations were not clear summarized the topics, missed five critiques the writing products were not related to the course	explanations of the concepts were improved writing about the concepts improved	very useful, did not use all the comments because lack of time very useful to find the missing parts, did not use all the comments	much better than the critiques explanations were much better than the critiques better than earlier writing products	A A ⁻ B ⁻
DC	missed some critiques		useful to discover themes did not use the reviewers' suggestions	did not follow the instructions at all	failing grade

¹ A is the top grade received in a course. Lower grades are B, C, D, Fail.

JS and TS tried to follow the instructions of the method properly, and they did not miss any critiques during the semester. In comparing their critiques, we find that their understanding of physics concepts improved during the semester and after the semester in writing the course dossier. For JS, the reviewers' comments were very useful, but he claimed that it was not possible for him to use them because of lack of time. The reviewers' comments were also very useful for TS to find out the themes although he did not use all the comments. DC missed five critiques. Although the reviewers could not give him many comments on the critiques, nonetheless they were helpful for him to find out the themes needed to write the final essay. LL

did not follow the method at all. Although very short but good suggestions came from the reviewers, he did not use them.

We also examined the writing products of eleven non-interviewed students to confirm that the interviewed students were representative of the whole class. Summaries of this examination of their writing products are found in Table 4, and the grades of these students are found in Table 5.

Table 4

A Summary of the Analyzed Data (Non-Interviewed Students)

Case	Earlier Critiques	Later Critiques	Usefulness of Reviewers' Comments	Final Essay	Changes in Views/Students' Comments ¹
AR	summaries of the topics	identified very important concepts, did not explain them in depth	very useful for finding the missing parts in the critiques	explanations of the concepts were much better than in the critiques	"I have to say that this has been an incredible experience. It has opened my mind to many of the inner working of the universe."
AV	identification of concepts, but unclear explanations	made a connection between the ideas found in his earlier critiques with new thoughts discovered later on in the course	helpful for identifying the missing ideas in pre-writing	explanations of the concepts were better than in the critiques	"Science becomes more of a continual process of improving human knowledge by constantly testing it and verifying hypotheses as new means of observation and experimentation."
BDS	identification of very basic concepts, explanations were somewhat unclear.	more details than in earlier critiques	very useful for further writings	concepts were clearer than in the critiques	"Prior to this course, I had thought that this (Quantum Mechanics) strictly opposed a classical, mechanical and deterministic view of reality... I now understand the uncertainty principle and quantum mechanics to be a predictive theory rather than a descriptive one."
CR	more descriptive rather than conceptual	more conceptual than in the earlier critiques	very useful for explaining the concepts	more conceptual than in the critiques	"I am grateful for having taken this class as it opened my mind to scientific approaches."
EW	more descriptive than conceptual	explained the concepts better than in the earlier critiques	helpful to clarify the concepts further	much better than the critiques	

JH	more descriptive than conceptual	better than the earlier critiques	helpful in writing the final essay	much better than the critiques, critiques were very helpful in writing the final essay	
JL	summaries of the important topics	more descriptive than conceptual	very helpful to identify the missing concepts	very well written compared to the critiques	“Rereading my critiques really helped me understand how many theories and concepts I wasn’t able to fully understand, and which ones I felt the most drawn to.”
KC	identification of the key concepts, explanations were not clear	improved explanation of the concepts	very helpful for further writings	explanations were clearer than in the critiques	
LGG	more descriptive than conceptual	improved explanation of the concepts	very helpful to understand the concepts	much better than in the critiques	“It just confirms that I have understood most of the concepts and my friend’s reviews have helped me to be able to better understand about what I’ve wrote.”
MF	summaries of the topics	more clear than earlier critiques	very helpful to reorganize the final essay	concepts were much better than critiques	“My initial ideas ... to physics... consists of technical formulas, equations and basic theories.” Later on, “I think the scientific framework needs to adjust its philosophy to take in intuitive thought.”
RW	explanations of the concepts were unclear	improved explanation of the concepts	helpful to expand the thought further	very well-written, better than the critiques	“The course dossier was an amazing tool for learning ... it forced me to re-evaluate my knowledge of the concepts ... also allowed me to go back to the concepts in more detail.”

¹ All quotes are taken directly from students’ course dossiers.

Table 5
Final Grades¹ of Non-Interviewed Students

	Non-Interviewed Students										
	AR	AV	BDS	CR	EW	JH	JL	KC	LGG	MF	RW
Final Grade	B ⁻ (missed 6 critiques)	A ⁺	A ⁺	A ⁺	not enrolled in the course	B ⁺ (missed 4 critiques)	A ⁺	A ⁺	A	A ⁻ (missed 1 critique)	A ⁺
Number of critiques missed	6					4				1	

¹ A is the top grade received in a course. Lower grades are B, C, D, Fail.

As shown in Table 4, students' (AV, BDS, CR, EW, JH, KC, LGG, MF, and RW) understanding of the concepts changed in the same way as the interviewed students during the semester. These students did not explain the concepts in the earlier critiques in a clear manner, but the explanations improved in the later critiques. AR missed six critiques, and during the semester, his concepts did not improve significantly. The reviewers' comments for AR could have been very helpful for him to improve his understanding of the concepts and could have helped him to write a final essay in a critical manner. He lost marks in the critiques so that his final grade was B-. JH also missed four critiques, and this affected his grade (B+); although, the reviewers' comments helped him to write a better final essay. For JL, in contrast, his understanding of the concepts did not improve during the semester, but in writing the final essay his understanding of the concepts were drastically changed by using the reviewers' comments, and this helped him to write a very good final essay (he received an A+ grade). Also, for AV, BDS, CR, EW, KC, LGG, MF, and RW, their reviewers' comments were very helpful to enhance their understanding of concepts as exhibited in in the final essay. AV, BDS, CR, KC, and RW, received a final grade of A+, and they wrote all the critiques.

Finally, note that the students' attitude to science changed in writing the course dossier. Moreover, JL, LGG, and RW's comments indicate that the course dossier method helped them in learning physics concepts in a different way.

Conclusion

We had an interesting example of one student (LL) who did not follow the method and received a failing grade. All of the other students' understandings of concepts improved markedly by using the course dossier method. Every week, critique writing helped them to raise questions in class, which motivated them to discover new concepts. Moreover, earlier critiques helped students in this study to link the prior concepts with new ideas. Rereading their own critiques after the semester helped them to discover their pre-understandings. For most of the students, the reviewers' comments were helpful to construct their physical concepts. Some of the reviewers asked many questions, and some of them gave very good suggestions after reviewing the critiques and the draft of the essay. The course dossier method allowed the students to structure and to restructure their conceptual knowledge in a clear manner with the help of peers.

The overall results and discussion show that the course dossier method helped the students to improve their understanding of concepts.

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Appendix

Pre-interview questions: Before starting to ask you questions I would like to explain to you the meaning of pre-understanding/ pre-knowledge. Pre-understanding/ pre-knowledge means the knowledge you had learned/experienced before. For example, maybe you have some ideas about space, galaxies etc. That means you have some previous knowledge about this course and these are your pre-understanding/pre-knowledge.

1. What is your pre-knowledge about physics/galaxies before starting the course PHYS-200?
2. What is your pre-understanding/pre-knowledge of this course in general?
3. How did you get this pre-understanding/pre-knowledge?
4. Do you think your pre- knowledge will be helpful to understand this course?
5. If Q. 4 is yes how and why?
6. What is your expectation from this course?
7. If you already know about the course dossier method from the course outline or from a class, do you think this method will fulfill your expectations?
8. If Q. 7 is yes how and why?
9. What is your personal thinking about the CDM before starting this course?

Post- interview questions: You used the course dossier method in your course PHYS 200; you know there were several activities like writing reflection (preview sheets), critique writings, final essay writing, I would like to ask you several questions on those activities. Let's start...

1. How did you prepare your preview sheets (reading reflections) before the lectures presented in the class?
2. What did you do when you were preparing your preview sheets?
3. How did these writing reflections influence you?
4. How did you prepare your critique sheets (concept reflections) after the lectures presented in the class?
5. What did you do when you were preparing these sheets?
6. What do you think was the point of writing a preview sheet?
7. How did the preview sheets influence your critique writing?
8. How did the critique writings open up your views on science?
9. What do you think was the point of writing a critique?
10. How did you prepare your final essay?
11. How helpful were your friends' comments on your writing the final essay?
12. What was the impact of your critique writings on your final essay?
13. Did working on the course dossier change your ideas about material in the course?
(Probe: if yes, in what way?)
14. After the course what is your personal thinking about the course PHYS 200?
15. What are your personal feelings about the course dossier method?
16. Do you think the course dossier method helped you to fulfill your expectations in this course? (Probe: if yes how?)
17. Has this course changed your ways of thinking about other people's ideas? (Probe: if yes how?)
18. What do you think was the point of writing a course dossier?
19. Has this course changed your perception about science? (Probe: if yes how?)