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ACCEPTANCE

This dissertation, CONSIDERING HANS-GEORG GADAMER'S PHILOSOPHICAL HERMENEUTICS AS A REFERENT FOR STUDENT UNDERSTANDING OF NATURE OF SCIENCE CONCEPTS, by JARED MICHAEL RASHFORD, was prepared under the direction of the candidate's Dissertation Advisory Committee. It was accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chair, as representatives of the faculty, certify that this dissertation has met all standards of excellence and scholarship determined by the faculty. The dean of the College of Education concurs.

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ABSTRACT

CONSIDERING HANS-GEORG GADAMER'S PHILOSOPHICAL HERMENEUTICS AS A REFERENT FOR STUDENT UNDERSTANDING OF NATURE-OF-SCIENCE CONCEPTS

by

Jared M. Rashford

The purpose of this study is to examine philosophical hermeneutics as a referent for student understanding of Nature-of-Science (NOS) concepts. Rather than focus on a prescriptive set of canons used in addressing NOS pedagogy in K-12 schools, this study seeks to explicate a descriptive set of principles based on Hans Georg-Gadamer's theory of interpretation that has the potential for developing dispositions necessary for understanding. Central among these are the concepts of fore-structure, prejudice, temporal distance, and history of effect, all of which constitute part of the whole of the hermeneutic circle as envisaged by Gadamer. As such, Gadamer's hermeneutics is contrasted with Cartesian epistemology and its primacy of method, the Enlightenment's prejudice against prejudice, the modernist/progressive tendency to consider all situations as problems to be solved by relegating all forms of knowledge to *techné*, and the subjective nature of interpretation inherent in a hermeneutics of suspicion. The implication of such a conceptual analysis for NOS pedagogy is that student understanding is considered not so much as a cognitive outcome dependent on a series of mental functions but rather as an ontological characteristic of *Dasein* (being-human) that situates learning in the interchange between interpreter and *text*. In addition, the philosophical

foundations implicit in addressing student understanding of NOS found in many curricular reform efforts and pedagogical practices in science education are questioned. Gadamer's hermeneutics affords science education a viable philosophical framework within which to consider student understanding of the development of scientific knowledge and the scientific enterprise.

CONSIDERING HANS-GEORG GADAMER'S PHILOSOPHICAL HERMENEUTICS AS A REFERENT FOR STUDENT UNDERSTANDING OF NATURE-OF-SCIENCE CONCEPTS

by

Jared M. Rashford

A Dissertation

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CHAPTER ONE

PHILOSOPHICAL HERMENEUTICS AND NATURE-OF-SCIENCE UNDERSTANDING

Introduction

Scholarship pertaining to the teaching and learning of nature-of-science (NOS) concepts in K-12 schools gained momentum in the 1990s as a result of the heightened significance imparted on both student and teacher understandings of scientific knowledge and the scientific enterprise found in three seminal curriculum reform documents released at the turn of the century.[1] Numerous scholars have sought to examine how such understandings relate to particular tenets posited to be representative of a consensus, desired view of NOS whereas others have explored their relationship to effective classroom practice.[2] While these studies may suggest similar findings supported through empirical observations, they generally fail to provide a philosophical analysis of the concept of understanding itself and, in fact, may potentially foreclose student and teacher understandings of NOS. I contend here that the discipline of hermeneutics affords NOS

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[1] American Association for the Advancement of Science, *Project 2061: Science for All Americans* (Washington, DC: Oxford University Press, 1989); American Association for the Advancement of Science, *Benchmarks for Science Literacy: A Project 2061 Report* (New York, NY: Oxford University Press, 1993); and National Research Council, *National Science Education Standards* (Washington, DC: National Academic Press, 1996).

[2] The scholarship pertaining to student NOS understandings is discussed at length both later in this chapter as well as in Chapter Three. For an example of research pertaining to a consensus view, see Norman Lederman and Molly O'Malley, "Students' Perceptions of Tentativeness in Science: Development, Use, and Sources of Change," *Science Education* 74 (1990): 225-239. For an example of research related to effective classroom practice, see Nancy Brickhouse, "Teachers' Beliefs About the Nature of Science and Their Relationship to Classroom Practice," *Journal of Teacher Education* 41, no. 3 (1990): 53-62.

scholars and the greater education community an opportunity to enlarge the discourse surrounding the concept of *understanding*; a form of reasoning that, at least in science education, seems to have almost entirely managed to escape any form of conceptual analysis despite its ubiquitous mention in both the literature and policy documents.

Shawn Gallagher, in his important work *Hermeneutics and Education,* initially addresses the conceptual ambiguity surrounding the use of the term hermeneutics in a variety of disciplines including theology, law, philosophy, literature, and the social sciences.[3] What he finds in common among the multifarious definitions included is their respective identification of understanding or interpretation as the subject matter of hermeneutics. In particular, this study emphasizes philosophical hermeneutics as explicated by Hans-Georg Gadamer. While he did not write extensively on the subject of education,[4] Gadamer is credited with developing a hermeneutics not as an attempt to prescribe a method or set of methods for understanding "…but to discover what is common to all modes of understanding and to show that understanding is never a subjective relation to a given 'object' but to the history of its effect; in other words, understanding belongs to the being of that which is understood."[5] Gallagher interprets Gadamer's philosophy as a moderate hermeneutics situated between the more conservative claims of Schleiermacher, Betti, and Hirsch, the more radical views of Nietzche, Heidegger, and Derrida, and the more critical perspectives of Habermas, Marx,

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[3] Shaun Gallagher, *Hermeneutics and Education* (Albany, NY: State University of New York Press, 1992), 3-4. This work will be cited as *HE* in the text for all subsequent references**.** Gallagher is explicit in his attempt to "…arrive at a working conception, although not a final or adequate definition, of hermeneutics."
[4] See for example, Hans-Georg Gadamer, "Education is Self-Education," *Journal of Philosophy of Education* 35, no. 4 (2001): 529-538.
[5] Hans-Georg Gadamer, *Truth and Method*, trans. Joel Weinsheimer and Donald Marshall (New York, NY: Continuum Press, 2006), xxxi. This work will be cited as *TM* in the text for all subsequent references.

and Freud, each of which is addressed more thoroughly later in this introductory chapter.[6] A limited number of scholars have explored the implications of philosophical hermeneutics for the field of general education and science teaching and learning respectively.

The goal of this study is to determine the viability of using philosophical hermeneutics to conceptualize student understanding of NOS. In particular, I attempt to expound the philosophical assumptions inherent in favoring student understanding of a consensus and/or desired view of NOS, as evidenced by the standards and empirical research. Rather than rely on the effectiveness of a prescriptive set of canons used in addressing NOS pedagogy in K-12 schools, this study then seeks to explicate a descriptive set of principles based on Gadamer's theory of interpretation that has the potential for developing dispositions for understanding NOS considerations. A description of such an analysis is contained in Chapter Two.

It is important to introduce briefly at this point the distinction between a Gadamerian conception of understanding and one credited to Descartes[7] as well as the Enlightenment ideal perhaps furthered by modernist progressives.[8] By favoring the primacy of method over knowledge, education can arguably be reduced to a set of

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[6] For a brief comparison of these perspectives, see *HE*, 9-11. It is in particular a moderate hermeneutical perspective that Gallagher uses to characterize Gadamer's thought that I will explicate in my consideration of NOS understandings.

[7] René Descartes, *Discourse on the Method for Conducting One's Reason Well and for Seeking Truth in the Sciences*, trans. Donald A. Cress (Indianapolis: Hackett Publishing Company, 1998).

[8] In chapter six of *HE*, Gallagher uses Gadamer's hermeneutics to present a strong argument against the modernist conception of education with its emphasis on *techné* and critical problem solving which he credits to the dualistic epistemology (subject/object) initiated by Descartes. Another scholar, however, uses the same Gadamerian notion of understanding to question the primacy Gallagher affords to his modest view of education over other philosophies, namely the modernist one under attack. See, Deborah Kerdeman, "Hermeneutics and Education: Understanding, Control and Agency," *Educational Theory* 48, no. 2 (1998): 241-266.

techniques which allow us to manage information which in turn can result in a direct transmission of the same information that amounts to a potential form of indoctrination.[9] In contrast, philosophical hermeneutics strives to retain "the term hermeneutics not in the sense of a methodology but as a theory of the real experience that thinking is"[10] and, as such, favors a view of education that remains open to the possibilities of interchange and subsequent interpretations that are constitutive in developing understanding.[11] This study explains the central concepts involved in Gadamer's hermeneutics as well as integrate these concepts in the discourse surrounding student understanding of NOS.

The remainder of this chapter contains an introduction to several themes that are further elaborated in subsequent sections, beginning with an overview of curriculum reform efforts and scholarly research centered on NOS instruction in K-12 schools. Similarly, a brief account of the development of the hermeneutic discipline is included so as to provide a context for comparing a variety of perspectives regarding understanding and interpretation as they relate to education. Lastly, the significance of the study for the field of science education is presented. I aim to further the work of other scholars in demonstrating that a hermeneutic approach to understanding not only provides a

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[9] This particular view is evidenced in the writings of Padraig Hogan and Richard Smith, "The Activity of Philosophy and the Practice of Education", in *The Blackwell Guide to the Philosophy of Education*, Nigel Blake, Paul Smeyers, Richard Smith, Paul Standish, eds., (Oxford, UK: Blackwell Publishing, 2003) as well as David Jardine's, "Reflection on Education, Hermeneutics, and Ambiguity: Hermeneutics as a Restoring of Life to its Original Difficulty," in William F. Pinar and William M. Reynolds, eds. *Understanding Curriculum as Phenomenological and Deconstructed Text* (New York, NY: Teachers College Press, 1992). This last reference offers a brief explanation of the relationship between hermeneutics and qualitative research.

[10] *TM,* xxxvi.

[11] While philosophical hermeneutics concerns itself more with the nature of understanding, other scholars have challenged Cartesian foundationalism for its epistemological merit. See for example, Giambattista Vico, *On the Study Methods of Our Time*, trans. Elio Gianturco (Ithaca, NY: Cornell University Press, 1990).

favorable framework for NOS pedagogy but for the broader context of educational philosophy as well.

NOS Considerations in the Standards and Scholarly Research

Nearly a decade ago, DeBoer explicated the historical and contemporary understandings of scientific literacy.[12] His thorough analysis addressed the varied implications inherent in the use of such an ambiguous construct for more than half of a century in the discipline of science education.[13] From considering science education as a vehicle for democratic change and a legitimate intellectual pursuit to positing a strong relationship between scientific progress, national security, and technological and societal change, agencies such as National Education Agency (NEA), the National Society for the Study of Education (NSSE), the President's National Research Board (PNRB), the National Science Teachers Association (NSTA), the National Science Foundation (NSF), the American Association for the Advancement of Science (AAAS), and the National Academy of Science (NAS) have attempted to define both broadly and specifically the concept of scientific literacy. Most recently, the latter two organizations, encouraged by the standards-based reform movement, developed *Science for All Americans*, *Benchmarks for Science Literacy*, and the *National Science Education Standards*, respectively.[14]

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[12] George E. Deboer, "Scientific Literacy: Another Look at its Historical and Contemporary Meanings and its Relationship to Science Education Reform," *Journal of Research in Science Teaching* 37, no. 6 (2000): 582-601.
[13] Rudiger Laugksch, "Scientific Literacy: A Conceptual Overview," *Science Education* 84, no.1 (1999): 71-94. In this article, the author explains how the notion of scientific literacy has come to represent a variety of perspectives depending on both its use and assessment by sociologists, public opinion researchers, and science education scholars alike.
[14] AAAS, National Research Council, op.cit.

While curriculum movements for the last forty years have consistently called for inquiry learning that attempts to create classroom experiences that mimic scientific research, two notable distinctions distinguish these late 20th century reform documents from their NSF- endorsed predecessors. While the former relied primarily on the direction and expertise of scientists themselves, stressing a rigorous curriculum and targeting future scientists, efforts of the AAAS and the NAS focused instead on minimum standards for all students, preparing an effective citizenry, and teaching for increased appreciation for science and technology.[15] Secondly, the documents of the last two decades contain significant references to nature-of-science (NOS) considerations. Collectively, these have been characterized as purporting traditional images of science such as being open, accommodating, and antiauthoritarian. They maintain that "science distinguishes itself from other ways of knowing …through the use of empirical standards, logical arguments, and skepticism"[16] thereby affording students the preeminent means of developing rational thinking skills. Simultaneously, researchers have noted the impact of the science studies community on NOS discourse as evidenced by the documents' insistence on the subjective nature of scientists themselves (not scientific knowledge), the absence of any clearly defined scientific method, and the empirical indeterminacy of evidence.[17]

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[15] Steve Turner and Karen Sullenger, "Kuhn in the Classroom, Lakatos in the Lab: Science Educators Confront the Nature-of-Science Debate," *Science, Technology, and Human Values* 24, no.1 (1999): 5-30.
[16] National Research Council, 201.
[17] One of the more influential philosophical/historical accounts of science in this regard is Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago, IL: The University of Chicago Press, 1996). For further reading on Kuhn and his response to criticisms of his seminal piece, see Thomas Kuhn, *The Road Since Structure* (Chicago, IL: The University of Chicago Press, 2000). While many science educators delineate nature of science concepts in terms of their agreement with Kuhn's characterization of normal and revolutionary science, claiming that his work inaugurated the postmodern era for philosophy of science, a few scholars question the overall impact of his text on the study of science. See, for example, D. Wade

The standards put forth by the AAAS in *Benchmarks* concerning NOS fall under one of three, principle categories: the scientific world view, scientific inquiry, and the scientific enterprise. The first of these suggests that the world is understandable and that scientific knowledge, while durable, is subject to change and limited. Scientific inquiry is explained as relying on evidence, involving both logic and imagination to explain and predict, and avoiding biases. Lastly, the scientific enterprise is characterized as a social activity organized into content disciplines, with generally accepted ethical principles, and consisting of individuals who participate in public affairs as specialists and as citizens. On the other hand, the standards published by the NAS include the construct of NOS in its section on *Principles and Definitions*:

> The relation of science to mathematics and to technology and an understanding of the nature of science should also be part of their [students'] education… Scientific literacy also includes understanding the nature of science, the scientific enterprise, and the role of science in society and personal life. The *Standards* recognize that many individuals have contributed to the traditions of science and that, in historical perspective, science has been practiced in many different cultures.[18]

While its significance in the national education arena may have indeed only been realized near the turn of the century, published discourse surrounding NOS closely parallels that of scientific literacy in the education research community and has thus existed for over a century. From a contemporary perspective, however, as early as the 1960s, scholars considered NOS understanding to be an integral component of the broader construct of scientific literacy,[19] perhaps receiving renewed impetus from Snow's

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Hands, "Reconsidering the Received View of the 'Received View:' Kant, Kuhn and the Demise of Positivist Philosophy," *Social Epistemology* 17, no.2 (2003): 169-173; and Steve Fuller, *Thomas Kuhn: A Philosophical History for Our Times* (Chicago, IL: The University of Chicago Press, 2000).

[18] National Research Council, 220.

[19] For a general overview of research in this area, see Laugksch, "Scientific Literacy," and Morris Shamos, *The Myth of Scientific Literacy* (Newark, NJ: Rutgers University Press, 1995). Shamos' perspective actually represented one of the more critical arguments against the call for universal scientific literacy on

"two cultures" thesis positing the need to be knowledgeable in both science and the humanities in order to be a contributing member of a changing society.[20] Still others in turn suggest that scientific literacy be considered as consisting of *knowledge about science* as well as *knowledge in science*, the first of these involving the epistemology and sociology of science, both of which are considered NOS perspectives.[21] Additionally, some consider scientific literacy to lie at the intersection of NOS, scientific inquiry, and traditional subject matter knowledge, further indicating a considerable degree of consensus among scholars in the science education community regarding the role of NOS considerations in effective science teaching.[22]

Scholarship pertaining to the teaching and learning of NOS in K-12 schools gained momentum in the 1990s as a result of the heightened significance imparted on both student and teacher understandings of scientific knowledge and the scientific enterprise in the aforementioned national documents. Leading researchers have explored and continue to explore the nature of such understandings as well as their relationship to

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the grounds that there exists no conclusive evidence to suggest that the level of literacy of Americans presents a challenge to our ability to compete globally and make informed decisions. One of the earlier recognized advocates of nature of science and the secondary curriculum was Joseph Schwab. See Joseph Schwab, "Inquiry, the Science Teacher, and the Educator," *The School Review* 68, no.2 (1960): 176-195; Joseph Schwab, "What Do Scientists Do?" *Behavioral Science* 5 (1960): 1-27; and Joseph Schwab, *Science, Curriculum, and Liberal Education* (Chicago, IL: University of Chicago Press, 1978). For a concise review of the influence of Schwab on science education see Gary Fenstermacher, "The Nature of Science and Its Uses for Education: Remarks on the Philosophical Import of Schwab's Work," *Curriculum Inquiry* 10, no. 2 (1980): 191-197.

[20] Charles P. Snow, *The Two Cultures and the Scientific Revolution* (Cambridge: Blackwell Synergy Press, 1959).

[21] Jim Ryder, "Identifying Science Understanding for Functional Scientific Literacy," *Studies in Science Education* 36, no.1 (2001): 1-44.

[22] Renee Schwartz, Norman Lederman, and Barbara Crawford, "Developing Views of Nature of Science in an Authentic Context: An Explicit Approach to Bridging the Gap Between Nature of Science and Scientific Inquiry," *Science Education* 88, no. 4 (2004): 611.

effective classroom practice.[23] Empirical evidence from such studies suggests a number of similar findings which include the idea that both students and teachers generally hold naïve views with regards to NOS and that pedagogy emphasizing inquiry learning coupled with explicit instruction in history, philosophy, and sociology of science, and reflective practice affords students and teachers the best opportunity for developing desired NOS understandings.[24] Consequently, these researchers claim that NOS should be given equal status to that of subject matter when considering curriculum objectives and teacher preparation.[25]

The rationale behind such a privileging of NOS closely mirrors that touted by advocates of universal scientific literacy. For example, some note that "science educators have come to believe that if students understand the source and limits of scientific knowledge they will be better equipped to make informed decisions about personal and societal problems that are scientifically-based."[26] Others propose five significant reasons as grounds for elevating the position of NOS considerations in K-12 pedagogy: to enhance learning of science content, to enhance understanding of science, to enhance interest in science, to enhance decision making, and to enhance instructional delivery. Historically, the resurgence of NOS discourse in the literature in some form for ninety or

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[23] See for example, William McComas, ed., *The Nature of Science in Science Education* (Los Angeles, CA: Kluwer Academic Publishers, 1998).
[24] Inquiry learning has been characterized as equally ambiguous in the science education literature as scientific literacy and nature of science. For an overview of current discourse surrounding inquiry in science education see Fouad Abd-El-Khalick, Saouma Boujaoude, Richard Duschl, Norman Lederman, Rachel Mamlok-Naaman, Avi Hofstein, Mansoor Diaz, David Treagust, and Hsiao-lin Tuan, "Inquiry in Science Education: International Perspectives," *Science Education* 88, no.3 (2004): 397-419.
[25] Renee Schwartz, Norman Lederman, and Tom Thompson, "Grade Nine Students' Views of Nature of Science and Scientific Inquiry: The Effects of an Inquiry-Enthusiast's Approach to Teaching Science as Inquiry," paper presented at the Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO (2001): 3-4.
[26] Ibid., 22.

more years attests to its significance with regard to science education.[27] I contend, however, that the nature of such discourse is questionable insofar as it seemingly favors an educational philosophy grounded on a set of epistemological assumptions that could result in directly transmitting the same information to students and possibly foreclosing their own understanding of science.[28] A view of understanding predicated on a continuous fusion of horizons between the familiarity of a knower, in this case the student, and the strangeness of a text, nature-of-science considerations, can conceivably extend the scholarship pertaining to NOS pedagogy in K-12 schools. The next section of this introduction briefly explains the evolution of such a view as maintained by the German philosopher, Hans-Georg Gadamer, in the 20th century.

The Development of Philosophical Hermeneutics

In an effort to compare a variety of perspectives regarding student understanding in educational contexts, this analysis considers the evolution of the discipline of hermeneutics itself, focusing primarily on a period of history beginning with the late 18th century, that led to the development of philosophical hermeneutics as posited by Gadamer. As with Chladenius and other pre-romantic hermeneuts, the practice of hermeneutics delineated between interpretation and understanding, where the former sought to rid a text of impediments to achieving the latter, in an effort to understand the

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[27] Norman Lederman, "Students' and Teachers' Conceptions of the Nature of Science: A Review of the Research," *Journal of Research in Science Teaching* 29 (1992): 331-359; and Robin Millar and Jonathan Osborne, *Beyond 2000: Science Education for the Future: A Report with Ten Recommendations* (London: King's College Press, 1998).

[28] While this particular idea will be explored throughout the subsequent pages of this dissertation, I wish here to briefly address the *possibility* of foreclosing understanding by adhering to either a consensus view of NOS or an explicit attempt to teach for NOS understandings. Regardless of the pedagogical methods used in the learning situation (i.e. didactic teaching, inquiry learning, etc.), I contend that the language used by NOS scholars and science education policy advocates connotes particular epistemological assumptions that narrowly confines understanding to a form of cognition. One of the major efforts of this dissertation is to further characterize and evaluate this perspective.

true meaning of the text itself.[29] The work of Schleiermacher, however, in developing an art of understanding beyond a collection of observations, as in the case of inductivism in the natural sciences, inaugurated a universal project of understanding detached from all content and recognized by Gadamer as fundamentally different from his predecessors.[30] Here the concept of misunderstanding replaced a lack of understanding, and interpretation itself became a problem of understanding. For Schleiermacher, the reproductive act involved in understanding a text moves beyond words and their respective meanings to include the individuality of the author of that same text, with the objective of understanding the author better than he understands himself.[31] Gadamer further suggests that perhaps for the first time the interpreter could claim superiority over his object in that "neither the saving truth of Scripture nor the exemplariness of the classics was to influence a procedure that was able to grasp every text as an expression of life and ignore the truth of what was said."[32]

In the middle of the 19th century, Dilthey expounded the romantic ideal of hermeneutics into a historical method and sought to require the same justification for the human sciences as was constitutive of pure reason as characterized by Kant.[33] As such, just as

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[29] *TM*, 184. Here Gadamer explains the preromantic literary hermeneutic experience as one predicated on point of view and the true meaning of the subject matter itself (as opposed to focusing on the *mens auctoris* or original intention of the author).
[30] John Connolly and Thomas Keutner, *Hermeneutics vs. Science? Three German Views* (Notre Dame, IN: University of Notre Dame Press, 1988), 9-12.
[31] *TM*, 186, 192. See for example, Friedrich Schleiermacher, *Hermeneutics: The Handwritten Manuscripts*, trans. J. Duke and J. Forstman (Missoula, MT: Scholars Press, 1977).
[32] *TM*, 197.
[33] Ibid., 219-221. For Gadamer, Kant's attempt to challenge metaphysics as a rational science and replace it with a pure science based on a mathematico-scientific epistemology in *Critique of Pure Reason* provides a framework within which to examine the analogous attempt of Dilthey to reframe the discourse on historical reason. See for example, Wilhelm Dilthey, "The Rise of Hermeneutics," trans. Fredric Jameson, *New Literary History* 3 (1972): 229-244.

> …the essence of the experimental method consists in rising above the subjective fortuitousness of observation and with the help of method attaining knowledge of natural laws, for Dilthey, the human sciences endeavor to rise methodologically above the subjective fortuitousness of their own standpoint in history through tradition accessible to them, and thus attain objective historical knowledge.[34]

Dilthey's work was predicated on a view of understanding that, epistemologically speaking, involves verification, falsification, and confirmation of *Geisteswissenchaften*, which identifies meaning with the subjective intention of the author.[35] While perhaps suggestive of espousing an idealistic metaphysics which claims an *a priori* meaning of a text, Dilthey attempted to situate the problem of understanding in hermeneutics rather than psychology so as to retain the historical worldview and guard against the objection of relativism. In fact, Gadamer contends that "he [Dilthey] knew that in the evolution of historical self-reflection leading him from relativity to relativity, he was on the way toward the absolute."[36] In Dilthey, as well as in the romantic hermeneutics of Schleiermacher, the apparent vagueness of thought concerning a subjective knower and an objective text is rooted in an unresolved Cartesianism that "expects the uncertainty and unsureness of life to be overcome not so much by the stability of the experience that life itself provides but by science."[37] Both favored the application of a strict, universal method for the human sciences that strives to eliminate the subjective bias of experience in an attempt to understand the meaning of a text. This completeness of understanding is similar, although not entirely analogous, to the notion of objectivity in the natural sciences.

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[34] *TM*, 236.
[35] Connolly and Keutner, *Hermeneutics vs. Science*, 14-15.
[36] *TM*, 237.
[37] Ibid., 239.

Both Schleiermacher and Dilthey espouse a form of methodological alienation of the subject from his relation to the past in an effort to free himself from the prejudices associated with his own historicity. Here, the situation of the knower can only have a negative value that the interpreter must attempt to transcend.[38] It was not until Heidegger, following the phenomenological impetus begun by Husserl at the turn of the 20th century, that hermeneutics developed its fundamentally ontological character in *Dasein*, which is concerned with being. With the purpose of renewing the question of being in general rather than producing a theory of the human sciences, Heidegger's *Being and Time* transcended the work of his predecessors in challenging Cartesian metaphysics and its insistence on privileging the notion of objectivity by attempting to separate the subject from the prejudices of his tradition and experiences.[39]

> Understanding is not a resigned ideal of human experience adopted in the old age of the spirit, as with Dilthey, nor is it, as with Husserl, a last methodological ideal of philosophy in contrast to the naivete of unreflecting life; it is, on the contrary, the original form of the realization of *Dasein*, which is being in the world.[40]

As such, Heidegger posited a mode of being for both the knower and the known as the center of inquiry that interprets all understanding as self-understanding and a projection of the knower himself upon his possibilities.

Rather than expounding on the nature of being and thinking, but nevertheless furthering the value of the prejudice-structure introduced by Heidegger, Gadamer situates his discourse in hermeneutics on the historical nature of tradition and understanding, now freed from the impediments of scientific objectivity. As such, the ontological (as opposed

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[38] David E. Linge, ed., *Philosophical Hermeneutics* (Berkeley, CA: University of California Press, 1976), xiv. This work will be cited as *PH* in the text for all subsequent references.
[39] Martin Heidegger, *Being and Time*, trans. John Macquarrie and Edward Robinson (Oxford: Blackwell Publishing, 1967).
[40] *TM,* 259.

to subjective) situations of the knower and the object constitute productive ground for all understanding which resides not in a reconstruction of the past but rather in a mediation between the past and the present, "… a comprehensive horizon in which the limited horizons of text and interpreter are fused into a common view of the subject matter-the meaning- with which both are concerned."[41] In order to further explicate this fusion of horizons that is central to this present study, Chapter Two includes a brief introduction to the salient elements of Gadamer's hermeneutics, each of which has been referenced in educational philosophy and has the potential for reconceptualizing student understanding of NOS. What follows here is an introductory discussion of how these principles have influenced the concept of understanding in both educational philosophy and science education.

Philosophical Hermeneutics and Educational Scholarship

Philosophy of Education

A select number of scholars have explored the implications of philosophical hermeneutics for the field of general education. One notable philosopher of education, Padraig Hogan, identifies six themes that emerge from the writings of Gadamer that he believes have the potential for transforming educational practice: the primacy of play, the principle of effective-history, the predisposing of thought by language, the plurality of tradition, the fusion of horizons, and the dialogue that we are. He suggests that understanding as embodying these components is oftentimes stifled and discouraged in educational settings influenced by rational, positivist Western philosophy. For example, he interprets the fusion of horizons to be "not a melting together in which all tensions are

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[41] *PH*, xix.

laid to rest, but an attentive to-and-fro between the otherness of that which addresses the learner."[42] Thus pedagogy is viewed not so much as a means of transmitting knowledge and values but rather as "…an interplay with overt and unseen consequences."[43]

Gallagher provides arguably the most comprehensive scholarship relating Gadamer's hermeneutics to educational philosophy. In his seminal piece, *Hermeneutics and Education*, he identifies philosophical hermeneutics with a moderate view of education, as distinct from espousing either a conservative, critical, modernist, or radical view of understanding. He compares a Gadamerian view of understanding with that espoused by more conservative hermeneuts with regards to the hermeneutic circle, the notion of objectivity, and the act of reproduction involved in interpretation. Seeming to take their lead from the ideals posited by Romantic hermeneuts such as Schleiermacher and Dilthey, individuals with a more conservative view of understanding attempt to reach full understanding through the completion of the hermeneutic circle.[44] Whereas the whole determines the parts but is itself determined by those same parts (as in the case of Biblical exegesis), complete understanding can be achieved as a result of the continuous back and forth between these two primary constituents of understanding, the whole and its parts. Similarly, whereas the systematic application of a controlled set of methods cannot lead to absolute truth, for the conservative hermeneut, objective understanding is possible through the use of a prescriptive set of canons. As such, the primacy of procedure is accepted as a means of reproducing the original meaning in the object under study.

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[42] Padraig Hogan, "Gadamer and the Philosophy of Education," *http://www.ffst.hr/ENCYCLOPAEDIA/gadamer.htm*, (2000), Accessed 20 December 2007.
[43] Ibid.
[44] See for example Emilio Betti, "Hermeneutics as the General Methodology of the *Geisteswissenschaften*," trans. Josef Bleicher, in J. Bleicher, *Contemporary Hermeneutics* (London: Routledge and Kegan Paul Books, 1980); and Edward D. Hirsch, Jr., *The Aims of Interpretation* (Chicago, IL: University of Chicago Press, 1976).

Gallagher notes, however, that for the conservative hermenuet, there may be a difference between understanding and meaning making, the former concerning that nature of the original meaning that exists in the text itself which is ascertainable through the methods described above, the latter relating to the particular significance of the text for the interpreter which is not amenable to such conservative views of understanding.[45]

In his consideration of the relationship between critical hermeneutics and philosophical hermeneutics, Gallagher focuses his analysis on the act of reproduction and the concepts of hegemony, habitus, and critical reflection. While the critical perspective is evident in the writings of Marx, Freud and numerous other scholars, Gallagher uses primarily the conversations that took place between Gagdamer and Jurgen Habermas to compare/contrast these two perspectives. Habermas challenged Gadamer's contention concerning the universality of hermeneutics, using as an example the monological nature-of-science as compared to the constitutive dialogical component inherent in a hermeneutical understanding of understanding.[46] But the primary difference between critical and moderate hermeneutics, according to Gallagher, involves the insistence of the former on striving for some form of emancipation through neutralizing the language of the text that seeks to reinforce or reproduce the traditional power structures. Such a liberation is possible only through critical reflection that attempts to acknowledge the extrahermeneutical factors involved in understanding, which Habermas contends that Gadamder fails to do.[47] For the critical hermeneut, the absence of this type of reflection

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[45] *HE*, 205-213.
[46] See Jurgen Habermas, "The Hermeneutic Claim to Universality," in Gayle L. Ormiston and Alan D. Schrift, eds., *The Hermeneutic Tradition: From Ast to Ricouer* (Albany, NY: SUNY Press, 1990).
[47] *HE,* 261-275.

results in a form of hegemony and a reproduction of a given habitus.[48] On the other hand, when included in the practice of interpretation, critical reflection can lead to an ideologically-neutral, objective understanding of a given text.

Lastly, Gallagher compares the views of more radical hermeneuts, such as Foucault and Derrida, with those of Gadamer, this time emphasizing the concepts of textuality, play, and radical suspicion. Unlike conservative and even critical perspectives that believe that objective understanding is possible, the former through methodological control and the latter through critical reflection, the radical view seems to eschew any form of principles and/or canons that would attempt to reach objective meaning. Focusing on the writings of Derrida,[49] Gallagher represents the radical perspective as on the one hand positing the non-existence of any form of justification for interpretation while on the other hand not entirely favoring a completely arbitrary process of meaning making. Herein lies the notion of textuality which limits the possible interpretations of a text by confining the interpreter to the language of the text itself. For Derrida, however, language is part of the play of the text, and as such holds no objective value. Unlike the critical hermeneuts who focus on the entrahermeneutical factors involved in understanding, such as power, authority, and tradition, the radical hermeneut does not look either internally (to the interpreter) or externally (outside of the text). Gallagher contends that the notion of play as described by Derrida results in a hermeneutics of suspicion that rejects any belief in the possibility of objective meaning and/or truth in the

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[48] For a discussion of habitus see Pierre Bourdieu and Jean Claude Passeron, *Reproduction in Education, Society, and Culture*, trans. Richard Nice (London: Sage Publications, 1977).
[49] See for example, Jacques Derrida, *Of Grammatology*, trans. Gayarti Chakravorty Spivak (Baltimore, MD: Johns Hopkins University Press, 1976); and Jacques Derrida, *Writing and Difference*, trans. Alan Bass (Chicago, IL: University of Chicago Press, 1978).

interpretation and simultaneously challenges what he describes as a type of conversation and dialogue predicated on a Kantian view of metaphysics.[50]

The above discussion addresses the major themes that emerge in Gallagher's comparison of Gadamer's philosophical hermeneutics with those that are more conservative, critical, and radical. How then does he consider the former's position to be moderate when compared to the others? According to Gallagher, Gadamer would consider complete objective meaning (conservative and critical) and emancipation (critical) to represent two unattainable extremes. He does not necessarily deny that neither is in part possible but he does not make the distinction between understanding and significance, as in the case of the conservatives, nor does he think it is possible to entirely transcend the notion of false consciousness and hermeneutical bias, as in the case of the critical scholars. Similarly, Gadamer does not favor exclusively the act of reproduction in an effort to reconstruct original meaning (conservatives) or ideologically-neutral meaning (critical), but rather suggests that meaning making is primarily a constructive and secondarily a reconstructive act. Unlike the radical hermeneuts who emphasize the notion of textuality that leads to a hermeneutics of suspicion and the conservative hermeneuts who strive to eliminate the influence of the interpreter's own situation with regards to understanding a text, Gadamer favors the concept of a dialogue of trust between the horizon of the interpreter and that of the object.

Aiming to use the educational experience over traditional textual analysis as a model for Gadamer's hermeneutics, Gallagher further explains learning in terms of the interchange of a variety of non-coinciding interpretations, such as student-teacher,

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[50] *HE,* 277-317.

student-subject, and teacher-subject. As such, teachers espousing a hermeneutic consciousness remain open to the possibilities of interchange and interpretations that subsequently follow. Understanding is not considered as a narrowly defined, epistemological cognition but rather an existentially comprehensive as well as constrained and ongoing activity in which we already find ourselves engaged, a characteristic distinguishing human existence, or *Dasein*. Rather than expound on the prescriptive nature of educational constructs such as questioning, application, and self-understanding, Gallagher situates his considerations of education in hermeneutics in an attempt to project their meaning into the traditional discourse of educational philosophers.

While Gallagher supports the position of others who suggest an element of familiarity between the writings of progressive educators and Gadamer in terms of ideas such as questioning and fore-structures, he is careful to distinguish between their respective considerations of notions such as productivity and application. Whereas modernists and progressives seemingly overemphasize methodological procedures, reduce all learning to problem solving (*techné*) and explain productivity in terms of inventiveness and application in terms of utility, philosophical hermeneutics regards understanding to be exemplified in the Greek's notion of *phronesis*, which, he purports, involves a self-knowledge not needed for *techné* and as such cannot be methodologically instilled in students.[51] For Gallagher then, Gadamer's hermeneutics rejects the modernist

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[51] The supposed relationship between *techné* and *phronesis*, as explicated by Aristotle in his *Ethics* and appropriated by Gadamer in his hermeneutics, has been thoroughly discussed by several notable educational philosophers. The two important texts that are used in the present analysis are Gallagher, *Hermeneutics and Education* and Joseph Dunne, *Back to the Rough Ground: 'Phronesis' and 'Techné' in*

tendency to reduce education to a set of techniques which simply allow us to manage information. Instead he favors opportunities that place the student's own possibilities at stake and provide the necessary resistance to encourage the student to project himself onto the tradition of which he is a part. As such, education becomes something that achieves culture rather than something that is achieved by culture. [52]

Similarly offering a compelling interpretation of the potential for incorporating Gadamer's hermeneutics into educational praxis, Kerdeman elaborates on and evaluates Gallagher's delineation between a Cartesian and hermeneutical (along the lines of Heidegger and later Gadamer) view of understanding.[53] Rather than subscribing to the former's insistence on a subject/object dualism that relegates all understanding to epistemology, the latter considers understanding as an ontological way of being. She recalls how for the hermeneut "meaning is not something that has to be produced methodically; nor is understanding an outcome we deliberately set out to achieve…it is a mode of ordinary practical experience."[54] She differentiates as well between what she terms pre-reflective and clear understanding, the former pertaining solely to the familiar, the latter attempting to negotiate with the strange. As opposed to traditional hermeneutics, existential hermeneutics does not consider this strangeness as an objective dilemma that we attempt to overcome but rather as part of human existence through which we live. For Kerdeman, clear understanding is not to be mistaken for complete understanding as sought by the earlier traditions in hermeneutics but rather is comprised

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Modern Philosophy and in Aristotle (South Bend, IN: University of Notre Dame Press, 1993). This last reference will be cited as *RG* in all subsequent notes.
[52] Ibid., 170-200.
[53] Kerdeman, "Hermeneutics and Education," 245-248.
[54] Ibid., 248-249.

of Gadamer's fusion of horizons and its constitutive interchange between the strange and the familiar.

The crux of Kerdeman's position, however, involves ameliorating the supposed tension touted by Gallagher and other proponents of existential hermeneutics between the modernist view of education and one that recognizes the situatedness of the learner: "In sum, while the epistemological subject is self-sufficient and detached, the hermeneutic being is ensnared and engaged."[55] She believes that Gadamer's approach to understanding de-centers without altogether negating individual control by encouraging the individual to remain open, thereby denying "neither our efficacy nor our finitude."[56] Furthermore, according to Kerdeman, Gadamer believed this life-orientation could be addressed in education by enabling students to encounter differences and challenging their assumptions, both of which can succeed only in the presence of teachers who themselves possess this disposition of openness.[57]

Narrow Lines of Inquiry

Whereas the aforementioned scholars concerned themselves with how philosophical hermeneutics relates to the broader context of philosophy of education, others have narrowed their focus on their respective lines of academic inquiry. A brief mention of their work here provides further evidence for considering the potential of situating educational discourse in Gadamer's hermeneutics. With particular attention given to the practice of deconstructing a text, Crusius offers philosophical hermeneutics as a viable alternative to Derrida's hermeneutics of suspicion for teachers of English

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[55] Ibid., 257.
[56] Ibid., 263.
[57] Ibid., 264.

language.[58] He begins his analysis with a thorough explication of various types of hermeneutics and compares their respective developments with a similar evolution within the philosophy of science. Crusius employs the Heideggerian notion of *Dasein* (human being in the world) to acknowledge our own historicity in engaging with a particular text. Since truth is dependent on *Dasein* and *Dasein* depends on being with others, he situates the earlier writing of Plato and Hegel with regards to dialogue as inquiry and a dialectical understanding of the truth, respectively, into Gadamer's hermeneutics. He contends that such an approach to textual deconstruction enables the listener/reader to construct meaning anew, together with the other, through a dialogue that moves in both directions, particularly when the interpreter is in tension-filled proximity with the text.

This dialogical nature of understanding involved in hermeneutics, coupled with a Deweyan conception of democracy, is attended to by Garrison in his attempt to suggest a hermeneutical approach for democratic listening.[59] The author notes that due to the ontological nature of openness as espoused by Gadamer, "… to listen well, we must actively strive to understand the meanings of others in their terms."[60] Simultaneously, the impartial listener ceases to exist as do prejudices against prejudices since "the point is not to free ourselves of all prejudice, but to examine our historically inherited and unreflectively held prejudices, and alter those that disable our efforts to understand others, and ourselves."[61] Garrison dismisses the idea of sympathetic listening as a viable

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[58] Timothy Crusius, *A Teacher's Introduction to Philosophical Hermeneutics* (Urbana, IL: NCTE Press, 1991), 2-4. In this text, the author actually distinguishes between what he understands to be five different levels of hermeneutic discourse: naïve/natural, normative, scientific, philosophical/hermeneutical, and negative/depth. Derrida serves as an exemplar for the last of these.
[59] Jim Garrison, "A Deweyan Theory of Democratic Listening," *Educational Theory* 46, no. 4 (1996): 429-451.
[60] Ibid., 433.
[61] Ibid., 434.

option along hermeneutic lines in that it relies on objectivity, the setting aside of fore-knowledge, and attempts to only reproduce the meaning of the other. His emphasis on such an approach to listening seeks to foster a critical form of education that challenges "the assumption that truth and goodness will prevail so long as everyone can speak their mind."[62] Whereas the preceding two references serve as exemplars describing the use of Gadamer's hermeneutics in specific contexts involved in educational practice, the next section situates such discourse in the field of science education, the area of focus of the present study.

Science Education

There appears to be a limited body of research in the science education literature pertaining to the use of Gadamer's hermeneutics as a theoretical framework. Martin Eger published a series of articles positing the use of hermeneutics as an appropriate theoretical framework for science education.[63] He incorporates the Gadamerian notions of positive prejudice-structures and interpretations as being constructions rather than reconstructions to address the meaning students make out of science as it is learned in educational settings, as opposed to directly from nature itself. As such, he uses the work of others relating to students preconceptions,[64] which can be likened to Kerdeman's pre-reflective understandings,[65] to exemplify the potential for hermeneutics in addressing how students interpret science through the fusion of horizons (that involving the 'fore-having' and that of the text itself). He ultimately questions, however, the dichotomy in

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[62] Ibid., 438.
[63] Martin Eger, "Hermeneutics and Science Education: An Introduction," *Science & Education* 1, no. 1 (1992): 337-348; and Martin Eger, "Hermeneutics as an Approach to Science: Part I," *Science & Education* 2, no. 1 (1993): 1-29.
[64] See for example Joseph Novak, *A Theory of Education* (Ithaca, NY: Cornell University Press, 1977).
[65] Kerdeman, "Hermeneutics and Education," 249-252.

understanding established by constituents of both the natural and human/social sciences to prevent against relativism on the one hand and scientism on the other. Sociologists of science suggest that the writings of the preeminent philosophers of science well into the 20th century privileged scientific knowledge while they themselves largely represent the postmodern perspective that has arguably challenged the objectivity of a scientific epistemology.[66] Eger instead contends that the scientists' reading of nature and the students' reading of science both involve an understanding of a text that is beyond the horizon of the interpreter and as such can be considered as a hermeneutic *aporia*.[67]

Focusing less on the prejudice structures inherent in understanding, Sammel applies the dialogical, intersubjective component of Gadamer's hermeneutics to the study of teacher meaning-making and critical environmental education.[68] Considering that the "goal of dialogue, for Gadamer, is to reach an understanding that centers less on asserting one's point of view and more on individual transformation,"[69] she contends that high school teacher understanding, and understanding in general, is not contingent upon "correctly" identifying the other but rather develops at the center of the "dialogical interplay."[70] She aligns her research method with the hermeneutic practice of de-centering the author of the text, both the text of her research and that of environmental education, in an effort to allow for the co-production of meaning, both with regards to her analysis and the participants' understanding of environmental education.

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[66] Turner and Sullenger, "Kuhn in the Classroom," 8-9. The discord between the significance of the various sciences has of course not only concerned contemporary scholars but dates back to at least the quarrels between the ancients and the moderns as explained in the translator's introduction of Vicos' *Study Methods.*
[67] Eger, "Hermeneutics and Science Education," 344-346.
[68] Ali Sammel, "An Invitation to Dialogue: Gadamer, Hermeneutic Phenomenology, and Critical Environmental Education," *Canadian Journal of Environmental Education* 8, no. 1 (2003): 155-168.
[69] Ibid., 159.
[70] Ibid., 160.

Most recently, Borda examines the implications of philosophical hermeneutics for developing particular dispositions in science students.[71] To do so, she establishes the notion of a hermeneutic consciousness from Gadamer's way of being that "allows us to become more aware of our human limitations and finitude."[72] Similarly, she subscribes to the hermeneutic commitment to consider understanding not as a cognitive achievement but rather as developing through "…a certain orientation to situations which challenge our preconceptions."[73] From his address given at the University of Leipzig in 1947, Borda ascertains Gadamer's hermeneutic scientist to espouse absent-mindedness, doubt, and humility, some of which have been characterized elsewhere[74] but for hermeneutics serve as understanding itself and not a method for understanding. She also augments these three dispositions with that of strength which she believes epitomizes the hermeneutic ideal of remaining rooted in the familiar and not losing site of one's own views while enabling one to remain open-minded in the presence of the strange.

The Study

Whereas the primary science education reform documents of the 1990s together with the body of scholarly research emerging since that time continue to play an integral role in shaping 21st century national and state standards, NOS considerations have perhaps influenced only to a limited degree the decisions of individual classroom teachers regarding student understanding of the scientific worldview, science inquiry, and the scientific enterprise. At the same time, some education scholars have cautioned against

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[71] Emily Borda, "Applying Gadamer's Concept of Disposition to Science and Science Education," *Science & Education* 16, no. 1 (2007): 1027-1041.
[72] Ibid., 1030.
[73] Ibid., 1031.
[74] See for example John Dewey, *Democracy and Education* (New York, NY: The Free Press, 1916); and Ron Ritchhart, "From IQ to IC: A Dispositional View of Intelligence," *Roeper Review* 23, no. 3 (2001): 143-150.

overemphasizing the seemingly shortsighted contention that NOS understandings, and scientific literacy more broadly, are integral to individual intellectual development, national security, and a democratic way of life.[75] Likewise others have suggested "that whatever the nature of (research) science, that 'nature' offers no legitimate warrant for the claim that the needs of students, or society, or the scientific enterprise itself, are best served" by explicit NOS instruction in the classroom.[76] While questioning the justification for any comprehensive reform effort is necessary, such a discussion is beyond the scope of the present concern. Instead, since NOS has received significant attention as a national curriculum objective, it is worthwhile to consider the philosophical assumptions inherent in currently held beliefs with regards to student understanding of NOS concepts which, I ultimately intend to suggest, remain seemingly rooted in the Cartesian tradition and subsequent Enlightenment ideal that equate understanding with epistemological cognition.[77] Such a view has the potential to reduce NOS pedagogy to the direct transmission of information, possibly resulting in a form of indoctrination and subsequently foreclosing rather than enlarging student understanding. A related question then, which is the primary focus of this study, is whether Gadamer's hermeneutics offers science education scholars and practitioners with an ontological view of understanding that can be used to reframe the discourse surrounding NOS teaching and learning in the K-12 curriculum.

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[75] See DeBoer, "Scientific Literacy" and Shamos, *The Myth of Scientific Literacy.*
[76] See Turner and Sullenger, "Kuhn in the Classroom," 25.
[77] Again, the present philosophical analysis focuses on the nature of understanding, not the nature of science. For a discussion on the metaphysical and epistemological assumptions in the various NOS tenets see Brian Alters, "Whose Nature of Science?" *Journal of Research in Science Teaching* 34, no.1 (1997): 39-55; Michael Matthews, "Constructivism and Science Education: A Further Appraisal," *Journal of Science Education and Technology* 11, no.2 (2002): 121-134; and Patricia Harding and William Hare, "Portraying Science Accurately in the Classroom: Emphasizing Open-Mindedness Rather than Relativism," *Journal of Research in Science Teaching* 37, no.3 (2000): 225-236.

A study of Gadamer's philosophical hermeneutics has numerous implications for NOS pedagogy as well as for the broader field of science education. First, such a study questions the epistemological assumptions behind the teaching of either a consensus or desired view of NOS, often purported in the science education literature. In fact, several education scholars now contend that the "scientific endeavor is looking more like a mosaic of disciplines with a host of ontological, epistemological, and methodological commitments, than a unified and homogeneous entity."[78] Simultaneously, teaching students to understand and/or accept a prescribed set of objectives that epitomize scientific knowledge claims and the processes used to arrive at such statements can all too easily become a form of indoctrination, enculturation, or adjudication.[79] Stemming from such opposition, various authors have encouraged scholars and practitioners to sincerely reflect on the role of education and the responsibility of educators.[80]

In that vein, then, I endeavor to use Gadamer's philosophical hermeneutics to inquire into student understanding of NOS concepts. Whereas there is an abundance of literature examining how such understandings relate to particular tenets posited to be representative of a consensus or desired view of NOS, there is an absence of scholarship pertaining to the concept of understanding itself. Chapter Two explains the approach used in the study, further addressing the particular themes of philosophical hermeneutics that serve as the

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[78] Fouad Abd-El-Khalick, et al., "Inquiry in Science Education ," 416.

[79] At least three different perspectives have been used to argue against teaching a consensus, desired view of NOS. Michael Matthews, "In Defense of Modest Goals When Teaching about Nature of Science," *Journal of Research in Science Teaching* 35, no. 2 (1998): 161-174 challenges the ontological assumptions inherent in NOS pedagogy. Wolff-Michael Roth, "'Enculturation': Acquisition of Conceptual Blindspots and Epistemological Prejudices," *British Educational Research Journal* 27, no.1 (2001): 5-27 questions the reproduction of a specific *habitus* through NOS teaching and learning. John Rudolph, "Reconsidering the 'Nature of Science' as a Curriculum Component," *Journal of Curriculum Studies* 32, no.3 (2000): 403-419 addresses the curricular consequences of teaching a general, consensus view of NOS.

[80] See for example Don Margetson, "Some Educational Implications of the Uncertain Identity of Science," *European Journal of Science Education* 4, no.4 (1982): 357-365.

basis for the inquiry. Chapter Three contains a description of both the rationale supporting the inclusion of NOS considerations in national reform efforts as well as a more detailed account of the body of empirical research that has resulted from such an inclusion. In Chapter Four, I explicate the various philosophical assumptions inherent in the use of the concept of understanding in the literature and policy documents, while in Chapters Five and Six, I incorporate the Gadamerian concepts of fore-structure, prejudice, temporal distance, and history of effect together with the problem of application, experience, and the priority of the question into the discourse pertaining to student understanding of NOS. Chapter Seven offers a discussion of the positive value of considering Gadamer's hermeneutics as a referent for both student understanding of NOS and the scholarly discourse surrounding that understanding.

CHAPTER TWO

INQUIRY

The present inquiry involves a philosophical analysis of the nature of student understanding in science education. Such an analysis is comprised of a number of interrelated activities, namely conceptual clarification and differentiation, an examination of the assumptions held by science education researchers and educators concerning nature-of-science (NOS) pedagogy, and an appeal to the tradition of hermeneutics to shed light on the discourse surrounding student understanding in educational praxis.[81] By considering what student understanding entails and explicating the various possible philosophical underpinnings implicit in interpreting *understanding*, I examine how this particular construct is used in the context of NOS teaching and learning and consider the implications of that usage for theory and practice, with the intention of remaining open to a more phronetic rather than technical form of inquiry, as incorporated into Gadamer's hermeneutics and summarized as a philosophy that does not:

> … meet the criteria of theory as *epistemé* or *sophia*. Its subject matter will not permit the same degree of exactness that we should expect to find elsewhere - in mathematics, for example. This subject matter contains so much variety and fluctuation that a theoretical account of it can be given only "roughly and in outline" and can do no more than hint at what is true "for the most part."[82]

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[81] For a categorical discussion of the use and respective value of such analyses in teacher education, see Margaret Buchmann and Robert E. Floden, "On Doing Philosophy of Teacher Education," *Oxford Review of Education* 16, no.3 (1990): 343-366.
[82] *RG*, 243.

While I aim to provide a thorough inquiry into the possibility of including philosophical hermeneutics into NOS considerations, I recognize the seemingly inherent limitations to such a study and anticipate to leave "…the reader with more questions to be asked, and with doubts and unclarities that remain."[83]

Introduction to the *Aporia*

The purpose of this study is to suggest the use of a hermeneutical view of understanding, as proposed by Gadamer, as a referent for student understanding of nature-of-science (NOS). My central argument is reinforced by a number of primary premises. Firstly, I contend that current views on the teaching and learning of NOS are predicated on a particular notion of understanding, whose inherent assumptions have yet to be analyzed for their philosophical import. Secondly, scholarship by philosophers proper as well as philosophers of education in the field of hermeneutics suggests that certain pedagogical practices may limit rather than allow for the development of student understanding. Lastly, I suggest that a Gadamerian view of understanding, unlike the dominant Cartesian, technical view arguably implicit in the majority of the NOS literature and reform efforts, has the potential for enlarging student understanding of NOS.[84] While a consideration of the use of philosophical hermeneutics has been discussed by only a limited number of philosophers of education, its inclusion in the science education literature is even sparser. Here I hope to make an original contribution

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[83] Buchmann and Floden, "On Doing Philosophy," 364. These same authors contend that "…examining the normative and conceptual underpinnings of social practice is like repairing a ship at sea. Only a few parts can be prized out at any one time," 363.

[84] Whereas a hermeneutic approach to understanding (and subsequently education) will be contrasted with the degenerations of Descartes' *cogito* and Aristotle's *techné* at various levels throughout this dissertation, it is assumed here that understanding for these latter two is equivalent to reason and narrowly defined as epistemological cognition in the case of the former and expert know-how in the case of the latter. See *HE,* 39-45.

to the field of science education by incorporating an ontological view of understanding into the discourse surrounding NOS pedagogy as well as to participate in the broader discussion pertaining to the educational implications inherent in a hermeneutical view of teaching and learning.

In an attempt to perpetuate late 20th century, curriculum reform efforts that favored minimum standards for all students, sought to prepare an effective citizenry, and aimed at teaching for increased appreciation for science and technology, the American Association for the Advancement of Science published its seminal *Benchmarks for Science Literacy* positing:

> When people know how scientists go about their work and reach scientific conclusions, and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically. The images that many people have of science and how it works are often distorted. Hence the study of science as a way of knowing needs to be made explicit in the curriculum.[85]

As a result of the ensuing imperative to teach a science for all Americans, renewed emphasis was afforded to nature-of-science considerations in the development of both school curriculum and lines of inquiry in the field of science education.[86] Concerning the latter, researchers primarily focused their investigations on either establishing a set of tenets representing a consensus view of NOS or assessing the effectiveness of particular

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[85] AAAS, *Benchmarks*, 3.

[86] As discussed in the first chapter of this dissertation, insofar as NOS understandings may be integral to the larger notion of scientific literacy, such considerations are evident in the literature and reform documents throughout the 20th century. See, for example, John Rudolph, "Epistemology for the Masses: The Origins of the Scientific Method in American Schools," *History of Education Quarterly* 45, no. 3 (2005): 341-376 for a discussion of the portrayal of the scientific method in the 1920s and 1930s. See also Fenstermacher, "The Nature of Science and Its Uses for Education" for a discussion of the import of Joseph Schwab's work, pertaining to nature of science, through the 1960s.

pedagogical efforts to improve student and teacher understandings of NOS.[87] Although several scholars seemingly recognized conceptions of NOS as being tentative and historical and subsequently cautioned against considering any one set as better than any other, their work in examining the particular approaches used to teach NOS continued to be predicated on the notion of a desired, valid, mature, or adequate understanding of NOS considerations.[88]

While the scholarship garnered from the efforts of such investigations may indeed be valuable in terms of its relationship to the aforementioned objectives espoused by adherents of science for all Americans, I contend that it presumes a particular understanding of *understanding* that may limit rather than allow for its development. To date, there is an absence of any serious philosophical analysis pertaining to the idea of understanding in the science education literature.[89] Several philosophers of education, however, have expounded on both the ontological and epistemological underpinnings of such constructs when considered in light of educational praxis. Notable among these contributions is Shawn Gallagher's *Hermeneutics and Education* in which the author, using Gadamer's hermeneutics as a "theory which illuminates the conditions of

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[87] For an example of research centered on a consensus view of NOS, see William McComas, Hiya Almazroa, and Michael Clough, "The Nature of Science in Science Education: An Introduction," *Science Education* 7, no. 6 (1998): 511-532. For an example of research evaluating NOS understandings, see Fouad Abd-El-Khalick and Norman Lederman, "Improving Science Teachers' Conceptions of Nature of Science: A Critical Review of the Literature," *International Journal of Science Education* 22, no. 7 (2000): 665-701.
[88] Abd-El-Khalick and Norman Lederman, 667-670.
[89] The issues surrounding the teaching and learning of evolution seem to encourage a periodic consideration of the conceptualization of the idea of understanding, together with knowledge and belief, in the science education literature. But even here the number of contributions remains insignificant. See for example, Sherry Southerland, Gale Sinatra, and Michael Matthews, "Belief, Knowledge, and Science Education," *Educational Psychology Review* 13, no.4 (2001): 325-251; Mike Smith and Harvey Siegel, "Knowing, Believing, and Understanding: What Goals for Science Education?" *Science & Education* 13, no.6 (2004): 553-582; and Peter Davson-Galle, "Understanding: Knowledge, Belief, and Understanding," *Science & Education* 13, no.6 (2004): 591-598.

possibility of understanding,"[90] questions the limitations of certain narrative definitions of understanding commonly subscribed to in the field of education. Here, I wish to similarly argue that the predominant view afforded to understanding in the NOS literature has roots in the Aristotelian notion of *techné* rather than *phronesis*, Descartes' foundationalism, and the resulting primacy of method purported by philosophers well into the 20th century.

In his *Nicomachean Ethics*,[91] Aristotle posits an account of knowledge consisting of various disparate although possibly interrelated types of knowing. Among these, two forms of reasoning differ in their respective modes of activity, that of production and that of conduct:

> Aristotle there aligns *techné* with a kind of activity which he calls "making" or "production" (*poieses*). This activity issues in a durable outcome, a product or state of affairs which can be precisely specified by the maker before he engages in his activity and which, as surviving the latter, provides it with its end or purpose (*telos*). *Techné* then is a kind of knowledge possessed by an expert maker; it gives him a clear conception of the why and wherefore, the how and with-what of the making process and enables him, through the capacity to offer a rational account of it, to provide over his activity with secure mastery…he recognized another type of activity, praxis, which is conduct in a public space with others in which a person, without ulterior purpose and with a view to no object detachable from himself, acts in such a way as to realize excellences that he has come to appreciate in his community as constitutive of a worthwhile way of life. As an activity that both involved one with other people and at the same time, was a realization of one's self, praxis engaged one more intimately, or afforded one less detachment, than the *poiesis* over which one exercised an uncompromised sovereignty. [92]

The latter form of reasoning he referred to as *phronesis* and, by it, formulated a means "… of viewing the regulation of practice as something nontechnical but not, however,

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[90] *HE*, 4.
[91] Aristotle, *Nicomachean Ethics*, 2nd edition, trans. Terence Irwin (Indianapolis, IN: Hackett Publishing Company, 1999).
[92] *RG*, 9.

nonrational."[93] Delineating between the agent, in the case of *phronesis*, and the producer, in the case of *poieses*, a further distinction has been drawn between the inability of the former to "…stand outside his materials and allow the productive process to be shaped by the impersonal form which he has objectively conceived" as "…he becomes and discovers who he is through [his] actions."[94] As such, *phronesis* does not stand outside or above oneself and is unable to be instrumentalized in the same way that *techné* can be manipulated by a sovereign maker.[95] Although scholars contend that Aristotle himself recognized the supremacy of theoretical knowledge, or *techné*, over *phronesis* and considered a life of contemplation as self-satisfying, he simultaneously acknowledged its limitations with regard to sustaining life, thereby conferring upon *phronesis* a notable distinction.[96]

In addition to developing his philosophical hermeneutics against a reducibly technical form of knowledge, Gadamer questioned the primacy of method afforded to hermeneutical inquiry, as influenced by Cartesian foundationalism. In his *Discourse on the Method*, Descartes suggests that "…whether awake or asleep, we ought never to be

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[93] Ibid., 10.
[94] Ibid., 263.
[95] Gallagher posits a further analogy between *techné* and *phronesis* derived from French philosopher, Gabriel Marcel's, problem and mystery, and similar to one suggested by Gadamer in his hermeneutics. As the editor of his *Creative Fidelity* explains: "…At the heart of Marcel's rejection of totalizing, representational, objectifying models of knowing (to use contemporary jargon) is the distinction between a problem and a mystery. There are problems, to be sure, when our cognitive challenge comes from not having enough of the world before us; but from the experience of ordinary sensibles to the experience of the absolute Thou, what we usually confront are mysteries in which experience gives us more than we can grasp or say. Mystery is not to be construed 'as a lacuna in our knowledge, as a void to be filled, but rather as a certain plenitude (p. 152). For this reason, the real 'is always more than anything I can say about it' (p. 224)." See Gabriel Marcel, *Creative Fidelity*, trans. Robert Rosthal (New York, NY: Fordham University Press, 2002), 152 and 154.
[96] It is worthwhile mentioning here that questions have been raised concerning the nature of the significance afforded to such a distinction between *techné* and *phronesis* in Aristotle's own thought. See for example, *RG*, 246-247.

persuaded of the truth of anything unless on the evidence of our own reason."[97] In his endeavor to discover the foundations necessary for his rationalism, he resolved to eradicate his previous opinions, which he believed depended more on custom and example than knowledge, that he "…might afterwards be in a position to admit either others more correct, or even perhaps the same when they had undergone the scrutiny of reason."[98] Descartes' four-step method, resulting in his *cogito ergo sum*, was predicated on an explicit attempt to avoid all sources of prejudice in an effort to acquire clearer and more distinct conceptions of the objects of his reason. Such a conceptualization of knowledge, and arguably understanding, inaugurated a significant reliance on the proper use of method and the subjugation of the ontological nature of both knowing and understanding. For example, echoing the sentiment of Descartes, Bertrand Russell sought "…to look into all [his] beliefs, and discard them if they seemed to have no foundation except tradition or [his] own prejudices." For Russell, the methods of science should be privileged because of their ability to distinguish between true knowledge and mere opinion:

> It is science that makes the difference between the modern world and the world before the 17th century. It is science that has destroyed the belief in witchcraft, magic, and sorcery. It is science that has made the old creeds and the old superstitions impossible for intelligent men to accept. It is science that has taught us the way to substitute tentative truth for cocksure error. The scientific spirit, the scientific method, the framework of the scientific world, must be absorbed by anyone who wishes to have a philosophic outlook belonging to our time, not a literary antiquarian philosophy fetched out of old books.[99]

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[97] Descartes, 12.
[98] Ibid., 4.
[99] Bertrand Russell, *The Art of Philosophizing* (New York: Philosophical Library, 1968), 9-10. Champions of this same scientific spirit are currently engaged in the discourse surrounding the teaching of evolution and creation science in the classroom. These philosophers, sociologists, and science educators favor a view of naturalism that either affords primacy to the methodological over the metaphysical or insist that the two remain disparate. For examples of the former see, Barbara Forrest, "Methodological Naturalism and Philosophical Naturalism: Clarifying the Connection," *Philo* 3 (2000): 7-29; and Michael Shermer, *Why*

Although distinguishable from foundationalists by their respective metaphysical assumptions, Gallagher suggests that champions of progressive education have likewise perpetuated the Cartesian emphasis on method over a consideration of a descriptive account of either knowledge or understanding.[100] Insofar as such a view of understanding as a form of cognition that is in turn only conceptualized in terms of epistemology (method) presents an *aporia* in bringing to light the potential limits imposed by such a perspective, I hope to enlarge the discourse on student understanding of NOS through a consideration of Gadamer's philosophical hermeneutics.

Approach to the Study

The substantive body of literature pertaining to NOS understandings generally addresses how such understandings relate to particular tenets posited to be representative of a consensus and/or desired view of NOS. Within this line of inquiry, philosophical discourse has been considerably limited to topics concerning the ontological assumptions inherent in the NOS tenets. The present study instead addresses the metaphysical and epistemological underpinnings of the notion of understanding commonly used in the discourse on NOS teaching and learning. Ultimately, I suggest the use of Gadamer's hermeneutics as a referent for considering student understandings of NOS concepts with the aim of enlarging rather than foreclosing those same understandings.

People Believe Weird Things: Pseudoscience, Superstitions, and Other Confusions of Our Time (New York, NY: Henry Holt and Company, 2000). For an example of the latter see, Stephen J. Gould, "Nonoverlapping Magisteria," *Natural History* (1997): 1-9; and Eugenie C. Scott, *Evolution vs. Creationism* (Berkeley, CA: University of California Press, 2005).

[100] For example, John Dewey aims to "…carry over into any inquiry into human and moral subjects the kind of method (the method of observation, theory as hypothesis, and experimental test) by which understanding of physical nature has been brought to its present pitch." See John Dewey, *Reconstruction in Philosophy* (Boston: The Beacon Press, 1960), ix.

Whereas earlier hermeneuts delineated between three major types of *subilitas*,[101] Gadamer considered understanding to involve interpretation and inherently imply application. Thus, the notion of student understanding achieves a hermeneutical significance insofar as NOS pedagogy involves multiple instances of interpretation such as those between teacher and student, student and NOS content, and teacher and NOS content.[102] Because the study of interpretation and understanding (hermeneutics) is inherently a philosophical endeavor, it is appropriate to engage in a philosophical analysis of the meaning students make when considering the scientific worldview, science inquiry, and the scientific enterprise.[103] Such an analysis provides a cogent argument for the need to reconceptualize the predominant view relating to student understanding of NOS in terms of a Gadamerian view of understanding which includes, but is not limited to, the notions of fore-structure, prejudice, temporal distance, and history of effect. It is important to note again at this point that, although the intent of the present study is described as such, the result of such an inquiry may yield an analysis not entirely articulated at the study's inception, as suggested by Dunne:

> For it was with a firm footing in the world of practical affairs (that of teaching and schools) that we first identified our problem and then went to the philosophers seeking a quite specific type of enlightenment. What we discover, however, is that philosophy will serve us only if we surrender to it. The original problem does not remain in a position to dictate what the terms of the conversation will be but is itself assumed into and transformed by it. It is as if one were to take up a game with the object of becoming fit and then to find that one has succumbed to the charm of the game itself so that one continues in a new and developing

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[101] As explained by Gadamer, *subilitas intelligendi* refers to understanding, *subilitas explicandi* to interpretation, and *subilitas applicandi* to application. See *TM*, 308.
[102] For a more detailed explanation of the various interchanges that occur in the educational context, see *HE*, Chapter 2.
[103] Here, philosophical analysis consists primarily of questioning the justification of a particular aspect of science education (i.e. views of student understanding of NOS) and basing recommendations on appeals to background knowledge (i.e. H.G. Gadamer's philosophical hermeneutics).

> relationship to it – with one's original purpose not unfulfilled but transmuted in a way not anticipated.[104]

Insofar as this study consists of a conceptual analysis of understanding, the remainder of this chapter contains a brief introduction to these salient elements of Gadamer's philosophy that are used in subsequent chapters to support a reconceptualization of the narrative definition commonly afforded to understanding in educational practice.

Fore-structure, Prejudice, Temporal Distance, and History of Effect

According to Gadamer, Heidegger's *Being and Time* provides the hermeneut with a circle of understanding that is comprised of working out a series of fore-structures (fore-having, fore-sight, and fore-conception) in an attempt to project a meaning for a given text.[105] Furthermore, understanding is possible only when these fore-structures are not arbitrary but rather considered in light of the things themselves. Gadamer is explicit in suggesting that what is constitutive to the art of understanding involves not a subjugation of these particular fore-structures but rather a hermeneutic consciousness that remains open to the meaning of the other:

> Of course this does not mean that when we listen to someone or read a book we must forget all our fore-meanings concerning the content and all our own ideas. All that is asked is that we remain open to the meaning of the other person or text. But this openness always includes our situating the other meaning in relation to the whole of our own meanings or ourselves in relation to it…this kind of sensitivity involves neither neutrality with respect to content nor the extinction of one's self, but the foregrounding and appropriation of one's own fore-meanings and prejudices. The important thing is to be aware of one's own bias, so that the text can present itself in all its otherness and assert its own truth against one's own fore-meanings.[106]

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[104] *RG*, 22.
[105] *TM*, 267. See also Hans-Georg Gadamer, "On the Circle of Understanding," in Connolly and Keutner, eds., *Hermeneutics vs. Science* (Notre Dame, IN: University of Notre Dame Press, 1988), 68-78.
[106] *TM,* 268-269.

Thus the concept of fore-structure serves as one point of departure between philosophical and earlier hermeneutic reform which remained entangled in the fundamental prejudice of the Enlightenment: the prejudice against prejudice itself, which denies tradition its power.

Gadamer addresses the prejudice-structure emanating from the 18th century at considerable length by referring back to the Kantian notion of understanding tradition correctly, rationally and without prejudice, and the Enlightenment ideal of accepting no authority and deciding everything before the judgment seat of reason.[107] Considering the primacy of an individual's tradition even over his judgments, he posits, instead, the need to restore the concept of legitimate prejudices, as distinct from those resulting from errors in the use of one's own reason, or overhastiness, and reject the mutually exclusive Cartesian division between reason and authority.

> If the prestige of authority displaces one's own judgment then authority is in fact a source of prejudices. But this does not preclude its being a source of truth, and that is what the Enlightenment failed to see when it denigrated all authority. In fact, the denigration of authority is not the only prejudice established by the Enlightenment. It also distorted the very concept of authority. Based on the Enlightenment conception of reason and freedom, the concept of authority could be viewed as diametrically opposed to reason and freedom: to be in fact blind obedience.[108]

Philosophical hermeneutics accepts the claims of authority as neither illogical nor capricious and also accepts the subsequent idea that the mature person is one whose insights and decisions are not freed from all tradition. As such, one of the primary tasks

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[107] Ibid., 272-273. I posit that the rejection of any legitimate authority in the event of understanding is evidenced in the writings of prominent philosophers from the 17th through the 20th century. See for example Descartes, *Discourse* and Russell, *The Art of Philosophizing*.
[108] Ibid., 279.

of hermeneutics is to explicate the separation of the productive fore-structures from those that hinder understanding that takes place in the process of understanding itself.[109]

This second point of departure between Gadamer's hermeneutics and that purported by both the romantics (Schleiermacher) and the historical school (Dilthey) is further evidenced by the distinction between their respective views on the circular structure of understanding or the hermeneutic circle. For Schleiermacher and other 18th century philosophers, actual understanding is achieved when the parts that are determined by the whole themselves also determine the whole, as exemplified by the Biblical exegetics who interpret Sacred Scripture by moving between the text in its entirety and the individual books that constitute it. Consequently, "the circular movement of understanding runs backwards and forwards along the text and ceases when the text is perfectly understood,"[110] and understanding has failed when this perfect harmony is not attained. Beginning with Heidegger and later for Gadamer, the circle is more fully realized rather than dissolved in perfect understanding and becomes recognized as an interplay that occurs in the temporal distance between the interpreter and the tradition. This interplay, in turn, allows for the development of understanding in that it is predicated on the interchange between the familiar and the strange, a constitutive element in the task of hermeneutics.

> Hermeneutics must start from the position that a person seeking to understand something has a bond to the subject matter, has come into language through the traditionary text and has or acquires a connection with the tradition from which the text speaks. Hermeneutic work is based on a polarity of familiarity and strangeness; but this polarity is not to be regarded psychologically, as the range that covers the mystery of individuality, but truly hermeneutically- i.e., in regard to what has been said: the language in which the text addresses us, the story that it

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[109] Ibid., 295-96.
[110] Ibid., 293.

> tells us. Here too there is a tension. It is in the play between the traditionary text's strangeness and familiarity to us, between being a historically intended, distanciated object and belonging to a tradition. The true locus of hermeneutics is this in-between.[111]

Furthermore, rejecting the idea that the meaning of a text resides in the contingencies of the author and original audience, philosophical hermeneutics claims that understanding is a productive act that does not amount to a better understanding, "either in the case of superior knowledge of the subject because of clearer ideas or in the sense of fundamental superiority of conscious over unconscious production."[112] To this end, the idea of temporal distance assists in distinguishing between true and false prejudices as they are stirred up and put to risk by being confronted with another text.

This tension between familiarity and strangeness is further described in terms of Gadamer's principle of history of effect, an element in the act of understanding characterizing the nature of the horizons of both the knower and the known. Here the notion of horizon replaces the more limited concept of situation so as to emphasize the need to see beyond what is nearby in an effort to position oneself in the situation of the other. Additionally, the hermeneutic situation depends on obtaining the necessary "…horizon of inquiry for the questions evoked by the encounter with tradition."[113] In explaining the history of effect as it relates to a fusion of horizons, Gadamer further distinguishes his notion of understanding predicated on a dialogical interchange between the past and the present:

> Understanding tradition undoubtedly requires a historical horizon then. For what do we mean by transposing ourselves? Certainly not just disregarding ourselves. This is necessary of course insofar as we must imagine the other situation. But

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[111] Ibid., 295.
[112] Ibid., 296.
[113] Ibid., 302.

> into this other situation we must bring, precisely, ourselves. Transposing ourselves consists neither in the empathy of one individual for another nor in subordinating another person to our own standards; rather it always involves rising to a higher universality that overcomes not only our own particularity but also that of the other. To acquire a horizon means that one learns to look beyond what is close at hand- not in order to look away from it, but to see it better, within a larger whole and in truer proportion. The horizon of the present cannot be formed without the past. Rather understanding is always the fusion of these horizons supposedly existing by themselves. The hermeneutic task consists in not covering up this tension (between horizons) by attempting a naïve assimilation of the two but in consciously bringing it out.[114]

Establishing the principles of historical effect, temporal distance, prejudice, and fore-structures then is integral to the development of a hermeneutic consciousness insofar as one seeks to make the meaning of what has been handed down through tradition intelligible without having to reach an agreement with his own historicity. Additionally, these same principles allow Gadamer to expound on a series of topics, namely the priority of the question, the meaning of experience, and the idea of application, that have been taken up by educational philosophers in the past and are similarly used in the forthcoming chapters of this analysis to reconsider student understanding of NOS.

The Problem of Application, Experience, and the Priority of the Question

As mentioned previously, Gadamer dissolves the traditionally disparate *subilitas* in positing a unified hermeneutics that is comprised of understanding, interpretation, and application. Concerning the latter, he writes "...that application is neither a subsequent nor merely an occasional part of understanding, but codetermines it as a whole from the beginning."[115] The art of interpretation implies application in the fusion of horizons that is constitutive of understanding. Such a notion, according to Gadamer, contrasts with the demands of science which purports that understanding is achievable only when the

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[114] Ibid., 305-306.
[115] Ibid., 324.

interpreter refrains from participating in such an interchange.[116] The crux of his argument regarding application centers on Aristotelian ethics that connects "…reason with knowledge, not detached from a being that is becoming, but determined by it and determinative of it."[117] This form of knowledge instead pertains to the conduct of one's life and has been characterized as a form of "…activity which may leave no separately identifiable outcome behind it and whose end, therefore, is realized in the very doing of the activity itself."[118]

Unlike both theoretical (*epistemé*) and technical (*techné)* knowledge, this moral form of reasoning, *phronesis*, is not objective knowledge but is rather something that the interpreter has to do. It is not a "…cognitive capacity that one has at one's disposal but is, rather, very closely bound up with the kind of person that one is...*phronesis* falls on the side of virtue rather than of knowledge."[119] Understanding hence, when considered in terms of *phronesis*, becomes more of an event than a method which the interpreter purposefully applies in objectifying a text, thereby precluding any distinction between the subjectivity of the individual and the objectivity of the text. While Gadamer, following Aristotle, relates *techné* and *phronesis* in that they both serve to determine and guide action, he emphasizes a primary distinction drawn by the Greek philosopher between the two by referring to the former as a knowledge of how to make for oneself and the latter as self knowledge.

> It is not only that moral knowledge has no merely particular end but pertains to right living in general, whereas all technical knowledge is particular and serves particular ends. Certainly if technical knowledge were available, it would always

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[116] For an example of such a view of science as referred to here, see Russell, *The Art of Philosophizing*.
[117] *TM*, 312.
[118] *RG*, 244.
[119] *RG*, 273.

> make it unnecessary to deliberate with oneself about the subject. Where there is a *techné*, we must learn it and then we are able to find the right means. We see that moral knowledge, however, always requires this kind of self deliberation.[120]

Gadamer is explicit in asserting that since moral knowledge is unknowable in advance but rather realized in the situation of the person acting, his principles on *phronesis* are incapable of being taught, although they "…really do correspond to the nature of the thing."[121]

Furthering the distinction between *phronesis* and *techné*, Gadamer next addresses the concept of experience (*Erfahrung)* for the philosophical hermeneut. He contends that self knowledge cannot be separated from experience as in the case of knowing how to do for oneself. The latter form of reasoning is predicated on a teleological view of experience that concerns itself with the knowledge to be gained through a confirmable event.[122] Gadamer expounds on this particular perspective through his analysis of a Baconian method of induction which "…seeks to rise above the accidental and irregular way that daily experience occurs and certainly above its dialectical use."[123] Such a method, which stands in opposition to what Bacon considered as interpretation *naturae*, or the interpretation that exists through the true being of nature, experimentally seeks to thwart the mind from entertaining impetuous generalizations. Because of the ontological

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[120] *TM*, 321.
[121] Ibid., 320. As Dunne posits: "*Phronesis* itself then is not a knowledge of ethical ideas as such, but rather a resourcefulness of mind that is called into play, and responds uniquely to, the situation in which these ideas are to be realized," *RG*, 272.
[122] Dunne explains the limited relationship between *techné* and experience in the following way: "…*techné* arises from experience through some process of induction and generalizing insight; but it can, it seems, become sealed off from the experiential base and remain concentrated on generalizations…while Aristotle describes the movement from experience to *techné*, he does not offer any satisfactory account of the movement back from *techné* to experience.," *RG,* 282. Contrast this relationship with that posited between *phronesis* and experience: "…for *phronesis* does not ascend to a level of abstraction or generality that leaves experience behind. It arises from experience and returns into experience. It is we might say the insightfulness - or using Aristotle's own metaphor – "the eye" of a particular type of experience, and the insights it achieves are turned back into experience," *RG*, 293.
[123] *TM*, 347.

nature of our prejudice-structure and fore-understandings, philosophical hermeneutics instead posits a dialectical view of experience, similar to although not synonymous with Hegel's *Phenomenology of Mind*, which precludes experiencing an object at random and allows for enlarging what we thought we knew before. While a Hegelian notion of experience ends in absolute knowledge, when all experience has been overcome, Gadamer favors a dialectic of experience that "…has its proper fulfillment not in definitive knowledge but in the openness to experience that is made possible by experience itself."[124] In describing the dispositions characteristic of the experienced person, Gadamer writes:

> The consummation of his experience, the perfection that we call "being experienced," does not consist in the fact that someone already knows everything and knows better than anyone else. Rather, the experienced person proves to be, on the contrary, someone who, because of the many experiences he has had and the knowledge he has drawn from them, is particularly well equipped to have new experiences and to learn from them.[125]

Such a view of experience resonates with Dunne's account of the value of experience as constitutive of *phronesis*:

> …experience signifies an achieved state that is the fruit of universalizing and consolidating the meaning of many previous discrete impressions; this primary significance is most perspicuously present in our own use of the phrase an experienced person… *phronesis* is what enables experience to be self-correcting and to avoid settling into mere routine.[126]

Insofar then as experience implies new experience, to be situated within a tradition, as in the case of historically effected consciousness, it establishes rather than limits the freedom of knowledge.

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[124] Ibid., 355. See also Georg W.F. Hegel, trans., James Black Baillie, *The Phenomenology of Mind* (London: G. Allen and Unwin, 1949).
[125] *TM*, 355.
[126] *RG*, 292.

Such a view of experience is made possible only by the asking of questions. For Gadamer, the priority of the question is exemplified in the Platonic account of knowledge, where in order to be able to ask questions, one must want to know and that means knowing that one does not know. This openness to asking, like the aforementioned openness to new experiences, is thus bounded by the respective horizons of the interpreter and the universal and results in a type of dialectical negativity, a knowledge of not knowing. Because it is considered more of a disposition than an action to be able to determine what is questionable, Gadamer contends that the idea of method thus remains limited for understanding.[127] Similarly, he is careful to distinguish such a form of knowledge from other variations of rhetoric which may attempt to use questioning as a means of persuasion:

> It requires that one does not try to argue the other person down but that one really considers the weight of the other's opinion. Hence it is an art of testing. A person skilled in the art of questioning is a person who can prevent questions from being suppressed by the dominant opinion. Dialectic consists not in trying to discover the weakness of what is said, but in bringing out its real strength. It is not the art of arguing (which can make a strong case out of a weak one), but the art of thinking (which can strengthen objections by referring to the subject matter).[128]

The perspectives assumed in interpreting the notions of questioning, experiencing, and application arguably contribute to defining understanding in education. I suggest in Chapter Four that the philosophical underpinnings inherent in current NOS teaching and learning, which seem to favor an epistemological as opposed to hermeneutical view of understanding, may indeed limit rather than enlarge student understanding.

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[127] Gallagher suggests that Plato and Gadamer may consider questioning more of an art than a technical method. See *HE*, 148.
[128] *TM*, 367.

Summary and Study Outline

The present study is educationally relevant in that it addresses the import of incorporating philosophical hermeneutics into the discourse surrounding student understanding of nature-of-science considerations. The next chapter contains a description of both the rationale supporting the inclusion of NOS considerations in national reform efforts as well as the body of empirical research that has resulted from such an inclusion. In the chapters that follow, I use the Gadamerian elements as explained here to analyze perspectives on student understanding as evidenced in the national reform documents of the last two decades and the science education literature from the same period, cognizant of my aim to avoid a uniquely technical analysis and willing to remain open to the multiple experiences that such an endeavor can afford:

> Philosophy is itself a practice, and, as in the case of any other practice, it is only when one gets caught up in the doing it that one can learn to get out of it what it has to give. What it has to give is indeed a kind of insight into the structure of our other practical engagements and, moreover, far from it being the case that experience in any of these (e.g., teaching) must be left behind when one takes it up, such experience is itself a prerequisite for fruitful participation in it.[129]

In the final chapter, I discuss the positive value of considering Gadamer's hermeneutics as a referent for both student understanding of NOS and the scholarly discourse surrounding that understanding.

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[129] *RG*, 22.

CHAPTER THREE

NATURE-OF-SCIENCE

A Rationale

Whereas a thorough analysis of the various rationales supporting the inclusion of NOS considerations in the secondary science curriculum is largely beyond the scope of this paper, a brief mention of the respective arguments of NOS advocates, both in the science education and curriculum reform policy communities, provides a context for situating the present discourse pertaining to student *understanding* of such considerations.[130] Nearly two decades ago, at the inception of what was to be a recognizable period of science education reform, policy makers touted the ability of science to "…help students to develop the understandings and habits of mind they need to become compassionate human beings able to think for themselves and to face life head on."[131] Ten years later, McComas, Almazroa, and Clough provided science education researchers with a concise overview of the case for NOS, referencing a four-pronged argument for NOS pedagogy that included utilitarian, democratic, cultural, and moral components.[132] According to the argument, students who understand NOS are better able to make sense of science and technology, participate in socio-scientific decision-making,

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[130] Chapter One of this dissertation references some of the general responses to arguments for the inclusion of NOS in K-12 education. See DeBoer, "Scientific Literacy," Shamos, *The Myth of Scientific Literacy*, and Turner and Sullenger, "Kuhn in the Classroom."
[131] F.J Rutherford and A. Ahlgren, *Science for All Americans* (New York, NY: Oxford University Press, 1990), xiii.
[132] McComas, Almazroa, and Clough, "The Nature of Science."

value science as central to the development of our culture, and understand the moral commitments of scientists, commitments which can be instrumentalized by the larger society.[133] Another ten years later, similar sentiments were evident in the editor's introduction of an important text on scientific inquiry and NOS:

> Such understandings are critical, especially when we quickly come to realize that it is unreasonable to assume that our citizenry will make decisions about scientifically and technologically-based issues by running to the garage to conduct authentic scientific investigations. More realistically, experiences with inquiry provide our students with foundational experiences from which they can reflect on the nature and limits of scientific knowledge and claims. It is based upon this knowledge that the general citizenry will derive meaning and research conclusions concerning knowledge claims. This is the value of nature of science.[134]

Resounding similarly with such democratic ideals as effective and responsible citizenship and personal and social decision-making, the last reference additionally includes an understanding of the limits of scientific knowledge claims as a favorable outcome of NOS instruction. Proponents of such a view argue that "…individuals who understand how science works will likely be less cynical about the scientific enterprise."[135] At the same time, a number of researchers posit that acknowledging such limitations enables learners to delineate between science and other epistemologies, thereby easing the possible tension caused by discussions pertaining to scientific concepts that may conflict

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[133] For a more detailed discussion of each of these components see Rosalind Driver, J. Leach, A. Miller, and P. Scott, *Young Peoples Images of Science* (Bristol, PA: Open University Press, 1996).
[134] Lawerence B. Flick and Norman G. Lederman, eds. *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education* (Dordrecht, Netherlands: Springer, 2006), xii. It is important to note here that other researchers have countered that several of the premises of this argument rest of untested assumptions, such as relating ones understanding of NOS to decision-making, and suggest the need for further empirical research to substantiate such a rationale. Some researchers claim, for example, that personal values are much more prevalent in decision-making than NOS understandings. See for example, Randy Bell and Norman Lederman, "Understandings of the Nature of Science and Decision Making on Science and Technology Based Issues," *Science Education* 87, no.3 (2002): 352-377.
[135] McComas, Almazroa, and Clough, "The Nature of Science," 518.

with certain metaphysical, theological, or other worldview assumptions.[136] While these same researchers may not explicitly purport a privileged status for scientific knowledge, one final group of NOS advocates maintains that, as the only truly verifiable and self-correcting mode of inquiry, the domain of science should be recognized for its remarkable effectiveness: "…unarguable and spectacular is the ace up science's sleeve. Whatever else we may think of it, we have to accept that science works. Penicillin cures diseases, aircraft fly crops grow more intensely because of fertilizers, and so on."[137] Such a view of science leads others in the science education community to the following interpretation of the work of evolutionary biologist, Edward O. Wilson:

> …evolutionary biologist Edward Wilson argues that only when all knowledge is grounded on the firm foundation of the natural sciences will we have the best chance of coping successfully with our existence. Taken to its logical conclusion, this view of science can become the basis of a new conception of what it means to '"know." The many nuances and complexities become apparent as one studies the history of science, but the essentially rational, progressive, universal nature of science is the more accurate picture that science teachers should help students understand. At the close of this century, Edward Wilson is saying that science will show all disciplines, not just philosophy, the way toward more valid and reliable knowledge. Science teachers should pay better attention to Wilson's ideas as they search for ways to help students better understand the nature of science.[138]

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[136] See for example McComas, Almazroa, and Clough, "The Nature of Science," Gould, "Nonoverlapping Magisteria," and Scott, *Evolution vs. Creationism.* The view that it is somehow possible to separate science from other ways of knowing and that such a delineation facilitates the learning of scientific concepts has been the focus of much debate in science education and philosophy of education. For a recent discussion of the topic see, Michael Reiss, "Imagining the World: The Significance of Religious Worldviews for Science Education," *Science & Education* 6-7, no. 18 (2009): 783-796; Stuart Glenn, "Whose Science and Whose Religion? Reflections on the Relations between Scientific and Religious Worldviews," *Science & Education* 6-7, no. 18 (2009): 797-812; and Francis Collins, *The Language of God* (New York, NY: Free Press, 2006). The deliberate attempt to remove or ease potential sources of tension is a considerable focus of the subsequent discussion in this dissertation.

[137] Bryan Appleyard, *Understanding the Present- Science and the Soul of Modern Man*, (New York, NY: Anchor Books Doubleday, 1992), 3. Scholars have of course questioned the validity of the empiricist's claim of what qualifies as knowledge. For a pertinent discussion on the primacy of science, as an empirical epistemology, over other ways of knowing, see William Cobern, "The Nature of Science and the Role of Knowledge and Belief," *Science & Education* 9, no.3 (2000): 219-246.

[138] Ron Good and James Shymansky, "Nature-of-Science Literacy in *Benchmarks* and *Standards*: Post-Modern/Relativist or Modern/Realist?" *Science & Education* 10 (2001): 183-184. The conclusion drawn by these authors favors a progressive, stable, and rational way of knowing over other more relativistic

Whether by acknowledging the epistemological authority of science, seeking to ameliorate the possible epistemic tensions encountered by learners and instilling in students a greater appreciation for the discipline, or attempting to promote a greater sense of responsibility and develop enhanced decision-making skills, advocates for the inclusion of NOS in secondary science pedagogy have noticeably engaged science educators and policy makers for the last two decades as evidenced by the considerable amount of research in the area. The next section of this chapter provides an overview of such research which subsequently serves as the focus of philosophical inquiry.

Research and Reform

Resulting from any combination of the various rationales supporting the inclusion of NOS instruction in the school science classroom, reform efforts for the last twenty years have focused largely on teaching a science that both promotes contemporary views of NOS and seeks to develop those same views in secondary students.[139] As such, the National Science Education Standards state that "…students should develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture."[140] Additionally, a consensus of researchers has

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accounts. See Forrest, "Methodological Naturalism" for a similar opinion in favor of science as a privileged way of knowing when compared to other worldviews that deny ontological naturalism.

[139] While this dissertation considers research and reform documents primarily from the 1990s to the present, many notable scholars in the field contend that NOS deliberations have been as integral to science education as the more generally recognized scientific literacy movement and thus present in some form for more than 100 years. See, for example, Chapter One of this dissertation, as well as Flick and Lederman, *Scientific Inquiry*; McComas, Almazroa, and Clough, "The Nature of Science"; Norman G. Lederman, Fouad Abd-El-Khalick, Randy L. Bell, and Renee S. Schwartz, "Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science," *Journal of Research in Science Teaching* 39, no. 6 (2002): 497-521; and Fouad Abd-El-Khalick, Randy L. Bell, and Norman G. Lederman, "The Nature of Science and Instructional Practice: Making the Unnatural Natural," *Science Education* 82, no.4 (1998): 417-436.

[140] National Research Council, *National Science Education Standards*, 21.

maintained that "…it is critical for us to do more than avoid debates about nature-of-science by rising to a level of generality where disagreements do not exist. As educators, it is absolutely critical that we carefully consider what aspects of nature-of-science are accessible to school-aged students and what aspects make sense for all students to know."[141] It is precisely this call for considering a set of NOS aspects that are both appropriate and accessible for students that has dominated a substantial portion of the research endeavor. What follows is a sampling of the numerous attempts found in the literature either to posit a desirable set of such NOS aspects for science students or to promote the use of NOS tenets to evaluate NOS understandings.

Beginning with the reform documents of the 1990s, The *Benchmarks for Scientific Literacy* and *National Science Education Standards* address a number of characteristics that pertain to NOS, examples of which include science as a way of knowing, involving curiosity, creativity, and chance, dependent on persuasive communication of ideas and findings, and built on a set of functional assumptions, some of which involve the behavior of the universe and the understandability and predictability of nature. [142] Extracting from some eight international science standards documents, researchers have added that science is durable yet tentative, comprised of theory-laden observations and both an evolutionary and revolutionary character, and affected by

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[141] Flick and Lederman, *Scientific Inquiry,* xii.
[142] Mike Smith and Lawrence Scharmann, "Defining versus Describing the Nature of Science: A Pragmatic Analysis for Classroom Teachers and Science Educators," *Science Education* 83, no.4 (1998): 493-509. It is perhaps worthwhile to note here as well that scholars have purported a lack of clarity concerning the language used in the Standards and Benchmarks to address NOS, suggesting contrasting statements that can be interpreted along various philosophical lines of inquiry. See Good and Shymansky, "Nature of Science Literacy."

social, historical, and cultural traditions.[143] Others have created models of nature-of-science to include premises of both the nature of the scientific enterprise, such as the social dimension of science and the major phases of the scientific endeavor, as well as the nature of scientific knowledge, such as the developmental character of scientific knowledge, to allow for appropriate curriculum development efforts and empirical research.[144]

Science educators have further appropriated these tenets to derive criteria they deem useful in assessing NOS understandings. In one such study of secondary science teachers, the ideas of tentativeness, empirical basis, subjectivity, creativity, sociocultural embeddedness, observation and inference, and laws and theories were used to compare NOS conceptions before and after a science research internship treatment course.[145] In another study of school age students, nine themes, including scientific methods, diversity of thinking, hypothesis and prediction, historical development of scientific knowledge, and cooperation and collaboration in the development of scientific knowledge, were considered in the development of a simplified account of NOS.[146] Lastly, in a study

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[143] See McComas, Almazroa, and Clough, "The Nature of Science." Here too disagreement exists concerning the establishment of such a consensus, or as some may refer to as pragmatic, view of science. For example, see Alters, "Whose Nature of Science?" and Edgar Jenkins, "The Nature of Science as a Curriculum Component," *Journal of Curriculum Studies* 28, no. 2 (1996): 137-150. Such disagreement however is often deemed irrelevant in favor of an acceptable level of generality and the predominant idea that the disagreements exists merely among philosophers, historians, and educators and do not pertain to K-12 instruction. For a further account of this view, see Norman G. Lederman, "Syntax of Nature of Science Within Inquiry and Science Instruction," in L.B. Flick and N.G. Lederman, eds., *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education* (Dordrecht, Netherlands: Springer, 2006), 303; and Fouad Abd-El-Khalick, "Developing Deeper Understandings of Nature of Science: The Impact of a Philosophy of Science Course on Preservice Science Teachers' Views and Instructional Planning," *International Journal of Science Education* 27, no.1 (2005): 15-42.
[144] David Moss and Eleanor Abrams, "Examining Student Conceptions of the Nature of Science," *International Journal of Science Education* 23, no. 8 (2001): 771-790.
[145] Schwartz, Lederman, and Crawford, "Developing Views of Nature of Science."
[146] Hannah Bartholomew, Jonathan Osborne, and Mary Ratcliffe, "Teaching Students 'Ideas-About-Science': Five Dimensions of Effective Practice," *Science Education* 88, no.5 (2004): 655-682.

involving science textbooks, researchers used a similar set of tenets to examine the inclusion and representation of NOS aspects.[147]

In addition to efforts aimed at establishing generally acceptable and appropriate NOS considerations for science education, researchers have focused their attention on various pedagogical approaches which support the teaching of these considerations. Recognizing the need to understand initial student understanding in order to successfully teach about NOS, there is an ample body of literature pertaining to preconceptions, a variable addressed in conceptual change learning theory.[148] Based on the premise that "…a conceptual change framework helps makes sense of the difficulties students often have developing robust understandings of the NOS that can be applied in a variety of settings,"[149] one study, for example, sought to identify the "…strategies used by secondary science teachers to diagnose their students' preconceptions in the regular classroom environment and the ways that teachers might use the information gathered in such a diagnosis."[150] Another study involving students in grades six, eight, and ten,

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[147] Fouad Abd-El-Khalick, Mindy Waters, and An-Phong Le, "Representations of Nature of Science in High School Chemistry Textbooks over the Past Four Decades," *Journal of Research in Science Teaching* 45, no. 7 (2008): 835-855. In addition to the aforementioned aspects, this set included the myth of the scientific method.

[148] The value placed on addressing preconceptions, while derived from a number of references, is largely credited by science educators to research on conceptual change theory as explicated nearly thirty years ago by George J. Posner, Kenneth A. Strike, Peter W. Hewson, and William A. Gertzog, "Accommodation of A Scientific Conception: Toward a Theory of Conceptual Change," *Science Education* 66 (1982): 211-227. See also J.J Mintez and J.H. Wandersee, *Research in Science Teaching and Learning: A Human Constructivist View* (San Diego, CA: Academic Press, 1988), 59-92. Several components of this theory are contrasted with philosophical hermeneutics in subsequent pages of this dissertation, such as the varied connotations afforded to such preconceptions between the two.

[149] Michael P. Clough, "Learners' Responses to the Demands of Conceptual Change," *Science and Education* 15, no.5 (2006): 489.

[150] Judith Morrison and Norman Lederman, "Science Teachers' Diagnosis and Understanding of Students' Preconceptions," *Science Education* 87, no.6 (2003): 850.

contained research questions predicated on the idea that students' existing conceptions are very resistant to change and tend to impact the learning of new concepts.[151]

Several researchers have, however, questioned the assumptions underlying the inherently rational account afforded to knowledge acquisition by such a theory. Notable among these is a challenge to the conceptual change model in that it acknowledges epistemological and metaphysical commitments among students as integral to the development of new knowledge only to later "…marginalize [such commitments] in favor of using anomalous data to induce conceptual shifts in students."[152] Additionally, scholars examining the differences in learning between students of varying cultural worldviews, suggest that those of non-Western origin have greater barriers to learning science that are not strictly based on language.[153] Rather than seek to promote cognitive transformations as suggested by change theorists, these science educators suggest that:

> The objective of initiating discussions upon the nature of science and culture should not be towards discovering constructions that are then labeled as "misconceptions." The purpose of encouraging students to disclose their ideas about science and traditional knowledge is to facilitate an increase in the understanding of the differences in the epistemological premises.[154]

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[151] Sukjin Kang, Lawrence Scharmann, and Taehee Noh, "Examining Students' Views on the Nature of Science: Results from Korean 6th, 8th, and 10th Graders," *Science Education* 89, no.2 (2004): 314-334.
[152] John Rudolph and Jim Stewart, "Evolution and the Nature of Science: On the Historical Discord and Its Implications for Education," *Journal of Research in Science Teaching* 35, no. 10 (1998): 1082. The authors contend that such commitments pose a significant barrier to learning and propose their inclusion as part of the sense-making process in science. In Cobern's, "The Nature of Science," the author maintains that such preconceptions are often viewed as beliefs rather than knowledge. In such instances, teaching can remain authoritarian if the reasons supporting those beliefs are ignored irrespective of the use of inquiry-oriented instruction.
[153] Dawn Sutherland and Reg Dennick, "Exploring Culture, Language, and the Perception of the Nature of Science," *International Journal of Science Education* 24, no.1 (2002): 1-25. The authors here report on the assimilative nature of the science curriculum in that it privileges Western science over other ways of knowing. They further contrast such an epistemology with the coming-to-knowing process valued by certain cultures. See 3-5.
[154] Ibid., 21.

While acrimony indeed surrounds the viability of a conceptual change theory of learning for all science students, its adherents, who undoubtedly comprise the majority of science education researchers, continue to believe that students interpret experiences from a framework consisting of prior knowledge and additional experiences, thereby positing that certain naïve views of NOS can be attributed partially to a lack of sufficient experiences with the sciences. It follows then that a subsequent focus of NOS research centers on both developing and evaluating those types of educational experiences necessary to promote students' understandings of NOS.

One of the more prominent discussions that have taken place in the literature concerning how to effectively promote NOS understandings revolves around the distinction between implicit and explicit attempts at instruction.[155] The former generally involve the inclusion of particular experiences in classroom instruction in an effort to engage learners in scientific inquiry with the hope that, in doing so, they will develop NOS conceptions aligned with current perspectives.[156] Critics of such pedagogical practices, however, caution against the likelihood of adequately advancing NOS understandings without the direct involvement of the teacher and the deliberate design of lessons to address particular NOS issues:

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[155] Although the focus of the present concern is on teaching for enhanced student understanding of NOS, researchers have similarly explored the methods used to promote teacher understandings of the same concepts. See Abd-El-Khalick and Lederman, "Improving Science Teachers' Conceptions," 691 for a summary of the research involving both implicit and explicit approaches to teaching teachers.

[156] In order to appropriately allow for students to engage in authentic inquiry, several researchers recognize the necessary transformation needed to take place in the context of classroom teaching. As one set of authors posit, "… for many teachers, encultured in the habitus of traditional science teaching, this would require a shift in their conception of their own role from dispenser of knowledge to facilitator of learning; a change in their classroom discourse to one which is more open and dialogic; a shift in their conception of the learning goals of science lessons to one which incorporates the development of reasoning and an understanding of the epistemic basis of belief in science as well as the acquisition of knowledge." Bartholomew, Osborne, and Ratcliffe, "Teaching Students 'Ideas-About-Science,'" 678.

> If school science content instruction consisted solely of activities and laboratory work without a teacher intentionally helping students make sense of those experiences, certainly the students' content understanding would compare poorly to that of another group of students whose teacher intentionally engaged them in wrestling with the same science content using the same activities… Mistaken notions of the NOS developed in this way, just like mistaken ideas regarding natural phenomena, resist later implicit and even many explicit attempts to modify those mistaken views. If a child's upbringing consisted entirely of accurate implicit experiences regarding the NOS, they would likely develop a number of accurate NOS ideas. [157]

Instead they favor an explicit approach to teaching and learning as characterized by planning through objectives, instructional attention, and assessments. Additionally, "…this approach intentionally draws learners' attention to aspects of NOS through discussion, guided reflection, and specific questioning in the context of activities, investigations, and historical examples."[158] Rather than consider NOS conceptions as dispositions towards science and attainable through effective inquiry experiences, proponents of explicit instruction view these same conceptions as cognitive learning outcomes.[159] Of course, researchers contend that there are, in fact, a variety of instructional methods that can be developed to incorporate aspects of both implicit and explicit approaches. One such study, for example, examined the use of guided attention to and reflection on NOS in the context of authentic scientific research, where the intention

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[157] Clough, "Learners' Responses," 466-467.
[158] Schwartz, Lederman, and Crawford, "Developing Views of Nature of Science," 614. For another example of a study using explicit approaches to teach for NOS understandings, see Rola Khishfe and Norman Lederman, "Teaching Nature of Science within a Controversial Topic: Integrated versus Nonintegrated," *Journal of research in Science Teaching* 43, no.4 (2006): 395-418.
[159] See for example, Abd-El-Khalick and Lederman, "Improving Science Teachers' Conceptions," 691 and Lederman, "Syntax of Nature of Science." This last author writes, "Nature of science, and scientific inquiry, should be thought of as a "cognitive" rather than an "affective" instructional outcome... then, as any cognitive objective, this outcome should be planned for, explicitly taught, and systematically assessed," 312. Reducing understanding to a cognitive outcome, as compared to a hermeneutic understanding, will be the focus of future analysis in this dissertation.

was not so much for the students to act as scientists but rather to become reflective about science within the context of the scientific community.[160]

It is worthwhile to mention here that, while seemingly favored by advocates of science education reform and leaders in the science education community, explicit approaches to teaching for NOS understandings have elicited a number of challenges, several of which serve as the basis for philosophical analysis in the chapters to follow. Primary among these is a concern that a deliberate attempt to promote desired understandings could amount to a form of direct teaching and transmission of information. In response to such a critique, researchers have maintained a clear distinction between explicit attention and didactic teaching, where the former simply includes NOS among the various other learning outcomes that serve as the focus of instruction, and have posited that explicit approaches to NOS provide students with an opportunity to further engage with their learning:

> It might be argued that an explicit approach entails imposing on students certain views of the scientific enterprise. However our counter argument would be that certain views of NOS have already been imposed on students. It is more likely that those students were explicitly taught certain naive ideas about NOS. As such, guiding students to internalize more informed views of NOS should not be viewed as an episode of formal indoctrination. Rather it should be viewed as an attempt to empower them to further pursue and make sense of the workings of a rich and interesting intellectual endeavor, the scientific enterprise.[161]

Several authors are cognizant of and caution against the tendency of such a position to assess student understanding based on its alignment with a prescribed set of views on the subject and instead reiterate an instructional commitment to student understanding absent

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[160] Schwartz, Lederman, and Crawford, "Developing Views of Nature of Science."
[161] Fouad Abd-El-Khalick and Norman Lederman, "The Influence of History of Science Courses on Students' Views of Nature of Science," *Journal of Research in Science Teaching* 37, no. 10 (2000): 1088.

of adopting any one desirable view of science or the philosophical position of the instructor.[162]

For these researchers, it logically follows that in order to evaluate the effectiveness of any given pedagogical strategy in promoting the advancement of a desired view of NOS, based on a consensus, pragmatic account of the nature of scientific knowledge and the scientific enterprise, the development and use of appropriate methods for assessing NOS understandings is a necessary complement to the existing body of empirical studies. The vast majority of assessment instruments used prior to the late 1990s involved any combination of a set of quantitative item responses such as multiple choice, agree/disagree, and Likert-type.[163] While the inevitability of having to employ such methods in some degree in large scale investigations is difficult to question, objections were raised against the interpretations of scores from such tests based both on the idea that they may lead to biased value judgments, if one assumes a particular philosophical position and subsequently a correct view of science, and inaccurate explanations of student views when compared to actual interviews.[164] Discrepancies arise when it is assumed that the understandings of both respondents and instrument developers coincide with regard to particular statements. As a response to these criticisms, a group of researchers collaborated on the development of the Views of Nature of Science Questionnaire (VNOS). Such an instrument, it is argued, "…was developed with an interpretive stance in mind, and aims to elucidate learners' NOS views and

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[162] See, for example, Smith and Scharmann, "Defining versus Describing;" and Michael Matthews, "James T. Robison's Account of Philosophy of Science and Science Teaching: Some Lessons for Today from the 1960s," *Science Education* 81 (1997): 295-315.
[163] For a list of studies using such instruments, see Abd-El-Khalick and Lederman, "Improving Science Teachers' Conceptions," 672; and Norman Lederman, Philip Wade, and Randy Bell, "Assessing the Nature of Science: What is the Nature of Our Assessment?" *Science and Education* 7 (1998): 595-615.
[164] See Lederman, Wade, and Bell, "Assessing the Nature of Science," 611.

generate profiles of the meanings they ascribe to various NOS aspects for the purpose of informing the teaching and learning of NOS rather than for labeling learners' views as adequate or inadequate or sum their NOS understandings into numerical scores."[165] For the last ten years, additional empirical studies have been designed with the intention of eliciting student understandings of NOS concepts through the use of interviews in combination with other various qualitative methods such as long term participant observation and peer collaboration.[166]

The above discussion provides an overview of the more salient lines of research pertaining to student understanding of the nature of scientific knowledge and the scientific enterprise that serve as the focus for philosophical analysis in the chapters to follow; namely, a consideration of viable NOS tenets for pre-college students, learners' preconceptions concerning NOS, the effectiveness of respective implicit and explicit approaches to teaching for the promotion of NOS considerations, and the use of varied methods for assessing student understandings. Before progressing to that analysis, however, brief mention is made here regarding the alleged results of a sampling of empirical studies surrounding a number of the aforementioned areas of research. Concerning the use of a previously identified, acceptable set of NOS tenets, one study presented findings indicating that the pre-college student participants held fully formed

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[165] Lederman, Abd-El-Khalick, Bell, and Schwartz, "Views of Nature of Science Questionnaire," 517. It is interesting to note that some of these same researchers just a few years before suggested that "…in terms of assessment, it is time we move on to questions of classroom practice and lay to rest the continued assessment of teachers' and students' assessment." See Lederman, Wade, and Bell, "Assessing the Nature of Science," 612.

[166] See Moss and Abrams, "Examining Student Conceptions," and Ping-Kee Tao, "Eliciting and Developing Junior Secondary Students' Understanding of the Nature of Science Through a Peer Collaboration Instruction in Science Stories," *International Journal of Science Education* 25, no. 2 (2003): 147-171.

NOS conceptions consistent with roughly one-half of the tenets.[167] Another study reported the inadequate alignment of multiple textbook sections with target NOS aspects, highlighting the discrepancies that exist between national and international science education reform documents and the representation and treatment of NOS in commercial school science publication materials.[168]

One study, focusing on the methods used to encourage desirable NOS views in the classroom, reported that although teachers admitted the importance of knowing prior ideas that students bring with them to the classroom, such an appreciation was neither well substantiated nor significant enough to encourage the actual use of diagnostic strategies in instruction.[169] Another study purported that, regardless of the methods used to teach NOS, only a small number of students were found to have developed an appropriate understanding of a particular view of scientific knowledge and the scientific enterprise.[170] Conversely, a different set of results suggested that, when given the opportunity to assume a reflective stance outside of the role of an inquirer, teachers are

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[167] Moss and Abrams, "Examining Student Conceptions." The authors of this study report that "… the designation fully formed or complete is utilized to imply that student beliefs were for the most part consistent with the premises of the model. It does not imply that student conceptions could not evolve further beyond the model. In contrast, partially conceived, incomplete, or not fully formed describes student understandings that were lacking when compared with the ideas outlined in the model," 776. It is important to recognize here the meaning ascribed to each of the designations used in the study as such designations are analyzed in the chapters to follow.

[168] Abd-El-Khalick, Waters, and Le, "Representation of Nature of Science."

[169] Morrison and Lederman, "Science Teachers' Diagnosis" and Kang, Sharmann, and Noh, "Examining Students' Views."

[170] Kang, Scharmann, and Noh, "Examining Students' Views." Various explanations have been offered concerning such apparent ineffectiveness ranging from the lack of a concerted professional development, a consistent and contemporary philosophy, and intentions within curriculum to an interference with students' everyday epistemologies and developmentally based constraints on reasoning. See for example Lederman, "Syntax of Nature of Science," 302, Renee Schwartz and Barbara Crawford, "Authentic Scientific Inquiry," 334-335, and Randy L. Bell, "Perusing Pandora's Box," 427-446, all in L.B. Flick and N.G. Lederman, eds., *Scientific Inquiry and Nature of Science: Implications for Teaching, Learning, and Teacher Education* (Dordrecht, Netherlands: Springer, 2006).

effectively able to promote the development of NOS views in an inquiry context,[171] further supporting findings that students are apt to attend to understandings of NOS that match their inadequate views, absent the guidance from the classroom instructor.[172] The inclusion of such an explicit approach to inquiry teaching can be problematic, however, in that in certain situations, the teacher remained ultimately in control of the discussion, limiting student input to answering only those questions posed by the instructor rather than engaging in a dialogic discussion.[173] Insofar as these results may signify "…significant progress toward understanding the whats, whens, and hows of nature of science instruction,"[174] scholars in the discipline have commented as recently as last 2008 "…that improving the teaching, learning, and assessing of NOS is still far from being clearly understood and translated into practice."[175] The following chapter considers the philosophical assumptions inherent in the teaching for NOS understandings as addressed in the aforementioned research endeavors.

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[171] Schwartz, Lederman, and Crawford, "Developing Views of Nature of Science."
[172] Tao, "Eliciting and Developing Junior Secondary Students' Understanding."
[173] Bartholomew, Osborne, and Ratcliffe, "Teaching Students Ideas-About-Science," 669.
[174] Bell, "Purusing Pandora's Box," 442.
[175] Michael P. Clough and Joanne K. Olson, "Teaching and Assessing the Nature of Science: An Introduction," *Science and Education* 17, no. 2 (2008): 143-145, 145.

CHAPTER FOUR

CURRENT ASSUMPTIONS

While prominent science education researchers interested in promoting student understanding of nature-of-science seem quick to maintain and agree upon the irrelevance of philosophical analysis pertaining largely to the metaphysical and epistemological views of science intended for school science curricula, a review of the literature as presented throughout the preceding chapters of this dissertation suggests an even greater eschewing, or rather complete absence, of such an inquiry on the nature of *understanding* itself. Whereas in the case of the former, their position is explicated in terms of curricular, psychological, and pragmatic considerations,[176] no explanations have been offered concerning the latter, suggesting perhaps not a deliberate effort to thwart such an attempt but rather a lack of recognition of the significance of striving for clarification and clarity. Philosophers of education, however, insist upon the importance of examining the assumptions underlying the use of such a widely used and poorly conceptualized construct as understanding, not only, of course, within narrow lines of inquiry but also in the broader context of education. In this chapter, I inquire into the fundamental assumptions that seem to support the present use of the idea of teaching for student understanding of NOS considerations, namely a Cartesian foundationalism and

[176] See, for example, Lederman, "Syntax of Nature of Science," 303; and Abd-El-Khalick, "Developing Deeper Understandings of Nature of Science."

Aristotelian theoretical knowledge, or *techné*, with the hope of then proceeding to offer a different conceptualization of the same idea along the lines of Gadamer's philosophical hermeneutics in the chapters to follow.

Cartesian Influences

As mentioned in Chapter Two, one of Descartes' signature contributions to the field of philosophy, and arguably a considerable number of disciplines as well, including education, was his attempt to discover the foundations necessary for rational knowledge by resolving to eradicate his previous opinions. The result of such an attempt was his infamous four-step method which, he maintained, avoided all sources of prejudice in an effort to acquire clearer and more distinct conceptions of the objects of his reason. When viewed from a Cartesian sense of tradition, these sources of prejudice "…would have to be something external, objective, and past," capable of being stepped outside of as in "…trying to step outside of our own skins."[177] As such, they acquire only a negative value and are relegated into an association with either authority or overhastiness.[178] The result of this "…dominant ideal of knowledge and the alienated, self-sufficient consciousness it involves" supports a hermeneutical perspective "…that regards understanding as a repetition of a past intention – as a reproductive procedure rather than a genuinely productive one that involves the interpreter's own hermeneutical situation."[179]

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[177] Gallagher, *HE*, 85 and 87.
[178] Gadamer writes: "The division of prejudices into those of 'authority' and those of 'overhastiness' is obviously based on the fundamental presupposition on the Enlightenment, namely that methodologically disciplined use of reason can safeguard us from all error. Overhastiness is the source of errors that arise in the use of one's own reason. Authority, however, is responsible for one's not using one's own reason at all." *TM*, 279.
[179] *PH*, xvi.

Insofar as the literature on student understandings of NOS involves a discussion of preconceptions and their development, considers nature-of-science as a cognitive outcome, and is derived in large part from a rationale consisting of both emancipatory and ameliorating elements, I argue that such a discussion is predicated on a Cartesian foundationalism as described above.[180] Two of the primary reasons provided in support of the inclusion of NOS considerations in reform documents and classroom teaching are based on the assumption that a mature understanding of such considerations enables learners to be more self-sufficient and responsible while simultaneously reducing any possible tensions that may arise from metaphysical, theological, or other worldview commitments at odds with a scientific epistemology. Such reasons resonate with Descartes' attempt to develop a subjective account of knowledge which, in eradicating all sources of prejudice, sought to rely less on the past and tradition and do away with obstacles that may interfere with its proper development. This development, in turn, as characterized by Descartes as consisting of a series of procedures that begin with the subjugation of tradition and end in a more reliable knowledge, is clearly evident in the attempt of NOS researchers to examine student preconceptions so as to promote deeper, more mature understandings. Whether seeking to analyze the more discrete transformation of inadequate into adequate views or the progressive change in naïve towards more intermediary or informed conceptions, the empirical studies mentioned

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[180] While the NOS research addressed here was thoroughly discussed in the preceding chapter, the following additional reference further exemplifies the rationale supporting teaching for NOS understandings: "…few individuals even have an elementary understanding how the scientific enterprise operates. The lack of understanding is potentially harmful, particularly in societies where citizens have a voice in science funding decisions, evaluating policy matters and weighing scientific evidence provided in legal proceedings. At the foundation of many illogical decisions and unreasonable positions are misunderstandings of the character of science." McComas, Almazroa, and Clough, "The Nature of Science," 511.

here all support a developmental model that serves as the foundation for understanding *understanding*.

Regardless of the view taken on such a developmental process by NOS researchers, all of the currently employed models of understanding are seemingly rooted in a conceptual change theory of cognition. As discussed in Chapter Three, such a theory considers prior knowledge mostly in terms of the difficulty it presents in developing more complete understandings. The attempt of many researchers to "…marginalize [such commitments] in favor of using anomalous data to induce conceptual shifts in students"[181] and consider them as a form of belief rather than knowledge[182] is remarkably analogous to the Cartesian inclination to denigrate preconceptions as mere opinion and unreliable. Similarly, as "…Descartes was most anxious to escape the tradition of metaphysical disputations, which seemed to him to provide all of the convoluted categories responsible for leading our thought astray,"[183] a significant portion of NOS research eschews any mention of including such commitments in the discourse on student understanding.[184] Instead, the focus is predominantly on successfully teaching for an adequate understanding of NOS as determined by a set of predetermined, appropriate tenets. As a result, the context for teaching and learning assumes a reproductive character where the student is often left to arrive at an answer previously

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[181] Rudolph and Stewart, "Evolution and the Nature of Science," 1082.
[182] Cobern, "The Nature of Science."
[183] *HE*, 84.
[184] See Rudolph and Stewart, "Evolution and the Nature of Science."

determined by the teacher and understanding is assessed based on the alignment of student responses with NOS tenets, a duplication of a past intention.[185]

A Privileging of *Techné*

Like Aristotle himself who appears to have granted theoretical knowledge a higher ascendancy over more practical ways of knowing, I contend that science education researchers have predicated their use of promoting student understanding of NOS on his reasoned account of *techné* over *phronesis*. Recalling from an introductory discussion in Chapter Two, the former is characterized as an objective, teleologically-based, form of understanding whose end, *poiesis*, contains "…a durable outcome, a product or state of affairs which can be precisely specified by the maker before he engages in his activity and which, as surviving the latter, provides it with its end or purpose."[186] The precise specification mentioned here, in turn, "…enables [the expert maker], through the capacity to offer a rational account of it, to provide over his activity with secure mastery."[187] As such, the master of a *techné* is in a position to teach for "…every *techné* seems to be teachable and what is known by *techné* is learnable,"[188] a knowledge of which, once learned, enables the learner to find the right means. Consequently, scholarship in the field of philosophy of education suggests that the influence of such an account of knowledge is apparent in the common practice of teaching and learning "…by isolating in precise terms the goals of the activity, [and providing] the teacher with guidelines for controlling

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[185] See, for example, J.J. Wellington, "What's Supposed to Happen Sir? Some Problems with Discovery Learning," *School Science Review* 63 (1981): 167-173.
[186] *RG*, 9.
[187] Ibid., 9. Dunne goes on to mention in another section of the same text that "…*techné* is then the source of the maker's mastery of his trade and of his ability therefore not only to accomplish a successful result (which any handy person might be equally capable of) but in doing so to give a rational account (logos) of his procedures." See *RG*, 250
[188] Aristotle, *Nicomachean Ethics*, 6.3, 25.

efficiency and straight-forward criteria for evaluating success."[189] A view of educational practice derived from the principles of Aristotle's *techné* is comprised of a careful deliberation of desirable objectives, a thorough analysis of the appropriate means to be used to achieve those objectives, and an intentional assessment of the product resulting from the intended *poiesis*:

> In profiling a teacher's objectives, this model sought to separate ends and means, to repose everything of value that a teacher might accomplish in the ends (i.e. objectives) and then to construe all problems of teaching as ones simply of finding the most suitable means to the achievement of these ends.[190]

When examined in light of such a philosophical perspective, it is not difficult to conceptualize the influence of an Aristotelian form of *techné* on the research and reform efforts centered on teaching for enhanced NOS understandings. To begin with, the sentiments expressed by proponents of the inclusion of NOS considerations as curriculum objectives regarding the enhancement of responsible citizenship among students is arguably based on the notion of *poiesis*, where the responsible student is the product of the teacher/expert-maker. The abundance of research related to the establishment of a set of NOS tenets to serve as reasonable, useful objectives in the planning of classroom lessons designed to explicitly teach for mature understandings similarly promotes a view of education which conceives of knowledge as knowable in advance. Such an explicit approach to pedagogy attempts to isolate the objectives of the particular lesson, and the body of research pertaining to the effectiveness of such methods interprets the problems of teaching for developed understandings mostly in terms of finding the most appropriate means for achieving such ends. Additionally, the extensive discourse surrounding the

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[189] *RG*, 5.
[190] Ibid.

development of appropriate instruments for assessing understandings as well as the language used by researchers in identifying such understandings as naïve, elementary, informed, mature, or otherwise, suggests a remarkably close parallel with the theoretical account afforded to experience, one which can be separated from knowledge itself and determined by knowing better.

Method, Cognition, Disengagement, and Teachability

Taken together, I maintain that Aristotle's *techné* and Descartes' *cogito* comprise the philosophical foundations upon which much of the discourse on student understanding of NOS is predicated; namely in the primacy of method, the reduction of understanding to the domain of cognition, the appeal to a certain distancing between the student and his knowing, and the teachability of an NOS curriculum. Knowledge, and arguably understanding, is viewed from both of these perspectives as resulting from the development and ensuing execution of a specific process, as exemplified by the work of the craftsman in the former and the four-step method in the latter. NOS studies influenced as such seek to continuously evaluate the effectiveness of pedagogical methods on promoting desired understandings while simultaneously assuming those understandings to be capable of their own methodical development as explained by various learning theories. In reducing understanding to a form of cognition, researchers have promoted an element of disengagement, such as in assuming a reflective stance following instruction[191] and negating previous conceptions in experiencing "… anomalous data to induce conceptual shifts in students,"[192] purported to be necessary for the development of adequate views. This type of disengagement is analogous to being able to step outside

[191] Schwartz, Lederman, and Crawford, "Developing Views of Nature of Science."
[192] Rudolph and Stewart, "Evolution and the Nature of Science," 1082.

of oneself, as exemplified in the Cartesian attempt to subjugate mere opinion in the search for reliable knowledge and the maker's ability to reside over and above his product. Lastly, in large part due to their privileging of method as thus conceived, both of these philosophical accounts suggest that, assuming a cognitive view, understanding is capable of being learned and, consequentially, taught. It would be rather difficult to deny the assertion that reform efforts and empirical endeavors asserting the importance of teaching for enhanced NOS understandings among secondary science students espouses a similar perspective regarding the teachability of NOS.

As presented, a strong argument exists in support of the influence of the collective legacy of both foundationalism and theoretical knowledge, as explicated by Descartes and Aristotle, respectively, on science educators' research on nature-of-science. Whether the assumptions that seemingly dominate the discourse on student understanding are intentional or even recognized for that matter is a question unanswerable at present considering the absence of any report whatsoever on their deliberation. Instead, researchers continue to attempt to answer a plethora of questions ranging from the appropriateness of certain NOS viewpoints to the degree to which teachers should simplify viewpoints for various learners by turning to both epistemological and psychological theories of cognitive development.[193] In the next chapters, I consider the *aporia* of student understanding of NOS from a philosophically hermeneutical perspective. In first questioning the limitations of the predominant view afforded to student understandings as presented in this chapter and then reconceptualizing the same

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[193] For a brief description of such questions and accompanying theories, see Bell, "Perusing Pandora's Box," 436-442.

using Gadamer's hermeneutics, I aim to extend student understanding and the scholarly discourse surrounding that understanding.

CHAPER FIVE

A GADAMERIAN RESPONSE

Introduction

As outlined in previous chapters, Gadamer offers a reconsideration of the concept of understanding in his central text, *Truth and Method*, which differs not only from the interpretation posited by Descartes four centuries earlier but also from the various explications put forth by prominent hermeneuts from the Romantic period through his own time.[194] He argues that "…philosophical hermeneutics takes as its task the opening up of the hermeneutical dimension in its full scope, showing its fundamental significance for our entire understanding of the world and thus for all the various forms in which this understanding manifests itself."[195] His voluminous writings on the subject purport to offer "…no new canon of interpretation or new methodological proposals for reforming current hermeneutical practice, but seek instead to describe what actually takes place in every event of understanding"[196] by "…throwing light on the fundamental conditions that underlie the phenomenon of understanding in all its modes, scientific and nonscientific alike, and that constitute understanding as an event over which the interpreting subject

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[194] As Linge writes in his introduction to *PH*: "… this reflexive [Gadamerian] dimension of understanding has been all but completely ignored by the science of hermeneutics during the last century. The result has been a distorted and one-sided picture of understanding and our relationship to tradition." *PH*, xii.
[195] Hans-Georg Gadamer, "On the Scope and Function of Hermeneutical Reflection," in David E. Linge, ed., *Philosophical Hermeneutics* (Berkeley, CA: University of California Press, 1976), 18. Here Gadamer goes on to provide a short litany of the diverse experiences that have been considered in light of hermeneutics.
[196] *PH*, xxvi.

does not ultimately preside."[197] The present chapter focuses on a further explication of philosophical hermeneutics, with particular attention to how such a view of understanding contrasts with a Cartesian foundationalism and a technical view of knowledge that, as explained in the preceding chapter, purportedly direct the predominant conceptualization of student understanding in the NOS literature. The first section takes up the themes of the hermeneutic circle and a "rehabilitation of authority and tradition," as described by Gadamer, while the second involves a discussion of questioning, experience and application as explored by the philosopher in his "recovery of the fundamental hermeneutic problem."

The Hermeneutical Circle, the Problem of Prejudice, and the Nature of Horizon

Gadamer's thesis on understanding is predicated largely on a hermeneutic circle, as explored primarily by Heidegger, and differs significantly from those favored by foundationalist and purely theoretical accounts of epistemology. As David Linge writes in his introduction to *Philosophical Hermeneutics*:

> Gadamer's principal contribution to hermeneutics is to be found in his concerted effort to shift the focus of discussion away from techniques and methods of interpretation, all of which assume understanding to be a deliberate product of self-conscious reflection, to the clarification of understanding as an event that in its very nature is episodic and trans-subjective.[198]

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[197] Ibid., xi. Although admitting of his intention to not explicitly develop a discipline antithetical to the scientific endeavor, he considers the relevancy of hermeneutics for even the natural sciences: "It [science] will continue along its own path with an inner necessity beyond its control, and it will produce more and more breathtaking knowledge and controlling power. It is senseless, for instance, to hinder a genetic researcher because such research threatens to breed a superhuman. Hence the problem cannot appear as one in which our human consciousness ranges itself over against the world of science and presumes to develop a kind of antiscience. Nevertheless, we cannot avoid the question of whether what we are aware of in such apparently harmless examples as the aesthetic consciousness and the historical consciousness does not represent a problem that is also present in modern natural science and our technological attitude toward the world," in Hans-Georg Gadamer, "Universality of the Problem," in David E. Linge, ed., *Philosophical Hermeneutics* (Berkeley, CA: University of California Press, 1976), 10.

[198] *PH*, xxviii.

He acknowledges the influence of such 'Enlightened' views by maintaining that "…the only thing that gives a judgment dignity is its having a basis, a methodological justification (and not the fact that it may actually be correct). This conclusion follows only in the spirit of rationalism. It is the reason for discrediting prejudices and the reason scientific knowledge claims to exclude them completely."[199] Arguing further against the use of any sort of four-step method or *poiesis*-derived protocol, Gadamer relates the proper role of prejudice in the event of understanding to the subjugation of any prescribed procedural description of the hermeneutic endeavor:

> It follows that its [hermeneutics] work is not to develop a procedure for understanding, but to clarify the conditions in which understanding takes place. But these conditions do not amount to a procedure or method which the interpreter himself must bring to bear on the text; rather, they must be given. The prejudices and fore-meanings that occupy the interpreter's consciousness are not at his free disposal. He cannot separate in advance the productive prejudices that enable understanding from the prejudices that hinder in and lead to misunderstandings. Rather this separation must take place in the process of understanding itself, and hence hermeneutics must ask how that happens.[200]

In questioning the idea that objectivity in knowledge is attainable only through the application of a "neutralized, prejudice-free consciousness", Gadamer suggests a view of understanding not as a reconstruction of a past tradition but as a mediation, "…an event, a movement of history itself in which neither interpreter nor text can be thought of as autonomous parts."[201] Such an event is conceptualized not in terms of its methodical precision and *techné*-like applicability, but rather as a game in which "…absorption into

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[199] *TM,* 273.
[200] *TM*, 295.
[201] *PH*, xvi.

the game is an ecstatic self-forgetting that is experienced not as a loss of self-possession, but as the free buoyancy of an elevation above oneself."[202]

Gadamer offers the metaphor of the game to emphasize the positive value of the inability of the interpreter to disengage arbitrarily not only from his prejudices but also from the objects of his interpretation as well, a disengagement ardently sought after by adherents to Descartes' *cogito*. In addition, the metaphor is extended to challenge a reducible form of knowledge predicated on *techné* by stressing instead a type of self-knowledge characteristic of a practical form of reason, or *phronesis*:

> Understanding is not self-understanding in the sense of the self-evident certainty idealism asserted it to have, nor is it exhausted in the revolutionary criticism of idealism that thinks of the concept of self-understanding as something that happens to the self, something through which it becomes an authentic self. Rather, I believe that understanding involves a moment of loss of self that should be investigated in terms of the structure of the game.[203]

When the hermeneutic circle, as envisaged first by Heidegger and later by Gadamer, assumes the structure of a game, understanding is no longer perceived as a circular movement, running backwards and forwards, and ceasing in perfect understanding, a view espoused by the Romantics and members of the historical school.[204] Instead the circle is more fully realized, rather than dissolved, through the interplay of the movement of both the interpreter and the tradition of the object of interpretation; an interplay that is not subjective but issuing forth from the universality that binds the two.[205] For Gadamer,

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[202] Hans-Georg Gadamer, "On the Problem of Self Understanding," in David E. Linge, ed., *Philosophical Hermeneutics* (Berkeley, CA: University of California Press, 1976), 55.
[203] Ibid., 51.
[204] See Chapter Two for an overview on the development of hermeneutics.
[205] *TM*, 293. Again, Heidegger writes in response to a Romantic, conservative view of hermeneutics for which "…the anticipation of meaning in which the whole is envisaged becomes actual understanding when the parts that are determined by the whole themselves also determine this whole. The harmony of all the details with the whole is the criterion of correct understanding. The failure to achieve this harmony means that understanding has failed." Ibid., 291.

this back and forth movement described is derived not from a set of rules over which the interpreter is capable of presiding, as in the event of craft-making, but rather from that which happens above our wanting and doing:

> The back and forth movement that takes place within a given field of play does not derive from the human game and from playing as a subjective attitude. Quite the contrary, even for human subjectivity the real experience of the game consists in the fact that something that obeys its own set of laws gains ascendancy in the game. To the movement in a determinate direction corresponds a movement in the opposite direction.[206]

Additionally, it should be noted that Gadamer made explicit mention of the uncertainty involved in such a notion of play; one that includes a venturing into a foreign, traditionary text on the part of the interpreter:

> Rather the game itself is a risk for the player. One can play only with serious possibilities. If, for the sake of enjoying his own freedom of decision, someone avoids making pressing decisions or plays with possibilities that he is not seriously envisaging and which therefore offer no risk that he will choose them and thereby limit himself, we say he is only playing with life.[207]

An understanding predicated on the metaphor of play, then, maintains the constitutive elements of Heidegger's circle and, consequently, Gadamer's hermeneutics; namely, the uncontrollable projection of a series of fore-structures and prejudices onto the horizon of a text in order to penetrate for meaning in an effort to "…see through the dogmatism of asserting an opposition and separation between the ongoing, natural 'tradition' and the reflective appropriation of it."[208]

In order to play the game, then, Gadamer elaborates extensively on the interdependent concepts of fore-structures, prejudices, and the nature of the horizon of both the interpreter and the text, or interchange, in which he is caught up. He is explicit in

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[206] Gadamer, "On the Scope and Function of Hermeneutical Reflection," 53.
[207] *TM*, 106.
[208] Gadamer, "On the Scope and Function of Hermeneutical Reflection," 28.

his attempt to "… fundamentally rehabilitate the concept of prejudice and acknowledge the fact that there are legitimate prejudices,"[209] an idea denied by a Cartesian view of rationalism which subsequently supported the fundamental prejudice of the Enlightenment, the prejudice against prejudice itself, which denies tradition its authority. According to Gadamer, the legacy of such a fundamental prejudice had profound implications for numerous academic disciplines due to its inherent reproducibility:

> At the same time, however, Gadamer's insight does give us occasion to question the abstract opposition between knowledge and tradition that has become a dogma in hermeneutical theory and to appreciate the sense in which scientific historical understanding is itself the bearer and continuer of tradition.[210]

Philosophical hermeneutics considers prejudices instead not as a "…prison that isolates us from the new, but a particular starting point from which understanding advances."[211] It is specifically these prejudices, "…constantly at stake right up to the moment of their surrender - which surrender could also be called a transformation,"[212] that condition all understanding. Writing in response to challenges emanating from a Marxist critique of ideology by Habermas, Gadamer acknowledges the influence of the fundamental prejudice on the denigration of all authority and the ascendancy of a neutral, tradition-free ideology:

> Authority is by his definition a dogmatic power. I cannot accept the assertion that reason and authority are abstract antitheses, as the emancipatory Enlightenment did. For in my opinion this abstract antithesis embraced by the Enlightenment is a mistake fraught with ominous consequences. In it, reflection is granted a false power, and the true dependencies involved are misjudged on the basis of a fallacious idealism. It seems evident to me that acceptance or acknowledgement is

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[209] *TM*, 278.
[210] *PH*, xviii.
[211] Ibid., xxx.
[212] Gadamer, "On the Scope and Function of Hermeneutical Reflection," 38.

> the decisive thing for relationships to authority. The obedience that belongs to true authority is neither blind nor slavish.[213]

He replaces the foundationalist prejudice against tradition and in favor of the subjugation of arbitrary fore-structures with a view of understanding predicated on the concept of a legitimate authority and the openness of all pre-understandings. In doing so, he furthers the task of hermeneutics beyond that of his predecessors who, as explained briefly in Chapter Two, arguably continued to consider understanding in terms of a possible disengagement between the interpreter and the object of his interpretation, a disengagement analogous to that espoused by adherents of both foundationalism and *techné*: "Beneath their assertion of the finitude and historicity of man, both Schleiermacher and Dilthey continue to pay homage to the Cartesian and Enlightenment ideal of the autonomous subject who successfully extricates himself from the immediate entanglements of history and the prejudices that come with that entanglement."[214]

Gadamer explains his rejection of a disentangled interpreter in terms of his concept of effective history and horizon, an extension rather than synonym of the idea of a situation, which itself does not admit of objective understanding in that one cannot stand outside of it [situation]:

> We define the concept of situation by saying that it represents a standpoint that limits the possibility of vision. Hence essential to the concept of situation is the concept of horizon. A person who has no horizon does not see far enough and

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[213] Ibid., 33.

[214] *PH*., xix. For the Romantic and other earlier hermeneuts, fore-structures were considered in terms of incorrect understandings and examined so as to allow for correct understanding. For Gadamer, however, "…misunderstanding and strangeness are not the first factors, so that avoiding misunderstanding can be regarded as the specific task of hermeneutics. Just the reverse is the case. Only the support of familiar and common understanding makes possible the venture into the alien, the lifting up of something out of the alien, and thus the broadening and enrichment of our own experience of the world," Gadamer, "Universality of the Problem," 15.

> hence over-values what is nearest to him. On the other hand, to have a horizon means not being limited to what is nearby but being able to see beyond it.[215]

This looking beyond one's horizon involves not so much a turning away as it does a seeing better, within a larger whole of the tradition and its past, by transposing oneself onto a historical horizon. Gadamer contends, however, that "…transposing ourselves consists neither in the empathy of one individual for another nor in subordinating another person to our own standards; rather it always involves rising to a higher universality that overcomes not only our own particularity but also that of the other."[216] As such, the discovery of another horizon affords an understanding that does not inherently admit of agreement on the part of the interpreter. A fusion of respective horizons, often considered to exist by themselves and constituting the fundamental hermeneutic task, strives to bring out the tension between them rather than eschew possible conflict by attempting a naïve assimilation of the two. Instead, the polarity that exists between the familiar and strange, or different horizons, when considered hermeneutically rather than psychologically, constitutes a necessary tension "…between being a historically intended, distanciated object and belonging to a tradition," that functions as "…the true locus of hermeneutics."[217] An explicit attempt to extricate this necessary tension is an integral element of both a foundationalist epistemology and, arguably, a theoretical approach to reason in their respective claims to maintain an element of sovereignty for the knower or maker over his understanding.

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[215] *TM*, 301.
[216] Ibid., 304.
[217] Ibid., 295.

The Value of the Dialectic

In addition to characterizing the nature of understanding in terms of fore-structures, legitimate prejudices, and a fusion of horizons, the metaphor of play is extended to include the priority of the question, the nature of experience, and the problem of application in conceptualizing the event that is *understanding*. For Gadamer, the function of hermeneutics "…becomes of itself a questioning of things and is always in part so defined,"[218] where "…working out the hermeneutical situation means acquiring the right horizon of inquiry for the questions evoked by the encounter with tradition."[219] Historically effected consciousness, which both determines and is determined by the aforementioned fusion of horizons, is effectual in finding the right questions to ask.

These questions, which serve to open up possibilities and keep them open, result from the productive condition afforded by the temporal distance between respective horizons and maintain the tension of prejudice structures put at risk:

> If a prejudice becomes questionable in view of what another person or a text says to us, this does not mean that it is simply set aside and the text or the other person accepted as valid in its place. In fact our own prejudice is properly brought into play by being put at risk. Only by being given full play is it able to experience the other's claim to truth and make it possible for him to have full play himself.[220]

Because it is considered more of a disposition than an action to be able to determine what is questionable, Gadamer contends that the idea of method, and consequently teachability, thus remains limited for understanding. Conceived of instead as the art of asking questions, the interpreter is able to remain open to further questioning and engages in a valuable dialectic that constitutes real dialogue. Here, again, the concept of play is

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[218] Ibid., 271.
[219] Ibid., 302.
[220] Ibid., 298.

used to characterize the type of self-understanding inherent in assuming such a hermeneutical perspective:

> It cannot be denied that in an actual dialogue of this kind something of the character of accident, favor and surprise - and in the end, of buoyancy, indeed, of elevation - that belongs to the nature of the game is present. And surely the elevation of the dialogue will not be experienced as a loss of self-possession, but rather as an enrichment of our self, but without us thereby becoming aware of ourselves.[221]

This type of questioning does not amount to either a technical quest for information, as in the case of posing a loaded question or calling for a familiar answer, or a successful means of persuasion, as in the case of the sophistic endeavor to argue another person down, but rather motivates the development of subsequent questions, limited, of course, by the horizon of the questioner.

The logical structure of the question is, in turn, implicit in the Gadamerian conceptualization of experience, as discussed in Chapter Two. Similarly bounded by the nature of horizon and caught up in the dialectic of interpretation, experience reaches its fulfillment in remaining open to new experiences and not in its being qualified as a confirmable event, as in the case of Aristotle's *techné*. For the expert maker, experience assumes a teleological function in that objective concepts or products assume the distinction of being its proper outcome. On the other hand, for Gadamer, the idea of experience is characterized by a Hegelian consideration of a "… new experience that impresses itself on us precisely by interrupting or contradicting our previous experience

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[221] Gadamer, "On the Problem of Self Understanding," 57. See also, John Cleary and Padraig Hogan, "The Reciprocal Character of Self-Education: Introductory Comments on Hans-Georg Gadamer's Address 'Education is Self-Education,'" *Journal of Philosophy of Education* 35, no. 4 (2001): 519-527.

and thereby enriching it."[222] This particular view denotes a sense of uncertainty, irreversibility, and the limitedness of prediction, all constitutive elements in his concept of play. As such, experience escapes any methodical attempts at control and objectification and permits for the continual development of new pre-understandings. Gadamer maintains a distinction between these understandings and those described by both Descartes' clear and distinct ideas and the Aristotelian notion of a sovereign maker presiding over his *poiesis*: "Understanding is not, in fact, understanding better, either in the case of superior knowledge of the subject because of clearer ideas or in the sense of fundamental superiority of conscious over unconscious production. It is enough to say that we understand in a different way, if we understand at all."[223]

Because the historical horizon of experience is neither accidental nor subjective but rather an ontological condition constitutively involved in understanding, the idea of application cannot be construed of as distinct from the event of interpretation itself. In fact, in the fundamental task of hermeneutics, to "…explicitly and consciously bridge the temporal distance that separates the interpreter from the text and overcome the alienation of meaning that the text has undergone,"[224] resides the very act of its application. Unlike the expert craftsman perfecting his *techné*, or the foundationalist employing his four-step method, or the adherent of a pragmatic philosophy reducing all situations to problems to be solved through technical or objective manipulation, the understanding interpreter does not apply himself to any sort of detachment, cognitive or otherwise, but rather remains

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[222] *RG*, 130. Dunne contends that, while Gadamer's use of experience has roots in both Aristotle's phronesis and Hegel's dialectic, he parts from these two predecessors primarily in his unwillingness to admit of any definitive *telos*. Instead, he suggests that Gadamer's view is analogous to Hannah Arendt's account of action. See *RG*, 131.
[223] *TM*, 296.
[224] Ibid., 310.

entangled in the mystery characteristic of self-understanding, as envisaged by Aristotle's *phronesis* and clarified by Gadamer:

> The genuine reality of the hermeneutical process seems to me to encompass the self-understanding of the interpreter as well as what is interpreted…The real event of understanding goes beyond what we can bring to the understanding of the other person's words through methodic effort and critical self-control...Through every dialogue something different comes to be... It is not really we ourselves who understand: it is always a past that allows us to say, "I have understood."[225]

Similar to the irreducibility of experience to a predictable, controllable event, the notion of application, when conceived of in terms of the ancient conception of moral self-knowledge, is subsumed in the very act of understanding which itself arises out of a dialectic of question and answer between the tension-filled temporal distance between the horizons of the interpreter and the object of interpretation, between the familiar and the unfamiliar.

As presented in this chapter, Gadamer posits a view of understanding that differs considerably from Descartes' epistemology and technical forms of reasoning. Predicated on the projection of non-arbitrary fore-structures, the possibility of legitimate prejudices, and a historically-effected consciousness that results in an interplay between that which is close at hand and that which is beyond, his philosophical hermeneutics undeniably rejects any sort of methodical, routinized attempt to reduce instances of interpretation to predictable, controllable events whose pre-determined *telos*, or end, prescribes all necessary action. Insofar as an argument has been made in Chapter Four concerning the considerable influence of this latter approach to understanding on the research and discourse surrounding student understanding of NOS, incorporating Gadamer's

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[225] Gadamer, "On the Problem of Self Understanding," 58.

hermeneutics into that same discourse permits not only a consideration of the limitations of such an approach but also allows for enlarging both the discourse itself and the nature of student understanding. In the next chapter, then, I use the constitutive elements of philosophical hermeneutics as explained here in the specific context of conceptualizing student understanding of nature-of-science.

CHAPTER SIX

ENLARGING THE DISCOURSE

Introduction

In the preceding chapters, I contend that the predominant view on teaching for developed student understandings of nature-of-science is largely predicated on particular philosophical assumptions that favor a foundationalist epistemology while simultaneously emphasizing the characteristic components of an Aristotelian form of technical reasoning. Additionally, I maintain that, when considered from a hermeneutic perspective, such assumptions may result in a foreclosed understanding, an understanding that is reproducible through a series of controlled, methodical attempts that aim to reduce it to a teleologically-based, readily assessable form of knowledge. I then offer philosophical hermeneutics, as explicated by Hans-Georg Gadamer, as a viable referent for reconceptualizing such understandings so that they may be more fully realized rather than perfectly completed. In this chapter, I incorporate the constitutive elements of Gadamer's philosophy, both from his "rehabilitation of authority and tradition" as well as his "recovery of the fundamental hermeneutic problem," into the discourse surrounding student understandings of NOS. In particular, I focus on such discourse as contained within the major lines of inquiry in the science education literature as presented in Chapter Three: namely, a multifarious rationale supporting NOS pedagogy, a consideration of viable NOS tenets for pre-college students, learners' preconceptions

concerning NOS, the effectiveness of explicit approaches to teaching for the promotion of NOS considerations, and the use of varied methods for assessing student understandings. Before proceeding, I think it important to reiterate here both the nature and purpose of engaging in a dialectic among arguably conflicting views related to the conceptualization of the notion of understanding.

Preserving Gadamer's intention to offer "…no new canon of interpretation or new methodological proposals for reforming current hermeneutical practice,"[226] I do not recommend a new approach to teach for enhanced understanding of NOS concepts, nor do I suggest a methodical, hermeneutic replacement for the currently accepted paradigm within the NOS literature of conceptual change theory and other psychologically-derived models of cognition. Instead, I strive to similarly "… retain the term hermeneutics not in the sense of a methodology but as a theory of the real experience that thinking is."[227] In that I began a philosophical examination of the nature of understanding because of a seemingly limited view afforded to it by researchers and policy makers in the science education communities, I aim to consciously avoid any attempt to present a view of understanding, or teaching and learning for that matter, that can result in a technical form of reasoning, devoid of new experiences and further questioning: "It is just that one cannot start out with serious misgivings about the ascendancy of technical reason and with a correlative desire to vindicate the integrity of practice and then, when one turns to philosophy for confirmation of these misgivings and of this desire, to entertain an implicitly technical notion of philosophy."[228] By engaging in hermeneutical inquiry thus

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[226] *PH*, xxvi.
[227] *TM,* xxxiii.
[228] *RG*, 22.

conceived, I acknowledge the necessary tension between the philosophical assumptions of the various participants engaged in the dialectic and endeavor to remain open to the horizon of the other; an openness perhaps not entirely adhered to by Gallagher in his hermeneutical questioning of the modernist view of education, as argued by Kerdeman and explained in Chapter Two. The next section of this chapter advances the discourse of student understanding of NOS considerations as Gadamer's hermeneutics sought to do for understanding in general.

Self- Understanding and Necessary Tension

As explained in Chapter Three, two of the rationales supporting the inclusion of NOS considerations in the seminal science education reform documents and substantial body of empirical research over the last two decades include seeking to ameliorate the possible epistemic tensions encountered by learners when confronted with metaphysical, epistemological, or other worldview perspectives that may differ from their own and attempting to promote a greater sense of responsibility and develop enhanced decision-making skills among students. Insofar as the latter of these seems more characteristic of a moral rather than technical development, a consideration of an Aristotelian practical wisdom, or *phronesis*, permits for an alternative understanding of such development, as distinct from that favored by a privileging of reason based on the analogy of an expert maker, or *techné*. The widely-accepted assertion that "… at the foundations of many illogical decisions and unreasonable positions are misunderstandings of the character of science"[229] both inaugurated and maintained a series of deliberate attempts on the part of leaders in the science education community to include NOS considerations among the

[229] McComan, Almazro, and Clough, "The Nature of Science in Science Education," 511.

important learning outcomes of both national curricula and exemplary pedagogical practices. These same researchers, while at times acknowledging the ability of students designated as having fully formed or complete understandings to further evolve beyond a prescribed model,[230] subsequently adhere to a prescriptive account of knowledge that varies from the idea of self-understanding. Rather than recognize the loss of self, as explained by Gadamer in the metaphor of play and inherent in his account of understanding in terms of *phronesis*, NOS advocates maintain a belief in the sought-after sovereignty of the expert over his *poiesis*, or craft, as evidenced by their insistence on the need "…to use scientific knowledge to make informed personal and societal decisions,"[231] denoting a sense of empowerment and freedom afforded to learners by a mature understanding of NOS. Conceived of instead as a dialectical experience that involves not so much "… a loss of self-possession, but rather [as] an enrichment of our self, but without us thereby becoming aware of ourselves,"[232] the idea of self-understanding offers researchers an alternative perspective through which to consider the various rationales supporting NOS instruction, such as personal and societal responsibility.

In addition to promoting enhanced decision-making skills and responsible citizenry, several NOS proponents contend that a consideration of the development of scientific knowledge and subsequent discussion contrasting such a development with other ways of knowing eschew potential tensions that may arise between conflicting worldviews. According to Gadamer, however, these tensions are in fact integral to the

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[230] See, for example, Moss, Abrams, and Robb, "Examining Student Conception," 771.
[231] Lederman, "Syntax of Nature of Science," 301.
[232] Gadamer, "On the Problem of Self Understanding," 57.

very act of understanding itself insofar as interpretation is comprised of an interplay between the horizons of the interpreter and the object of interpretation, in this case, the student and the nature-of-science, respectively. Referring again to the metaphor of play, the student understands NOS only when his own prejudices are stirred up and put to risk by being confronted with the various characteristics of the scientific enterprise and scientific epistemology, in all of their forms. A deliberate attempt to avoid any element of risk-taking, then, on the part of researchers and science educators alike espouses a view of understanding in which "… for the sake of enjoying his own freedom of decision, someone avoids making pressing decisions or plays with possibilities that he is not seriously envisaging and which therefore offer no risk that he will choose them and thereby limit himself."[233]

Another line of inquiry that explicitly aims to dismiss the Gadamerian concept of a necessary, tense-filled proximity between the familiar and the strange involves the consideration of a consensus view of nature-of-science and resultant tenets purported to be appropriate for secondary science students. In the case of the former, a denial or, at best, a relegation of philosophical discord concerning the nature-of-science and its characterization for students contrasts greatly with the hermeneutical endeavor to question the dominant opinion by remaining open to the hermeneutical idea that unless one understands differently, one does not understand at all. In the case of the latter, a set of prescribed NOS tenets that serve to provide for the construction of standardized definitions of fully formed NOS understandings promotes a view of understanding conceptualized by the hermeneutic circle as envisaged prior to the work of Heidegger and

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[233] *TM*, 106.

Gadamer in the last century. For these researchers, student understandings are evaluated in terms of their alignment with such pre-determined tenets. Gallagher explains this alignment in terms of a desired coincidence between the understandings of the student and those of the teacher or science education community. Whereas, for the majority of NOS researchers, the concept of fully formed or complete understandings is evidenced by a perfect alignment between these respective understandings, such a coincidence results in a foreclosed understanding by attempting to move back and forth along the hermeneutic circle until perfect understanding is achieved. When conceptualized in terms of philosophical hermeneutics instead, "…the back and forth movement that takes place within a given field of play does not derive from the human game and from playing as a subjective attitude."[234] Understanding conceived in terms of a conservative hermeneutics assumes a purely reproductive character that arguably leads to a form of education in which "…the teacher remains very much in control of the discussion and students' input is limited to answering questions that are posed by the teacher."[235] A Gadamerian view of dialectic, alternatively, challenges the use of questions constructed so as to elicit particular responses and, instead, encourages a dialogic conversation that results from questions emanating from an interchange between the particular horizons of the known and the unknown.

Appropriated *Telos*, Positive Prejudices, and Different Understandings

In addition to foreclosing the dialectic of understanding by intentionally avoiding necessary tensions, a prescribed set of tenets, representative of a consensus view of NOS, inevitably functions as viable, predetermined objectives to be applied in the development

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[234] Gadamer, "On the Problem of Self Understanding," 53.
[235] Bartholomew, Osborne, and Ratcliffe, "Teaching Students Ideas-About-Science," 670.

of explicit teaching practices aimed at enhancing student understandings of NOS. In such instances, these objectives constitute the desirable end of the instructional process; a process that can be conceptualized in terms of Aristotle's teleological account of knowledge, or *techné*: "This activity issues in a durable outcome, a product or state of affairs which can be precisely specified by the maker before he engages in his activity and which, as surviving the latter, provides it with its end or purpose (*telos*)."[236] As discussed earlier, *techné* provides "…a clear conception of the why and wherefore, the how and with-what of the making process,"[237] and consequently provides a foundation for constructing explicit, controllable pedagogical methods over which a teacher can preside with certain mastery. Dunne maintains that such a view of education considers teaching as "…no longer embedded in particular contexts or within cultural, linguistic, religious, or political traditions which may be at work in all kinds of tacit and nuanced ways in teachers and pupils as persons."[238] In contrast, teaching for enhanced student NOS understanding, considered in terms of philosophical hermeneutics, attempts to refrain from assuming a similar teleological perspective. Instead, the end is conceived of as constitutively caught up in the activity of teaching itself and does not admit of being isolated from the horizon of the classroom, as in the case of praxis which "... required for its regulation a kind of knowledge that was more personal and experiential, more supple and less formulable, than the knowledge conferred by *techné*."[239]

Just as in the event of teaching where "its secret is that there is an element in it of "happening"- so that one can never preside over it, or experience sovereignty through it,

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[236] *RG*, 9.
[237] Ibid.
[238] Ibid., 5.
[239] Ibid., 10.

as one can in the case of making,"[240] NOS understandings conceptualized in terms of Aristotle's *phronesis* and Gadamer's hermeneutics do not admit of an autonomous knower capable of extricating himself from the authority of his tradition. Such a position contrasts greatly with both Descartes and later members of the Romantic period and the historical school who respectively endeavored either to eschew entirely or to relegate to the designation of misunderstandings anticipatory prejudice structures so as to achieve correct understandings. The influence of both a foundationalist epistemology and conservative hermeneutics on research pertaining to student understanding of NOS is evidenced by the plethora of empirical studies advocating for the proper diagnosis of student prior knowledge so as to teach for conceptual change or enhanced views of the development of scientific knowledge and the scientific enterprise. As discussed in Chapter Three, these studies espoused a particular understanding of fore-structures and oftentimes reduced their significance in favor of inducing a desirable conceptual shift. For philosophical hermeneutics, these prejudice structures assume a positive rather than negative value and, similar to the notion of temporal distance as explained earlier, are actually integral in the act of understanding considered as a projection of such fore-structures onto a foreign horizon. As such, student prejudices pertaining to NOS are not inherently opposed to but rather constitute the necessary conditions for developing different understandings. At the same time, these prejudices are not amenable to methodical manipulation, as in the case of case of Descartes' foundationalism, Romantic hermeneutics, and conceptual change theory, and must remain open not so much to "what

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[240] Ibid., 12.

we do or what we ought to do, but [to] what happens to us over and above our wanting and doing."[241]

Insofar as fore-structures maintain their positive value, understanding is not regarded as a forward-moving, progressive development as conceptualized in cognitive models of learning. Rather than characterize understandings in terms of a transformation from inadequate into adequate views or naïve towards more intermediary or informed conceptions, Gadamer's hermeneutics considers understanding as capable of being enlarged into different understandings, not necessarily superior or better, than those inherited from the horizon of tradition. Such a perspective is predicated on the aforementioned Gadamerian notions of experience and questioning, both of which seek to retain an open dialectic that does not admit of routine or foreclosure. In that this same dialectic does not have "…its proper fulfillment in definitive knowledge,"[242] efforts to assess student understandings, through either quantitative or qualitative methods, and subsequently characterize those understandings, either categorically or as being situated along a developmental continuum, become questionable. Philosophical hermeneutics additionally permits a reconsideration of these assessments in light of its insistence on an inseparable relation between understanding and application, where "... application is neither a subsequent nor merely an occasional part of understanding, but codetermines it as a whole from the beginning."[243] This descriptive account of the event that is understanding further affords NOS researchers the opportunity to enlarge the

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[241] *TM*, xxv-xxvi.
[242] Ibid., 355.
[243] Ibid., 324.

philosophical discourse pertaining to the act by which students make sense of the multifarious descriptions of both scientific epistemology and the scientific enterprise.

As presented in the last three chapters, a consideration of philosophical hermeneutics engages a dialectic with current assumptions on the nature of understanding which underpin much of the research and policy pertaining to NOS pedagogy. Whether in their attempt to propose criteria or tenets to function as cognitive learning objectives capable of being assessed or their ongoing consideration of the effectiveness of various pedagogical strategies aimed at promoting the development of desirable, informed understandings, science educators remain indebted to the tradition of the foundationalist primacy of method and a technical privileging of *telos*, both of which advance a notion of understanding that is teachable. It is precisely because of its perceived teachability that NOS understandings continue to maintain a prominent position in the larger discourse on science education reform. As addressed in earlier chapters, however, an educational philosophy predicated on such a view of understanding might result in a view of teaching and learning reduced to a set of techniques which simply allows us to manage information which in turn can result in a direct transmission of the same information that amounts to a potential form of indoctrination. In that Aristotle's *phronesis* concerns itself with a self-understanding that does not admit of a specific, predetermined *poiesis*, Gadamer's hermeneutics permits an enlarged discourse that avoids both the foreclosure of student understanding and the forestalling of the discourse itself.

CHAPTER SEVEN

SUSTAINED DIALECTIC

In the preceding chapters of this dissertation, I have attempted to make the case for a reconceptualization of student understanding of nature-of-science concepts based on philosophical hermeneutics. Firstly, I contend that current views on the teaching and learning of NOS, as explained in Chapter Three, are predicated on a particular notion of understanding, whose inherent assumptions were analyzed in Chapter Four, argued by philosophers of education to contribute to pedagogical practices that may limit rather than permit for the development of student understanding. Then, I suggest in Chapter Six that a Gadamerian view of understanding, as described in Chapter Five, unlike the dominant foundationalist, technical view arguably implicit in the majority of the NOS literature and reform efforts, has the potential for enlarging student understandings of NOS as well the broader educational discourse surrounding such understandings. In these concluding pages, I wish to further support this last assertion regarding the value of Gadamer's hermeneutics in sustaining the dialectic between the multiple perspectives concerning student understandings of NOS considerations.

As mentioned in Chapter Three, several of the primary reasons provided in support of the inclusion of NOS pedagogy in both research and policy reform are predicated on both acknowledging the epistemological worth, and even supremacy, of scientific knowledge and maintaining a positive image and public opinion of the scientific enterprise. The impetus for such proposals has been argued to have resulted

largely in reaction to the influence of a variety of factors, some of which include the publication of Thomas Kuhn's *The Structure of Scientific Revolutions*, subsequent discourse by prominent sociologists of science, and work by learning theorists positing constructivist accounts of knowledge - all of which have been interpreted, at least in part, to present a relativistic view of NOS.[244] While the question of whether or not Kuhn's seminal text did in fact provide the necessary background against which to launch a postmodern rebuttal to the claims of science or researchers interested in explicating the sociology of scientific knowledge collectively sought to undermine its development and reduce its epistemological merit are worthwhile and interesting, they have been taken up elsewhere and are not the subject of present concern.[245] Likewise, the ongoing debate regarding the impact of particularly radical constructivist learning theories, such as those explicated by Ernst von Glasersfeld,[246] on both the ontological and epistemological views afforded to science in recent national reform documents has garnered extensive attention from notable scholars and continues to be a point of discussion among concerned science educators.[247] The point I wish to make here does not involve an evaluation of the various assertions put forth by philosophers, historians, sociologists, and science educators concerning the value of the respective views on the nature-of-science but rather I suggest

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[244] For a brief overview of the NOS debates surrounding each of these, see Turner and Sullenger, "Kuhn in the Classroom."
[245] See Hands, "Reconsidering the Received View," for a discussion of Kuhn's influence and Harry Collins, "The Uses of Sociology of Science for Scientists and Educators," *Science & Education* 16 (2007): 217-230 for a discussion of the latter concern.
[246] Ernst von Glasersfeld, "Questions and Answers About Radical Constructivism," in M.K. Pearsall, ed., *Scope, Sequence, and Coordination of Secondary School Science, Volume II: Relevant Research* (Washington, D.C: The National Science Teacher Association, 1991), 169-182.
[247] For one such discussion, see Matthews, "Constructivism and Science Education." For examples of proposed alternatives to constructivism in science education, see Matthews, "In Defense of Modest Goals," and Jim Garrison, "An Alternative to Von Glasersfeld's Subjectivism in Science Education: Deweyan Social Constructivism," *Science & Education* 6 (1997): 543-554.

that, by situating the *aporia* arrived at through the interpretation of multiple perspectives in Gadamer's hermeneutics, scholars can sustain the discourse surrounding student understandings without succumbing to the temptation to consider such understandings as either perfectly foreclosed or subjectively relativistic interpretations of NOS.

As explained in Chapter One, Gallagher positions philosophical hermeneutics as a moderate form of understanding situated between the more conservative claims of Schleiermacher, Betti, and Hirsch, and the more radical views of Nietzche, Heidegger, and Derrida:

> Moderate hermeneutics proposes a somewhat optimistic view of interpretation. Interpretation involves creativity and not just reproduction; the reader participates, just as much as the author does, in putting together the meaning… This optimism might be contrasted, on the one side, with the wishful thinking of the conservative school and, on the other side, with what might appear to be the nihilism of radical hermeneutics.[248]

He supports his contention by explaining the event that is understanding in terms of the Gadamerian fusion of horizons resulting from the projecting of prejudice structures, embedded in language, onto the horizon of the object of interpretation. Gallagher maintains that language functions so as to limit our ability to gain absolute meaning, as in the case of conservative hermeneutics, while still permitting some access to interpretation in the form of a dialogical conversation, a conversation that does not then admit of a purely subjective account of understanding. As such, the philosopher of education suggests that subjective and objective interpretations represent the extremes of understanding, both of which are inaccessible.

The case against a conservative rendering of understanding, as advanced in some mode by literary scholars of the Romantic period, historians of the 18th and 19th centuries,

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[248] *HE*, 10.

and educational philosophers up to the present, has been a significant focus throughout this thesis and, as such, has been addressed, in considerable detail, throughout the preceding chapters of this paper. Rather than differentiate between the acts of interpretation and meaning making, as did Schleiermacher, Dilthey and Hirsch, and strive for complete understanding of a supposedly original intention, Gadamer, by uniting the once disparate *subilitas* of understanding, interpretation, and application, proposed an alternative description of the very experience of thinking itself. The value, of course, of incorporating such a perspective into the discourse of NOS understandings is evidenced by the inherent inability of its adherents to provide a complete or final account of understanding, thereby forestalling the very nature of the dialogue. But the question may remain, however, as to how to avoid relegating the various perspectives involved in the conversation to merely subjective opinions or mental operations incapable of being reconciled and therefore arbitrary and of no consequence. It is in response to this final, particular *aporia*, then, that I appeal to Gadamer's realism, as described by at least one philosopher, in my attempt to offer some further explanation of the import of his hermeneutics of understanding for both science educators and the larger educational community as well.

In his editor's introduction to *Hermeneutics and Truth*,[249] philosopher Brice R. Wachterhauser distinguishes between the various hermeneutical perspectives that resulted from a turning away from a belief in dialectical completeness and absolute certainty. While agreeing that such conceptions "… can no longer be considered as unproblematic hallmarks of truth," he contends that a number of prominent hermeneuts, such as Derrida,

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[249] Brice R. Wachterhauser, "Introduction: Is There Truth after Interpretation?" in Brice R. Wachterhauser, ed., *Hermeneutics and Truth* (Evanston, IL: Northwestern University Press, 1994), 1-24.

Nietzche, and Rorty, are guilty of committing a non sequitur in their assuming that, as a consequence, "… the concept of truth itself has outlived its cognitive usefulness and philosophic importance"[250] as well.

> Only by seeing our conversation as ultimately governed by the norm of truth do our many attempts to make a point in a conversation become something more than the utterance of a series of sounds which we hope will affect the behavior of our interlocutor for our own advantage. Only the sincere search for truth adequately distinguishes rational inquiry from mere sophistry.[251]

Rather than maintain a principled impossibility of any sort of real communication between different viewpoints, each hermetically sealed off from the other, he argues that Gadamer's hermeneutics, by understanding these same differences as differences of perspective, assumes a shared sense of reality beyond them, thereby precluding any attempt at positing a relative account of knowledge. Instead, he characterizes Gadamer's theory of understanding as perspectival realism:

> …because Gadamer insists again and again that the thing itself is always grasped from a historically contingent, linguistically mediated perspective. This lingustic/historical perspective functions as both a condition and a limit on our understanding. The upshot of such a position is a view of human knowledge which is inherently 'open', unable to come to final closure, or chart an unambiguous line of progress but which does not despair of the possibility that finite human beings can know reality itself.[252]

This knowing of reality can be traced to Heidegger's earlier interpretation of truth that takes place in the "…clearing of Being's disclosure," whereby particular aspects of reality are uncovered in the act of understanding. Such understanding, however, is not to be construed as either complete or exhaustive in that "…the conditions which make for

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[250] Ibid. 2
[251] Ibid.
[252] Brice R. Wachterhauser, "Gadamer's Realism: The 'Belongingness' of Word and Reality," in Brice R. Wachterhauser, ed., *Hermeneutics and Truth* (Evanston, IL: Northwestern University Press, 1994), 154.

disclosure also make for some inevitable obfuscation and covering over."[253] Wachterhauser develops a set of theses that seek to encapsulate this distinctive form of realism which maintains that "…the whole thing or reality is present in the finite linguistic view and yet no linguistic view exhausts the thing."[254] Insofar, then, as he accepts the inherent contradictions that will arise from the inevitable incompatibility of certain linguistic views, Gadamer understands such discord to be a positive, productive impetus to a deeper truth: "Because I experience both the truth of each account, as well as the contradictions between these accounts, I both need to interpret to eliminate the contradictions and simultaneously have reason to think that the interpretation can in principle, be successful."[255]

The value of recognizing the "…the possibility of any interpretation that is simultaneously linguistically-mediated, socially-constituted and reality based"[256] is hopefully obvious with regard to student understanding of NOS concepts as well as the broader discipline of education. By taking understanding to be more than a simple re-construction of some *a priori* pattern of meaning and an effort to reach some type of agreement about something, philosophical hermeneutics advances the primacy of the question in such a manner so as to suggest that "… one questions every question one understands."[257] Preserving the Hegelian ideal of a whole truth while acknowledging that the whole is never actually arrived at functions as an integral assumption for our efforts at

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[253] Wachterhauser, "Introduction," 3.
[254] Wachterhauser, "Gadamer's Realism," 167. The particular theses are: 1. There are different linguistic views of reality, 2. There is no fundamental incompatibility between these linguistic views and reality, 3. Each linguistic view can be seen as a finite presentation of reality, 4. Each linguistic view contains potentially within itself all other linguistic views. See Wachterhauser, "Gadamer's Realism," 156.
[255] Ibid., 158.
[256] Ibid., 171.
[257] Hans-Georg Gadamer, "What is Truth?" in Brice R. Wachterhauser, ed., *Hermeneutics and Truth* (Evanston, IL: Northwestern University Press, 1994), 45.

interpretation that, as Wachterhauser maintains, is "neither naïve nor nihilistic" and does not admit simply of "…an exchange of noises either in chorus or counterpoint designed to produce a desired effect, but in no sense are they noises which contain truth."[258] The constitutive elements of such a view of understanding, then, do not allow for a complete interpretation of some specified object, nor do they diminish the concept of understanding to subjective opinion or mere belief, but rather they provide the necessary conditions for sustaining the dialectic and subsequently enlarging both student conceptions of NOS and our own perspectives regarding the event that takes place in the fusion of horizons between the familiar and the strange, involving both disclosure and concealment, and remaining open to further experiences – the event that we call *understanding*.

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[258] Wachterhauser, "Gadamer's Realism," 170.

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