

## ABSTRACT

FURBISH, DEAN RUSSEL. A Philosophical Examination of Mead's Pragmatist Constructivism as a Referent for Adult Science Education. (Under the direction of Carol E. Kasworm.)

The purpose of this study is to examine pragmatist constructivism as a science education referent for adult learners. Specifically, this study seeks to determine whether George Herbert Mead's doctrine, which conflates pragmatist learning theory and philosophy of natural science, might facilitate (a) scientific concept acquisition, (b) learning scientific methods, and (c) preparation of learners for careers in science and science-related areas. A philosophical examination of Mead's doctrine in light of these three criteria has determined that pragmatist constructivism is not a viable science education referent for adult learners. Mead's pragmatist constructivism does not portray scientific knowledge or scientific methods as they are understood by practicing scientists themselves, that is, according to scientific realism. Thus, employment of Mead's doctrine does not adequately prepare future practitioners for careers in science-related areas. Mead's metaphysics does not allow him to commit to the existence of the unobservable objects of science such as molecular cellulose or mosquito-borne malarial parasites. Mead's anti-realist metaphysics also affects his conception of scientific methods. Because Mead does not commit existentially to the unobservable objects of realist science, Mead's science does not seek to determine what causal role if any the hypothetical objects that scientists routinely posit while theorizing might play in observable phenomena. Instead, constructivist pragmatism promotes subjective epistemology and instrumental methods.

The implication for learning science is that students are encouraged to derive scientific concepts based on a combination of personal experience and personal meaningfulness. Contrary to pragmatist constructivism, however, scientific concepts do not arise inductively from subjective experience driven by consummatory activity. The broader implication of this study for adult education is that the philosophically laden claims of constructivist learning theories need to be identified and assessed independently of any empirical support that these learning theories might enjoy. This in turn calls for educational experiences for graduate students of education that incorporate philosophical understanding such that future educators might be able to recognize and weigh the philosophically laden claims of adult learning theories.

A PHILOSOPHICAL EXAMINATION OF MEAD'S PRAGMATIST  
CONSTRUCTIVISM AS A REFERENT FOR ADULT SCIENCE EDUCATION

by

DEAN RUSSEL FURBISH

A dissertation submitted to the Graduate Faculty of  
North Carolina State University  
in partial fulfillment of the  
requirements of the Degree of  
Doctor of Education

ADULT AND COMMUNITY COLLEGE EDUCATION

Raleigh

2005

APPROVED BY:

---

Robert Hambourger

---

John Penick

---

John Pettitt

---

Carol Kasworm  
Chair of Advisory Committee

## BIOGRAPHY

Dean Furbish is an honors graduate of North Carolina State University, where he earned several undergraduate degrees: B.S., botany; B.A., chemistry; B.S., entomology; B.A., psychology; and B.S. zoology. In addition, Dean earned a B.A. in Russian from Thomas Edison State College. Dean earned his M.S. in zoology from the University of Kentucky. Dean's graduate studies include neuroethology at the Marine Biology Lab at Woods Hole, Massachusetts, and Russian at the University of North Carolina at Chapel Hill. He is a member of the National Slavic Honor Society, *Dobro Slovo*, and the National Honor Society, *Phi Kappa Phi*.

Dean has sixteen years experience teaching community college biology and has received numerous teaching awards. Dean received an excellence award from the North Carolina Community College Biology Curriculum Improvement Project. He has served as a faculty mentor and as a minority student mentor, the latter with the North Carolina Biomedical Transitions Program sponsored by the UNC General Administration and the National Institutes of Health.

Dean's interests include literature. He is a published poet and a literary translator. His translations from the Russian of Yevgeny Vinokurov's poetry were nominated for a Pushcart Prize. Dean is the Founding Editor and a current Editor of *Reflections Literary Journal*. Additionally, he was named both a Fellow and a Visiting Scholar to the Center for Slavic, Eurasian, and Eastern European Studies at the University of North Carolina at Chapel Hill.

## TABLE OF CONTENTS

	Page
CHAPTER ONE . . . . .	1
Pragmatist Constructivism: Theory of Knowledge, Philosophy of Science, and Learning Theory . . . . .	1
Introduction . . . . .	1
The Place and Challenge of Adult Science Education. . . . .	4
Adult Education . . . . .	6
Constructivism . . . . .	9
Constructivism: A Theory of Learning . . . . .	12
Constructivism: A Theory of Knowledge . . . . .	15
Disconnects Between Constructivist and Realist Epistemologies . . . . .	18
Focus of This Study: Pragmatist Constructivism . . . . .	22
Pragmatist Constructivism: Introduction . . . . .	22
George Herbert Mead and Pragmatism . . . . .	22
Mead’s Interactional Pragmatism and Adult Learning Theory . . . . .	24
Problems with Mead’s Interactional Philosophy of Science . . . . .	25
Pragmatism and Adult Learning Theory Revisited . . . . .	26
The Study . . . . .	27
Implications of a Study of Mead’s Constructivist Theory of Knowledge. . . . .	28
 CHAPTER TWO. . . . .	 33
Methods: Philosophical Inquiry . . . . .	33
Introduction . . . . .	33
Methods of This Study . . . . .	40
The Research Question . . . . .	40
What This Study Hopes to Demonstrate . . . . .	41
How this Study will show that Constructivist Learning Theory is Ineffective . . . . .	41
Concept acquisition . . . . .	41
The nature and practice of science . . . . .	44
Preparation for professional practice and future science education . . . . .	47
The Central Role of Philosophy in Science Education . . . . .	51
Summary and Study Outline . . . . .	54

CHAPTER THREE . . . . .	55
Constructivist Philosophy in Adult Education and its Relation to Realism . . . . .	55
Introduction . . . . .	55
Constructivism is a Philosophical World View . . . . .	56
Epistemological Constructivism . . . . .	58
Metaphysical Constructivism . . . . .	61
Methodological Constructivism . . . . .	62
Constructivism Versus Realism . . . . .	63
Introduction . . . . .	63
Constructivist Metaphysics Opposes Realist Understanding . . . . .	66
Mead's metaphysics . . . . .	66
Candy's metaphysics . . . . .	68
Constructivist Epistemology Opposes Realist Understanding . . . . .	72
Subjectivist epistemology . . . . .	72
Experiential epistemology . . . . .	73
Relativist epistemology . . . . .	76
Constructivist Methodology Opposes Scientific Understanding . . . . .	78
Methodological inductionism . . . . .	78
Methodological instrumentalism . . . . .	81
Summary of Philosophical Considerations of Constructivism for Adult Education . . . . .	83
 CHAPTER FOUR . . . . .	 86
Pragmatist Constructivism and its Viability in Science Education . . . . .	86
Introduction . . . . .	86
Scientific Concept Acquisition . . . . .	86
Introduction . . . . .	86
Empiricist Themes in Mead's Philosophy . . . . .	87
Mead's metaphysics . . . . .	87
Mead's epistemology . . . . .	91
Mead's Alternative Reading of the Scientific Revolution and Newtonian Concepts . . . . .	94
The Scientific Concept of Cellulose . . . . .	100
The Scientific Concept of Food . . . . .	103
Learning and Applying the Methods of Science . . . . .	116
Introduction . . . . .	116
The Rotating Earth and Hypothesis Generation . . . . .	117
Introduction . . . . .	117
The rotating earth hypothesis . . . . .	119
Foucault's pendulum and the rotating earth hypothesis . . . . .	120

Mead's Scientific Method and the Discovery of the Malarial Parasite . . . . .	135
Introduction . . . . .	135
The Discovery of the Malarial Parasite. . . . .	135
Mead's Scientific Method and the Malarial Parasite. . . . .	142
Preparation of Adult Learners for Professional Practice and Further Science Education. . . . .	149
Introduction . . . . .	149
Are Students' Interests Sufficient Determinants for Course Design? . .	150
Introduction. . . . .	150
Critique of student centeredness as a basis for course design . .	154
Is Theoretical Knowledge Inductively Abstracted from Experience?. .	166
 CHAPTER FIVE. . . . .	172
Study Conclusions, Constructivism in Adult Education, Educational Implications and Recommendations . . . . .	172
Introduction . . . . .	172
Findings in the Context of Current Topics in Adult Education . . . . .	173
Constructivism in Adult Education . . . . .	185
Origins of Constructivism in Adult Education . . . . .	189
Piaget, von Glasersfeld, and Candy in Adult Education . . . . .	190
Kuhn in Adult Education . . . . .	190
Dewey in Adult Education . . . . .	192
The Nature of Constructivism in Adult Education . . . . .	194
Constructivism . . . . .	194
Pragmatist Constructivism . . . . .	201
Postpositivist Constructivism . . . . .	210
Postmodernist Constructivism. . . . .	227
Recommendations for Adult Graduate Education, Educators, and Further Research. . . . .	244
Recommendation for Adult Graduate Education. . . . .	247
Recommendations for Educators . . . . .	250
Recommendations for Further Study. . . . .	258
 References . . . . .	266

## CHAPTER ONE

### Pragmatist Constructivism: Theory of Knowledge, Philosophy of Science, and Learning Theory

#### *Introduction*

According to a survey conducted in 1989-1990, there were nearly two-hundred thousand adult (age 24 or older) undergraduate science majors enrolled in higher education in the United States (National Center for Education Statistics [NCES], 1995). In spite of the huge number of adults that enroll each year in undergraduate science courses, the field of adult education has provided little guidance for teaching or learning science (Hacker & Harris, 1992).

One learning perspective that may have potential as a science education model for adult learners is constructivism. One reason is that constructivism is currently a leading science education model at both the primary and secondary education levels (Tobin, 1993). Further, many of our traditional views of adult learning emanate from pragmatist constructivism (Brookfield, 2000, p. 37). Lastly, pragmatist interactional constructivism has been recommended specifically as a science education model (Bentley, 1998; Bredo, 2000). This study will focus primarily on George Herbert Mead's (1938) pragmatism (Bredo, 2000). Mead was a close friend, colleague, and intellectual ally of John Dewey (Phillips, 2000c), and their ideas regarding pragmatism were similar (Garrison, 1998). In the adult education literature, John Dewey is often associated with the "learning by doing" tradition" (Gibson, 2000, p. 430). This tradition focuses "on learners and their needs and experiences rather than on predetermined content" (Merriam & Brockett, 1997, p. 36). This educational tradition, called progressivism, "drew from the philosophy of

pragmatism” connected to Dewey (p. 35). Merriam and Brockett describe the profound effect that pragmatism—through the progressive movement—had on adult education.

The progressive movement in the United States coincided with the development of the adult education field, and for this reason has had a pervasive impact on adult education. From the 1930s on, many architects of the field . . . have been profoundly affected by the ideals of progressivism (Merriam & Brockett, 1997, p. 36).

My goal in this study will be to ascertain whether pragmatist constructivism is a suitable science education model for adult learners. In order to make this determination, I shall assess whether its use: (a) provides adults a means for learning scientific concepts, (b) provides for learning scientific methods and thinking, and (c) prepares science majors for careers in science and science-related fields. This will be done according to the methods detailed in Chapter Two (p. 40). Attention will also be paid to the crucial background role of pragmatist philosophy that influences these important aspects of learning science, since pragmatist philosophy drives pragmatist constructivist learning theory.

It must be underscored that pragmatism is a comprehensive philosophical system. Mead’s doctrine is said to account for all animal and human learning (de Waal, 2002; Mead, 1936). At its core, pragmatism is a theory of knowledge, or epistemology (Burke, 1962/1992; Mead, 1938). Thus, epistemological pragmatism drives both pragmatist philosophy of science and learning theory (de Waal, 2002; Mead, 1938; Phillips, 1995). Were Mead’s doctrine only a learning theory, then it would be appropriate to address it

solely as such. But a determination of constructivist interactionism's suitability as a science education learning theory must take into account its epistemology and philosophy of science.<sup>1</sup> Entertaining constructivist epistemology is not an esoteric exercise without practical educational significance. According to philosophers, constructivist philosophy has a significant, though underappreciated, impact on learning theory (Irzik, 2000; Nola, 1997, 2003; Phillips, 1995, 2000a). Thus, while this study notes crucial elements of pragmatist philosophy underpinning pragmatist interactional constructivism (Chapter Three), the thrust of the study (Chapter Four) entertains questions of learning science.

The remainder of this first chapter introduces several themes contained in this study, most of which are further explicated elsewhere. First, the lack of a science education model in adult education is noted. So is the important link between adult learning theory and pragmatist constructivism, particularly pragmatism's foregrounding of experience and activity as epistemological keys to learning. Further, the important difference between constructivist learning theory and philosophy are described. An introduction to the philosophical dimension of constructivism is especially important, since it conflicts with the philosophy of science adopted by most practicing scientists—scientific realism. Some of the disconnects between philosophical constructivism and realism are introduced in this chapter, while a fuller explication of the similarities and differences of the two philosophies crucial to an understanding of this study is to be found in Chapter Three (p. 55). A brief introduction to Mead and his

---

<sup>1</sup>

For comparative purposes, this study assumes a realist philosophy of science (Matthews, 1994; Nola, 1997), specifically scientific realism (Devitt, 1997; Psillos, 1999).

philosophical doctrine are also provided in this first chapter. Finally, the aims of this study and its importance for adult science education are addressed in this introductory chapter.

In this study, I hope to show that pragmatist interactional constructivism is an inadequate learning model for adult science education. If true, this is significant not only for science education, but for adult learning theories that are based on constructivist pragmatism.

### *The Place and Challenge of Adult Science Education*

A surprising number of adults seek undergraduate science knowledge and related skills for both personal use and in pursuit of a degree. According to data from a 1989-1990 survey conducted by the National Center for Education Statistics (1995), 6.5 million undergraduates in the United States were 24 years or older. The same study reveals that 2.7% of these 6.5 million adults were science majors: life sciences (1.5%), physical sciences (1.2%). This means that there were approximately 175,500 adult undergraduate science majors during the fall of 1989. If health, engineering, and non-science curricula which require some coursework in science are included, then the number of adult learners enrolled in undergraduate science courses may have approached one million that same academic year. The number of adult learners as a percentage of undergraduates has steadily increased in recent decades. In 1999, for example, 39% of all undergraduates were 25 years or older as compared to 28% in 1970 (U. S. Department of Education

[USDE], 2002b). Thus, even by conservative estimates, there are hundreds of thousands of adults enrolled in science courses in higher education each year.

Science education for adults poses unique challenges. Many adults do not have strong science backgrounds. For example, about 9% of adults who enter postsecondary education do so with a GED/certificate, while another 3% have neither a high school diploma nor a GED/certificate (NCES, 1995, p. iii). Such high school equivalencies do not require science coursework. Even adult undergraduates who are high school graduates may be ill-prepared for science. One reason is that many students take fewer science courses as they progress from middle school to high school (National Science Foundation [NSF], 1993). To put this in perspective, American high school students take fewer courses in science than they do (in order of increasing frequency) in mathematics, history/social studies, and English (NSF, 1993).

There may be adverse consequences for academic underpreparedness. Later in life, many adults seek career advancement, career changes, or desire personal understanding requiring postsecondary knowledge. Many adults who did not pursue postsecondary education when they were younger may not have been prepared academically and consequently struggle as adult learners (USDE, 2002a, p. 2). Both as a sign of the problem of underpreparedness and an attempt to remedy it, many postsecondary institutions, especially community colleges, commit to remedial education (Cohen & Brawer, 1996, pp. 257-259). The Center for the Study of Community Colleges (1978) notes that 13 percent of all chemistry classes offered in 1977-1978 were remedial. The percentage of remedial courses remained high during the early 1990s. For example,

“18 percent of the credit-course enrollment in Illinois and in Washington community colleges was in remedial courses” (Cohen & Brawer, 1996, p. 259). Cohen and Brawer summarize the academic prospects of students enrolled in remedial classes by saying, “Generally speaking, if students complete their remedial coursework successfully, they go on to succeed in the regular college program. However, less than half the students entering the remedial courses complete them” (p. 260). In addition, current statistics on degree completion note that there is less likelihood that adult undergraduates will complete baccalaureate degrees as compared to younger students (NCES, 1995; USDE, 2002a). Given the large number of adults enrolled in undergraduate science courses, it seems that science educators, administrators, and policymakers should be interested in educational perspectives that might provide guidance for teaching and learning science. One place to turn for such guidance is the field of adult education.

### *Adult Education*

The field of adult education has traditionally sought to determine: (a) who the adult learner is, (b) under what conditions adults choose, and are able, to pursue learning opportunities, and (c) how adults learn (Merriam & Caffarella, 1991, 1999). Generally speaking, adult learning theory suggests that adults are motivated to learn when learning has practical relevance to their everyday world; that adults rely on past experience when learning; and that adults prefer some form of activity or active expression in course work (Merriam & Caffarella, 1991, 1999).

These adult learning principles are based in part on the work of Eduard Lindeman (1926/1989) and Malcolm Knowles (1968, 1970), who emphasized the roles of both experience and activity in learning. These two adult learning theorists also noted the value of educational opportunities that were of direct practical importance to students' everyday lives. Eduard Lindeman notes that,

Experience, the stuff out of which education is grown, is after all a homely matter. The affairs of home, neighborhood and local community are vastly more important educationally than those more distant events which seem so enchanting. Experience is first of all, doing something; second, doing something that makes a difference. . . . we enjoy experiences in proportion to the effectiveness of our actions. (Lindeman, 1926/1989, p. 87)

For his part, Malcolm Knowles believed that adult learning was different from childhood learning, thus his introduction of the term "andragogy" in contrast to pedagogy. Although the term "pedagogy" means the art and science of instruction generally (Webster's, 2002), Knowles wished to distinguish between the education of children and adults. Thus, for Knowles (1980), "andragogy"<sup>2</sup> was defined as "the art and science of helping adults learn" (p. 43). Andragogy "was based on four assumptions" of adult learning regarding "self-concept, the role of experience, readiness to learn, and orientation of learning" (Merriam & Brockett, 1997, p. 135). For some, andragogy became viewed "as *the* theory of adult education" (p. 135). Like Lindeman, Knowles emphasized practical problem

---

<sup>2</sup>

The prefixes "*paed-*," "*paedo-*," "*ped-*," and "*pedo-*," from the Greek, refer to "child," while "*andr-*" and "*andro-*," also from the Greek, refer to "male" or "man" (Webster's).

solving motivated by learners' lived experience and interests. Knowles believed that: (a) "Adults become ready to learn those things they need to know . . . or to cope effectively with their real-life situations" and that, (b) "In contrast to children's and youth's subject-centered orientation to learning, adults are life centered (or task centered or problem centered) in their orientation to learning" (1989, pp. 83-84).

Even today, many adult educators emphasize the role that experience plays in learning. Merriam and Brockett note that, "The idea of experience as a core aspect of adult learning is so pervasive in the theory and practice of adult education that it would be difficult to find examples that do not address the role of experience" (p. 153). Thus, from an adult learning perspective, the roles of experience and practical problem solving activity are likely to influence thinking about adults learning science.

A quest for science educators of adults is to locate adult learning perspectives that might inform science education. Typically, however, adult learning perspectives tend to be subject-matter neutral. This tendency is not unique to the field of adult education. Lee Shulman, an educator at Stanford University, states that "critical features of teaching, such as the subject matter being taught . . . are typically ignored in the quest for general principles of effective teaching" (1987, p. 6). Science education is rarely addressed in the adult education literature (Hacker & Harris, 1992). Consequently, adult educators have been provided little guidance either in determining which adult learning theories might be best suited for science education or on what basis such a determination can be made.

There is one relatively new learning perspective in the field of adult education that has a direct link with science education—constructivism. Constructivism is becoming

increasingly popular in the field of adult education where it seems to be compatible with a number of adult learning perspectives (Candy, 1991; Fenwick, 2000a; Merriam & Brockett, 1997; Merriam and Caffarella, 1999, p. 261).

For example, Philip Candy (1991), an adult educator who works from a constructivist perspective, provides an example of a science education setting in which a student learns about a swinging pendulum based on constructivist learning principles. The use of constructivist inspired examples as they inform adults learning science is rare, however. Nonetheless, it seems that constructivism is a learning perspective that might inform adult science education. Thus, there is sufficient reason to pursue constructivism as an adult education learning model for learning science, given the demonstrated number and needs of adults enrolled in undergraduate science courses and programs.

### *Constructivism*

What is constructivism and where did it come from? While most educators who are aware of constructivism see it as a contemporary learning perspective, constructivism originated as a theory of knowledge, or, if one prefers, an epistemology or philosophy of science (Matthews, 1994; Phillips, 1995; von Glasersfeld, 1995a).

According to one leading constructivist, Ernst von Glasersfeld (1995a), constructivism stems largely from the British empiricist philosophers—Locke, Berkeley, and Hume—Kant, and the early 18<sup>th</sup> century Italian philosopher Giambattista Vico. Von Glasersfeld believes that “Vico’s treatise on epistemology (1710)” was the “first explicit formulation of constructivism” (p. 6). Thus, von Glasersfeld views constructivism

primarily as an epistemology as opposed to a learning theory. Von Glasersfeld connects philosophical constructivism with education through Piaget. It should be noted at this juncture that von Glasersfeld's (1993, 1995a) constructivist philosophy opposes realist theories metaphysically, ontologically, and epistemologically.

Denis Phillips, oftentimes a constructivist critic (1995, 1998, 2000a), has also provided a synopsis of the roots of educational constructivism (1995). Like von Glasersfeld, Phillips (1995, 1998, 2000a) avers that educational constructivism is a postmodernist philosophy. Phillips's (1995) list of early "constructivist" thinkers includes Kant, Piaget, Kuhn, and the American pragmatist philosophers. At the head of Phillips's list is Ernst von Glasersfeld, who has had a great influence on contemporary educational constructivism, particularly in mathematics and science education (Laroche & Bednarz, 1998; Matthews, 1994, 2000a; McCarty & Schwandt, 2000; Niaz et al., 2003; Nola, 1997; Phillips, 1995, 2000c; Solomon, 2000; Steffe & Gale, 1995; Steffe & Thompson, 2000; Tobin, 1993). Indeed, the title of a recent text edited by Steffe and Thompson (2000) *Radical Constructivism in Action: Building on the Pioneering Work of Ernst von Glasersfeld* attests to von Glasersfeld's influence. In addition, von Glasersfeld's work has begun to influence the field of adult education (Candy, 1991; Merriam & Caffarella, 1999). Based on its historical roots, both von Glasersfeld and Phillips conclude that educational constructivism is at its core a philosophical, or epistemological and ontological, doctrine.

Today, constructivism is a popular learning perspective in science education. Constructivist Peter Fensham (1992) writes that, "The most conspicuous psychological

influence on curriculum thinking in science since 1980 has been the constructivist view of learning” (p. 801). One constructivist educator notes that, “Most recent reforms advocated by national professional groups are based on constructivism,” including “the National Council for Teachers of Mathematics” and “the National Science Teachers Association” (Fosnot, 1996b, p. x). Constructivism not only “represents a paradigm change” in science education (Tobin, 1993, p. ix), but it has been referred to both as “science education’s ‘grand unifying theory’” (Colburn, 2000, p. 9) and a “world view” (Candy, 1991; Fler, 1999).

As a worldview, constructivism is more than a learning theory. Worldviews include philosophies about reality and how reality can be known. Constructivist Eric Bredo (2000) describes the important philosophical nature of constructivism. Bredo asserts that while talk of constructivism may begin with “innocuous questions about how children’s knowledge develops, or how scientific knowledge has been formed, it quickly leads to much deeper philosophical issues concerning relations between knowledge and reality” (Bredo, 2000, p. 127). Questions of knowledge and reality are not issues to which learning theories speak. They are epistemological and ontological issues, respectively. Thus, a full understanding of how constructivism might inform science education must entail an understanding of both constructivist learning theory and constructivist epistemology and ontology (Phillips, 2000a).

Since constructivism has roots in science education and seems consistent with a number of adult learning perspectives (Candy, 1991; Merriam & Brockett, 1997; Merriam & Caffarella, 1999), it appears to be a potential learning theory candidate for adult

science education. In appraising constructivism as a learning perspective for adult science education, its educational, epistemological, and ontological dimensions warrant consideration since constructivism's origin is epistemological (von Glasersfeld, 1995a). That is, a consideration of educational constructivism "quickly leads to much deeper philosophical issues concerning relations between knowledge and reality" (Bredo, 2000, p. 127). A brief overview of constructivist learning theory and constructivist epistemology follow.

### *Constructivism: A Theory of Learning*

What is constructivist learning theory? In attempting a synopsis of constructivist learning theory, a caveat is in order. Constructivism is a diverse movement such that "the environment in which the term 'constructivism' is very widely and very confusingly used is complex and often intransigent" (Phillips, 2000a, p. 2). Therefore, there is no unanimity when characterizing constructivism, including its learning theory. Nonetheless, the following five tenets are considered by many as constituting constructivist learning theory. Constructivist learning theory is based on psychological notions of how learning occurs.

The first tenet of constructivist learning theory is the idea that knowledge is a human construct (Phillips, 1995, p. 5). This means that the content of disciplinary knowledge, such as science, is not "handed down, ready formed, from on high" (p. 5). Rather, human knowledge, whether from the academic disciplines "or the cognitive structures of individual knowers or learners—is *constructed*"(p. 5, original italics).

According to this view, inquirers do not obtain knowledge directly by “reading” nature. Rather, knowledge of nature is “constructed” by humans. A second constructivist learning theory tenet regards the educational situation, itself, which “must be congruous with the individual student’s level of intellectual development” (Renger, 1980/1992, p. 151). Piaget, for example, describes various levels of cognitive development, while Vygotsky (1987) insists that formal concept learning is dependent upon adolescence. A third constructivist learning theory tenet is that new knowledge must be built on previous knowledge. This is because learning “involves continually connecting prior knowledge with new information” (Hausfather, 2001, p. 16). Fourth, most constructivists believe that students must be active agents responsible for constructing their own knowledge (Bredo, 2000, p. 132). This opposes the view that students are passive recipients of knowledge, in other words, that they are “blank slates” to be written on or “vessels” awaiting to be filled. Fifth, and last, there is less agreement as to whether constructivists believe that knowledge is a social, rather than an individual, construct. The majority constructivist position appears to be that knowledge is socially constructed (Phillips, 1995, p. 11).

Again, it must be emphasized that these tenets of constructivist learning theory are generalizations, that many constructivist positions represent variations on these themes, and that some constructivists may reject one or more of them while adding others. For example, Joan Solomon (1994) and Paul Cobb (1994), both sympathetic to constructivism, question constructivism’s adoption of the idea of “active learning” which they consider a trivial notion. Cobb believes that students actively construct their own knowledge even in non-constructivist environments (p. 4). Similarly, Solomon wonders

whether learning can be anything other than active. Solomon maintains that constructivist learning activities which are designed specifically to alert learners to discrepancies in their “alternative” belief systems often fail, because students are facile at accommodating “discrepant” data into already-existing belief systems (p. 12). On this view, active learning does not necessarily change students’ belief systems leading them to scientific knowledge. On the other hand, Eric Bredo (2000), who is a social constructivist, maintains that active learning is *the* core constructivist learning tenet and that students should be allowed to redefine the objects with which they interact according to students’ own objectives (p. 132). Perhaps Mark Bickhard (1998), himself a constructivist, sums up the situation best when he suggests that the term “constructivism” provides only negative information about what an author opposes, while on the positive side it indicates a “wild multiplicity” of approaches (p. 99).

While it is perhaps fair to say that most educators view constructivism as a learning theory, constructivism is much more than a set of beliefs about how students learn science. For many constructivists, constructivist theories of knowledge, or epistemologies, speak directly to learning theory (Bentley, 1998; Bettencourt, 1993; Bredo, 2000; Colburn, 2000; Fosnot, 1996a, 1996b; Laroche & Bednarz, 1998; Pépin, 1998; Tobin, 1993; von Glasersfeld, 1993, 1995a). However, the epistemological dimension of constructivism has not received the attention it deserves in spite of its enormous influence on constructivist learning theory (Phillips, 1995).

*Constructivism: A Theory of Knowledge*

Theories of knowledge (epistemologies) try to show how reality can be known and, in doing this, must involve beliefs about the nature of reality. Although they are separate issues, epistemological theories are always closely related to ontological theories.<sup>3</sup> Adult educator and constructivist Philip Candy (1991) maintains that constructivism is to be understood as “*a cluster of related perspectives that are united in their underlying view of the world*” (p. 254, italics added). Seen in this way, constructivism is a philosophical system and, when referring to science, a philosophy of science. Constructivism is not simply an empirical study, but is based on serious assumptions of philosophy. And those assumptions are ones that can rightly be questioned since they cannot be proven by empirical research. The importance of this epistemological dimension of constructivism cannot be overemphasized given that, while constructivist epistemology often conflicts with modern realist science, it purports to inform science education. Were constructivist learning theory easily distinguishable from constructivist theories of knowledge, there would be no problem in attending only to the learning theory dimension of constructivism. This is seldom the case, however. Denis Phillips (1995) notes: “The problem is that readers of the constructivist literature are

---

3

Although knowledge is always about something, ontology and epistemology are nonetheless separate issues. The use of the term epistemology in this study assumes realist ontology. Arguing from a realist perspective, for example, philosopher Michael Devitt (1997) notes that ontological considerations should precede epistemological ones. The reversal of this order, as constructivist critic Michael Matthews (2000a) points out, often leads to the discredited philosophy of idealism. In reference to one leading constructivist, Matthews notes: “And finally, in a move that many idealists before him have made, von Glasersfeld proceeds from an epistemological position to an ontological one” (p. 173).

usually left to figure out for themselves which of these programs is being pursued” (p. 6). This is because constructivist learning theories and constructivist theories of knowledge are often conflated, giving the impression that they support one another, when that need not be the case (Irzik, 2000).

In his *Educational Researcher* article in which he attempts a characterization of constructivism, Denis Phillips (1995) makes a rather strong claim at the outset regarding the epistemological dimension of constructivism. Phillips states that constructivism, “whatever else it may be, [is] a ‘powerful folk tale’ about the origins of human knowledge” (p. 5). Phillips adds: “Clearly, all forms of constructivism take a stand on epistemological issues. . .” (p. 10). Notwithstanding Phillips’s belief that epistemology imbues all constructivist “sects,” one might ask: What difference does it make if epistemology is included in the different varieties of constructivism? The answer, according to critics of constructivism, is that epistemological constructivism has great bearing on science education in terms of the kind of scientific knowledge that is learned, how it is learned, and how the practice of science is portrayed to learners (Irzik, 2000; Matthews, 1994; McCarty & Schwandt, 2000; Nola, 1997, 2003; Osborne, 1996; Solomon, 2000). The question in Phillips’s mind is whether science education should be guided by a “powerful folk tale about the origins of human knowledge;” that is, by constructivist epistemology, on the one hand, or by a more traditional scientific epistemology, on the other, such as realism.

Constructivist epistemologies are, in fact, often antithetical to both learning science and scientific knowledge (Nola, 2003). McCarty and Schwandt (2000) state that

discredited epistemologies are often incorporated in constructivist positions as a “garage sale of outdated philosophical falsisms” (p. 42). In other words, constructivist learning theories are interlaced with philosophical views that may be questionable. In short, there are disconnects between constructivist epistemologies, on the one hand, and science epistemologies, on the other, as they relate to science education. The following claim made by one constructivist science educator illustrates this point:

Today, inquiry and discovery are back again. . . . The strength of constructivism is that it unifies trendy teaching strategies. Many so-called fads in education turn out to have a firm, research-supported foundation in constructivist learning theory. Constructivism . . . refers to a philosophical view about the nature of reality and perception, is a theory about how people learn, and—more and more often—represents an array of teaching strategies. (Colburn, 2000, p. 9)

Because, as Colburn says, constructivism refers to a philosophical view both about the nature of reality and perception and is an empirical theory both about how people learn and how to teach, it becomes difficult to distinguish between these issues or to know what supports what. This leads to two dangers. First, that which seems to be pure empirical work about how people learn is in fact philosophically laden and assumes principles that cannot be established empirically. The second danger is that it gives the illusion that philosophical theories can be proven by empirical inquiry. This implies that constructivists have special expertise above more professional philosophers. To the extent that untenable epistemologies are included in constructivist positions, constructivist learning theories and pedagogies become compromised. Thus, according to critics of

constructivism, there is a need for separating out constructivist epistemology, learning theory, and pedagogy from each other (Matthews, 2000a). Further, the situation indicates the need for differentiating between constructivist ontologies and epistemologies from other more traditional realist theories.

### *Disconnects Between Constructivist and Realist Epistemologies*

Realist epistemology concerns itself with knowledge of the real world. On the other hand, epistemological constructivism seeks both to disestablish realist epistemology and to supplant it with its own array of epistemologies. Immediate concerns for educators is first knowing how to distinguish between constructivist epistemology and constructivist learning theory and, second, knowing how epistemological constructivism impacts science education. Several epistemological themes are evident in constructivist theorizing which are incongruous with realist epistemology. Some of these epistemological concerns are briefly outlined.

The first epistemological concern is as subtle as it is important. Constructivist learning theory is often conflated with epistemology. Thus, according to one perennial constructivist critic (Matthews, 2000a), how one learns about reality (a psychological theory of learning) becomes the very justification for knowledge of reality (an epistemological theory). This occurs when learning theory substitutes for epistemology. Constructivist Eric Bredo (2000) provides an excellent example from the pragmatist tradition of the conflation of learning theory with epistemology:

To back off from these heady [philosophical] issues for a moment, however, we might also consider what “constructivism” means from a purely practical educational standpoint more concerned with “making” knowledge than with claims about objects or reality. Here constructivism seems to have two implications: (1) a concern for students’ having an active role in learning and (2) their being allowed to redefine or discover new meanings for the objects with which they interact. (Bredo, 2000, p. 132)

Here, Bredo implies that students’ beliefs about reality count as scientific understanding of reality when he alleges that students should be “allowed to redefine or discover new meanings for the objects with which they interact.” Thus, active learning becomes epistemology. Said differently, “making knowledge” (or constructivist learning), has everything to do with epistemology in that, when they learn, students make “claims about objects or reality.” If Bredo were simply stating that students’ beliefs change as they increasingly accord with the scientific view, then he would be addressing learning and not advancing an epistemological position. But Bredo’s position is not epistemologically non-partisan, because, as he says, it “contrasts with the *correspondence* theory of traditional realism” (p. 141, original italics). Thus, to adopt Bredo’s constructivist theory of learning is to adopt an epistemology which opposes scientific realism. Hence, for Bredo, learning theory advances a non-realist (constructivist) view of reality.

Second, and related to the first issue, there is confusion with many constructivist positions with “the manner in which new [scientific] knowledge is made with the manner in which old [scientific] knowledge is learned, assuming the two are one and the same”

(Osborne, 1996, p. 53). Here the conflation is with learning science and the practice of science. This confusion is driven by what Derek Hodson (1998) calls an absurd metaphor: the idea “that *everyone* is a scientist” (p. 44, original italics). Such is the case, however, when adult educator Phillip Candy (1991), operating from a constructivist position, maintains that an individual learner can learn about a swinging pendulum by recursive cycles of interacting with a pendulum and reflecting on its motion. This form of inquiry-based learning assumes that the manner in which individuals learn about pendulums is the same as how the science of pendulums was originally generated. However, humans watched pendulums for millennia without determining the science of pendulums or experiencing any cognitive dissonance that would cause them to change their beliefs about pendulums (Matthews, 2000c).

Third, constructivist epistemology is predicated on various philosophies which hold that reality is basically unknowable (Nola, 2003). Constructivist Yvon Pépin (1998), for example, candidly alleges that, “*We have no direct . . . knowledge of any external or objective reality*” (p.174, italics added). Similarly, constructivist Jere Confrey (1990) states that constructivism maintains the belief “that all knowledge is necessarily a product of our own cognitive acts” and that, as a result, “we can have no direct . . . knowledge of external or objective reality” (pp. 108-109). In other words, these constructivists assert that epistemological considerations precede ontological considerations. Rather than assert an object’s existence and then attempt to learn more about it, constructivists maintain that the object’s existence is predicated on knowledge of it. It follows from this that an apple’s ontic reality changes with my ever changing knowledge of it. When applied to science

education, critics of constructivism state that constructivism allows students to construct their own belief systems rather than learn science (Matthews, 1994; Nola, 2003; McCarty & Schwandt, 2000; Phillips, 1997). This is not the right conclusion for constructivists to draw, however. Such skepticism concerning knowledge about reality can lead to relativism. If no one can know the truth, then no one has the right to draw any conclusion, since he or she does not know the conclusion is true.

Fourth, and related to the last item, individual or group experience is taken by many constructivists as a necessary and sufficient condition for generating scientific knowledge. When experience is taken as the *sine qua non* constructivist epistemology, it places constructivism within the philosophical empiricist camp which opposes realism. The problem for experiential learning models vis-à-vis science education is that realist science is not based in experience either methodologically or epistemologically.

A fifth epistemological concern, one alluded to already, is relativism. When individual learners or groups maintain their own belief systems independently of one another, such belief systems can be conflictive and, thus, relativized in the absence of objective methods and standards of adjudication. Phillips (1995) asserts that many varieties of constructivism, whether or not they acknowledge it, are relativist positions.

## *Focus of This Study: Pragmatist Constructivism*

### *Interactional Constructivism: Introduction*

This study focuses on a particular school of constructivist thought that serves as a basis for adult learning theory—pragmatist constructivism (Brookfield, 2000, p. 37). Pragmatist constructivism emanates from American pragmatist philosophy, especially the thought of Peirce, James, Dewey, and Mead (Scheffler, 1974). In particular, this study addresses the pragmatism of George Herbert Mead (1936, 1938), who was a close friend, colleague, and intellectual ally of John Dewey (Garrison, 1998). Mead’s philosophical doctrine focuses on activity, experience, and practical problem solving which are also foundational elements of adult learning theory. Mead’s pragmatism, known as *interactionism* (Bredo, 2000), is not only a theory of knowledge—which is to say that it is an epistemology—but a philosophy of science and learning theory (de Waal, 2002; Mead, 1936, 1938). It is because of pragmatist constructivism’s epistemological influence on adult education that it deserves attention.

### *George Herbert Mead and Pragmatism*

What role did Mead play in pragmatist thought? Mead was a central figure in the pragmatist movement. And his views have contributed greatly to current educational constructivist thought (Bredo, 2000; Garrison, 1998; Phillips, 2000b).

Mead was a close friend and intellectual ally of Dewey (Phillips, 2000b). After Dewey, Mead is considered the most creative pragmatist philosopher between World War

I and the Great Depression (Reck, 1964, p. v). Mead was a student of William James at Harvard University and a colleague of John Dewey, first at the University of Michigan, and then at the University of Chicago. Dewey's going to Chicago was contingent upon Mead being offered a professorship there in philosophy (Miller, 1973, p. xxii). Mead worked closely with Dewey at the University Laboratory School at Chicago which Dewey founded. Eventually, Mead became head of the philosophy department at the University of Chicago. Dewey would eventually leave Chicago and go to Columbia. Such was their friendship that in 1931, just before his death, Mead "had agreed to leave Chicago and go to Columbia University" where Dewey was (Miller, 1973, p. xxxvii).

The evidence suggests that not only did Mead and Dewey exert considerable influence on each other (Reck, 1964, p. lx) but that Mead helped steer the course of pragmatist thought. Morris (1934) claims that, "If Dewey is at once the rolling rim and many of the radiating spokes of the contemporary pragmatist wheel, Mead is the hub" (p. xi). Jim Garrison writes that,

Mead and Dewey maintained a lifelong relationship and were colleagues for many years during which they visited each other nearly every day. So intermeshed was their influence on each other that it is often impossible to determine who originated what. (Garrison, 1998, p. 43)

Dewey (1931), himself, says of Mead that, "I dislike to think what my own thinking might have been were it not for the seminal ideas which I derived from him" (pp. 310-311). It is important to note that in terms of his "*theory of knowledge*, Mead's philosophy joins that of Dewey" (Reck, 1964, p. lix, italics added). Because of his direct contribution

to constructivist thought (Bredo, 2000; Garrison, 1998) and his influence on Dewey, Mead's interactionism is of great importance to adult education.

### *Mead's Pragmatist Interactionism and Adult Learning Theory*

The importance of the epistemological dimension of constructivist pragmatism as it influences learning theory is as follows. According to constructivist learning theory, individuals and groups construct knowledge based on activity, experience, and practical problem solving. When applied to science education, the assertion is that learners should be "allowed to redefine or discover new meanings for the objects with which they interact," but not according to "traditional realism" (Bredo, 2000, pp. 132, 141). Indeed, pragmatism and realism oppose one another in important ways. Pragmatism is based on activity, experience, and practical problem solving.

Merriam and Brockett (1997) state that, "From Dewey and others emerged a philosophy of education, the major principles of which found expression in adult education" (p. 35). The two adult educators go on to provide four principles of adult learning arising from pragmatism, two of which are listed here: (a) "A focus on learners and their needs and experiences rather than on predetermined content" and (b) "The use of scientific methodology incorporating problem-solving, activity, and experience-based approaches to instruction" (p. 36). These are the very ingredients of Mead's *philosophy of the act* (1938) which endow epistemological legitimacy to students' knowledge arising from activity. This doctrine views "the learner as a potential contributor to the remaking of 'reality'" (Bredo, 2000, p. 132). On this view, learning is synonymous with knowledge

creation which is situated in experience arising from activity devoted to problem solving. Moreover, reality has no fixed forms but is malleable according to human interests (Bredo, 2000). Adult educator Stephen Brookfield (2000) says of pragmatist constructivism that it “rejects universals and generalizable truths, and focuses instead on the variability of how people make interpretations of their experience” (p. 37).

Indeed, Mead’s philosophy of the act (1938) is a scientific theory of knowledge in which knowledge is derived during experiential problem-solving activity. As it relates to science education, pragmatism purports simultaneously to depict scientific practice; define and explain how scientific knowledge is generated; and describe how students learn science. The applicability of constructivist pragmatism to science education is compromised, however, if the theory of knowledge and philosophy of science on which it rests do not accord with modern realist science.

### *Problems with Mead’s Interactional Philosophy of Science*

There are several problems with Mead’s theory of knowledge and, by extension, his philosophy of science. These, in turn, have bearing on science education. Although a fuller discussion of Mead’s interactionism, including its characterization and critique, must await until chapters Three and Four, some of the concerns are as follows.

The first problem with Mead’s pragmatism is that realist science is not based on experience (Nowak, 1994). Second, realist science is theoretical because it necessarily involves discourse (theories) about invisible entities, such as electrons, atoms, and genes. Pragmatists are suspicious of scientific (realist) theories which purport to talk about

invisible entities, and they do not fully commit to the invisible entities suggested by the theories. As the Meadian scholar David Miller (1973) avers, the pragmatists, including Dewey, have been repeatedly criticized for not having “succeeded in defending the thesis that there is a world there, whether we are aware of it or not” (p. 95). Third, pragmatism accords efficacious problem-solving activity supreme epistemological status (Mead, 1938). Hence, pragmatism is a means-end epistemology which equates truth with the solution to a particular problem in a particular setting. In other words, “truth” is what works in a given context and is not applicable to other contexts. All three of these concerns are characteristic of instrumentalism, a form of philosophical empiricism, which contrasts with the realism of modern science.

### *Pragmatism and Adult Learning Theory Revisited*

The connection between adult learning theory and constructivist pragmatism is transparent. Knowledge, or truth, obtains from efficacious problem solving emphasizing human interests at the expense of ontic reality. It is because of this that a consideration of constructivist pragmatist philosophy is important for science education. Adult learning perspectives based on pragmatist epistemology emphasize experience, activity, and problem solving in the everyday world of adult learners (Knowles, 1980; Lindeman, 1926/1989; Merriam & Brockett, 1997; Wilson, 1993; Wilson & Hayes, 2000). Adult educator Arthur Wilson provides a nice summational history of adult education which mirrors pragmatist philosophy based on experience, activity, and everyday problem solving:

Adult educators, too, have been concerned with the relation between learning and activity. One of the philosophical and instructional foundations of twentieth-century adult education is a focus on experience as essential to learning. Dewey's (1938, p. 25) notions of education rest solidly on experience as a foundation of learning: "All genuine education comes about through experience." Lindeman (1926, pp. 6, 9) tied the meaning of adult education to experience: "The approach to adult education will be via the route of situations, not subjects because the resource of highest value is the learner's experience." This traditional emphasis on experience shows up fully articulated in Knowles (1980) depiction of andragogy, in which experience is again proposed as the central ingredient of learning. It is here that Knowles makes his central claim that meaningful adult learning is associated with the everyday problems of adults in their social worlds. (Wilson, 1993, p.74)

It is therefore no coincidence that adult learning theory is based on activity, experience, and practical problem solving of adults in their everyday social worlds. Thus, what educators take as the primary elements of adult learning theory are, in fact, the basic epistemological ingredients of pragmatist philosophy. But the question arises as to whether these particular ingredients of pragmatist epistemology have any bearing on the portrayal of modern realist science, scientific knowledge generation, or learning science.

## *The Study*

Like many forms of constructivism, pragmatist constructivism is first and foremost a theory of knowledge. Second, it is at the same time both a philosophy of science and a learning theory. In conflating these issues, pragmatist constructivism not only defines the very nature of scientific knowledge that students learn from its own epistemological point of view but determines exactly how this scientific knowledge is generated and how it is learned. From a science education standpoint, the question then is whether pragmatist constructivism accords with a modern understanding of realist science epistemologically and methodologically. To the extent that Mead's constructivist interactionism is at variance with modern realist science on epistemological and methodological issues, it becomes unworkable as a science education model. This is because students are presented a distorted picture of what constitutes scientific knowledge, how it is generated, and how it is justified. A related educational question, which is the primary focus of this study (p. 1, also Chapter Four), is whether Mead's constructivism enables students to acquire scientific concepts; whether it allows them to learn the methods of science; and whether it prepares adult learners for professional practice. How these determinations will be made is outlined in Chapter Two.

### *Implications of a Study of Mead's Interactional Constructivist Theory of Knowledge*

A study of Mead's constructivist theory of knowledge has many potential implications for adult education. Minimally, such a study will alert educators to the fact that common elements of adult learning theory—activity, experience, and practical

problem solving—contain philosophical assumptions that cannot be established empirically. Such elements of adult learning theory can be examined only by the standards of philosophy. This is important for the following reason. There exists the real possibility that there might be limits to what can be learned by employing adult learning theories that are based on learners' experiences and activities, or that define knowledge in terms of practical problem solving. More strongly, it is possible that this combination of adult learning theory elements actually conspires to prevent scientific understanding. But unless the philosophical aspects of these elements of adult learning theory are examined philosophically, this cannot be determined.

Popular activity- and problem-based constructivist learning approaches may in fact sabotage the learning of science. For example, while adult educator Philip Candy's (1991) autodidactic learning theory may be popular because it simultaneously allows for student activity, creativity, reflection, problem-solving, and autonomy, these learning theory elements offer no guarantees that students will learn science. In fact, students cannot learn the science of pendulum motion simply by interacting with pendulums and reflecting on those actions (Matthews, 2000c).

Mead's (1938) philosophy of "the act" asserts that efficacious problem solving in conjunction with the dictates of human interests leads to knowledge. This is an epistemological theory, and it underpins Mead's pragmatist learning theory. In short, that which leads to consummation and makes one happy is truth (Mead, 1938). Efficacious problem-solving activity results in consummation for Mead and "is satisfaction, and if you like, happiness" (p. 136). As both a philosophy of science and a learning theory—in

addition to its being a theory of knowledge—the act is applied by Bredo (2000) in constructivist learning situations which “view the learner as a potential contributor to the remaking of ‘reality’” (p. 132). Thus, “reality” is defined according to students’ interests and experiences as they interact with objects. Pragmatist interactional constructivism foregrounds activity “by giving priority to *doing* rather than *knowing*” (p. 141, original italics).

There are serious educational implications for such a theory of knowledge at the practical level relating to teaching and learning science. These practical educational implications can be drawn out by analyzing concrete examples and asking whether pragmatist interactional constructivism allows for: (a) acquiring scientific concepts, (b) learning and applying scientific methods, and (c) preparing students for the exigencies of professional practice. This is the goal of my study. Thus, the suitability of pragmatist interactional constructivism as a science education model can be assessed and understood at both the epistemological and practical educational levels. Moreover, such an analysis will indicate how epistemology, learning, and learning theory relate to one another.

Mead’s ideas are widely held in adult education. Therefore, an epistemological analysis of Mead’s interactional constructivism is called for. While Candy (1991) notes the importance of epistemology for adult education learning theory, he states that it is rarely addressed by adult educators. This study seeks to fill that void. Although pragmatist constructivism is an epistemology on which many adult learning theories are based, its epistemological implications for teaching and learning remain largely unexplored. The implicit assumption, therefore, is that pragmatist constructivism is

epistemologically accommodating to science education. Moreover, the implication is that pragmatist constructivism is an adequate portrayal of science and that both scientists and learners construct scientific knowledge experientially through efficacious problem solving. But unless pragmatist constructivism is addressed as an epistemology, philosophy of science, and learning theory, these assumptions cannot be appraised, particularly as they relate to science education.

In terms of learning science, are there epistemological *limits* to adult learning theories based on the centrality of learners' experiences, learners' activities, and learning that bases relevancy on practical problem-solving? In addressing these issues in accordance with the methods of this study (Chapter Two), it is my hope that this study will make much needed contributions to adult learning theory which can be used by administrators, program planners, and educators. Indeed, many educators are not aware that constructivism is inherently epistemic and how this impacts education. Phillips (1995) states that the "fields of epistemology and philosophy of science" are two areas that "are rarely, if ever, mentioned by those embroiled in the educational debates" surrounding constructivism (p. 5). A study which addresses these issues is therefore timely.

This study, which is an analysis of Mead's constructivist interactional theory of knowledge as it relates to learning science, will constitute Chapter Four. Chapter Two will contain the methods of this study, outlining the specific learning issues to be explored and how they will be approached. Chapter Three will address background material that is essential for understanding Mead's philosophical doctrine. Thus, it will

include pertinent background information relating to philosophy. Chapter Five will consider the important educational implications of adopting interactional constructivism as a science education learning model and will offer recommendations for graduate education, educators, and further study. It is my hope that this study will help to refine adult learning theory, particularly as it relates to science education. This refinement will begin by calling into question philosophical assumptions of adult learning theory in their constructivist manifestations.

## CHAPTER TWO

### Methods: Philosophical Inquiry

#### *Introduction*

The purpose of this study is to examine whether pragmatist interactional constructivism is an adequate learning theory for adult science education; that is, does it provide adult learners a good way to learn science? There are four basic points that will underpin my central argument. Some of these points have already been made in general by educational researchers and philosophers. Here, however, I hope to extend them to adult science education. Additionally, the original contribution I shall try to make in this study will be to show that pragmatist interactional constructivism is a deficient model for science education.

The first of the four points that are foundational to this study is that many constructivist learning theories harbor philosophical viewpoints (Matthews, 1992a, 1992b, 1993; Phillips, 1995). In other words, constructivist learning theories are not just empirical theories of how we learn; they are also philosophies. This is important because they need to be judged as philosophy, with the standards used by professional philosophers. Expertise in learning theory does not guarantee that one's philosophical theories will be correct. Further, coupling deficient philosophies with learning theories will only render those learning theories deficient. Indeed, many philosophers have seriously criticized the philosophies behind constructivist learning theories (Irzik, 2000; Nola, 1997, 2003; Phillips, 1997, 2000; Suchting, 1992). The second point is that

scientists do not subscribe to constructivist philosophies (Devitt, 1997; Musgrave, 1998; Psillos, 1999). Philosopher of science Alan Musgrave (1998) states “that realism is the instinctive philosophy of working scientists . . .” (p. 1096). This matters because a major purpose of science education is to give students an understanding of how scientists themselves view the world and how they practice their disciplines. Whether they agree with the philosophies of working scientists or not, it is appropriate for science teachers to point out the philosophical assumptions of scientists, and perhaps at times to raise questions concerning them, but not to replace them with their own assumptions. Third, not only do scientists not subscribe to constructivist philosophies, but they do not conduct science in the manner suggested by constructivist philosophies. I will discuss this further in Chapter Three as part of the comparative review of constructivist and realist philosophies (p. 55) and then again in Chapter Four in the section dealing with pragmatist interactional constructivism’s employment of scientific methods (p. 116). Fourth, if the above points are correct, it follows from a pedagogical viewpoint that constructivist learning theories are simply not adequate for teaching and learning science, since the philosophies they promulgate provide students with the wrong account of how scientists view the world and how science is conducted. Also from a pedagogical viewpoint, the enactment of constructivist learning theories leads to science being taught and learned in a manner that ignores how scientific knowledge is generated. The reason for this is that constructivist learning theory confuses the manner in which new scientific knowledge is created, on the one hand, with how students learn science, on the other, treating both matters as if they were one and the same thing (Osborne, 1996).

Because constructivists maintain that learning science and doing science are one and the same, they have confused two very important issues. Constructivists have equated learning theory with scientific method. Constructivists wrongly conclude that, by enacting constructivist learning theory, students are able to construct scientific knowledge on their own. But the processes of learning science and conducting science are not one and the same. There are three aspects of this mistaken assumption. The first is the notion that scientific concepts can be learned experientially. The second is implied. It is the idea that scientists, themselves, learn science largely experientially rather than from others. The third notion is that students are intuitive scientists, who are engaging in scientific knowledge creation while learning science.

Critics of constructivism, on the other hand, point out that students learning science are not actually engaging in scientific knowledge creation (cf. Hodson, 1998). That is, learning science is not the same thing as being involved in the cooperative but arduous and time-consuming processes of theory testing and theory development in which scientists engage (Irzik, 2000). Moreover, most of what scientists know about science they do not learn through personal discovery, but from others. Isaac Newton made this very point in a letter to Robert Hooke when he wrote: “If I have seen further it is by standing on the shoulders of giants.” Constructivist critics Niaz et al. (2003) state that science educators, psychologists, and philosophers would perhaps agree that there is a limited relationship between “the process of theory development by scientists and a student’s acquisition of knowledge,” or the conception of the student as “a *‘developing scientist’*” (p. 793, original italics). These constructivist critics go on to state that “hardly

any science educator would perhaps accept the thesis that students work/learn as scientists. . .” (p. 793). Science educator Julie Bianchini (1997) notes the difference between the knowledge students construct on their own when learning science, on the one hand, and scientific knowledge generated by scientists, on the other, when she states that, working together in groups “students socially construct context dependent knowledge rather than the overarching theories common to science” (p. 1043). When this type of constructivist learning occurs, the divide only widens between everyday and scientific ways of understanding the world (Bianchini, 1997; Solomon, 1987).

The nature of scientific concepts presents challenges to learning. Undergraduates have difficulty thinking in terms of scientific concepts, according to a group of scientists (Lawson et al., 2000). The scientists note: “Because the entities and processes upon which theoretical concepts are based cannot be directly observed, acquiring understanding of theoretical concepts is relatively difficult” (p. 1012). Of significance was this group’s finding that less than one third of students, including adults, “develop thinking skills associated with hypothesis testing when the hypothesized entities are unobservable” (p. 1011). Examples of unobservable entities, whose causal effects are noted only indirectly, are numerous in science. They include photons, electrons, atoms, molecules, and genes. It is, therefore, important for educators and others associated with science education to realize that the “meaning of theoretical concepts comes not from direct sensory input but from the theories from which ideas originate” (p. 1012). However, if higher-order knowledge, like scientific theories, is not derivable from experience (Charlesworth, 1982), then how are students to learn this aspect of science? Richard Prawat (2000)

suggests that it is the teacher's responsibility to divest students of their idiosyncratic beliefs by ensuring that the latter are brought into contact and reconciled with the disciplinary side of concepts (pp. 805-807).

The challenge of learning scientific concepts seems to be ignored by constructivist learning theory. Many constructivist learning theories are experientially based because it is thought that experience captures the philosophical-methodological nature of scientific knowledge generation and that students can learn science experientially, following the same path. The constructivist argument founders, however, if scientific knowledge is not experientially derived. This is where the history and philosophy of science prove indispensable. Science historian Alexandre Koyré has noted that not only is science not based in experience, but that experience can be an impediment to science:

. . . observation and experience—in the meaning of brute, common-sense observation and experience—had a very small part in the edification of modern science; one could even say that they constituted the chief obstacles that it encountered on its way. . . . the empiricism of modern science is not experiential; it is experimental. (Koyré, 1968, p. 90)

Experience based on sense impressions does not lead to scientific understanding.

Philosopher Lesek Nowak (1994) describes the contribution of Galileo and others on this matter when he writes: “The Galilean revolution consisted in making evident the misleading nature of the world image which senses produce. . . . senses do not contribute in the slightest to the understanding of the facts” (p. 123).

The manner in which science is portrayed, how scientific knowledge is generated and justified, even scientific knowledge, itself, are all important considerations for adult science education. The purpose of adult science education is to help adults learn science in the broadest sense of the term (e.g., knowledge, methods, aims) and how to apply that knowledge. This includes learning to think scientifically. This differentiates the goal of a Deweyan science education for primary grade children, on the one hand, which takes into consideration developmentally appropriate activities from that of adult undergraduate science majors, on the other. In the Deweyan classroom, while it is certainly justifiable for children to learn some aspects of and an appreciation for chemistry by cooking (cf. Ryan, 1998), the hundreds of thousands of adults, who are undergraduate science majors in the United States, want to learn “what is already part of the *‘funded capital’* of society,” to borrow Dewey’s marvelous term (cited in Ryan, 1998, pp. 397-398, italics added). Richard Prawat (2000), a Deweyan scholar, describes the second of these two educational aims when he states: “In this second approach, which assigns an equal priority to public as opposed to private knowledge, powerful ideas appropriated from the disciplines are the instrument of choice for getting the learning process underway” (p. 805). Adult students do not enroll in undergraduate science courses for the purpose of constructing their own scientific knowledge from the ground up. Nor are adult learners laboring under the illusion that this can or ought to be done. Rather, adult learners embark as science majors hoping to learn the “powerful ideas appropriated from the disciplines” from those who know something about them. Adult learners need to learn science so that, when they graduate from their respective programs, they are prepared to apply their

knowledge in science-related settings. This includes not only having some science knowledge, but being able to think scientifically in order to communicate with others and to accomplish common goals. Thinking scientifically, however, “is not natural,” nor does it “automatically unfold as children either confront the world, or participate in culture” (Matthews, 1994, p. 161). Nor does adulthood ensure that individuals will automatically think conceptually or scientifically (Lawson et al., 2000; Vygotsky, 1987). Scientific knowledge is not built from the ground up by students because it is not possible, *contra* constructivist claims.

This study will seek to show that the enactment of pragmatist constructivist learning theory leads to the deficient acquisition of scientific concepts and that pragmatist constructivism gives a distorted view of both the nature and practice of science as understood by scientists themselves. It is also argued in this study that adherence to constructivism does not adequately prepare adults for careers in science or in science-related fields. Not only is pragmatist interactional constructivism an outmoded philosophy, but its application as a learning theory hampers learning science in the broadest sense to include the imparting of the values and goals of science, its methods (including its manner of thinking), and scientific knowledge. How I hope to show this is detailed in the methods which follow.

## *Methods of This Study*

### *The Research Question*

The question this study addresses is whether pragmatist interactional constructivism is a viable learning theory for adult science education. In other words, does the use of pragmatist constructivism facilitate learning science? Learning science includes at least the following: (a) scientific concept acquisition, (b) learning scientific methods, and (c) preparing students for further scientific studies or for professional practice, which require building on and applying previous scientific knowledge.

The research question is of a philosophical nature, and therefore it will be addressed by philosophical analysis. Pragmatist constructivism is at its base not just a learning theory but primarily a philosophy of natural science. In other words, philosophy and scientific methodology drive pragmatist constructivist learning theory. Because pragmatist constructivist learning theory is philosophically laden, one must determine whether its philosophical commitments facilitate or impede the learning of science. Such a determination cannot be made by attending solely to the learning dimension of pragmatist constructivism. This can only be done by first noting and then addressing the philosophical aspect of pragmatist constructivism. If pragmatist constructivism deviates from what is accepted as current scientific knowledge and methods, imposing its own alternative views on adult learners, then one cannot know this except by philosophical inquiry into its metaphysical, epistemological, and methodological nature.

### *What This Study Hopes to Demonstrate*

In this study, I hope to show that the use of pragmatist constructivism does not help adult students: (a) acquire scientific concepts, (b) understand the aims and methods of science as it is understood by scientists, and (c) prepare for professional practice. Because pragmatist constructivist learning theory inherently employs a questionable philosophy of science, it prevents students from gaining a true understanding of science, acquiring science knowledge, and, in the process, does not adequately prepare students for professional careers in science and science-related fields.

### *How This Study Will Show That Constructivist Learning Theory Is Ineffective*

This study will seek to show the inadequacy of pragmatist constructivism by indicating its shortcomings in three areas that are crucial to any science education learning model for adults. These areas include: (a) scientific concept acquisition, (b) an understanding of the goals and methods of science, and (c) preparation for professional practice. In the following subsections, I shall present how I think each of these matters should be framed.

*Concept acquisition.* In order to show that interactional constructivist learning theory frustrates the learning of scientific concepts, my approach will be to discuss examples from the literature in which the learning theory is used ostensibly for this very purpose. When I say that pragmatist constructivist learning theory is deficient, I mean that it does not enable students either to acquire scientific concepts or to address scientific topics.

Eric Bredo (2000) provides two different examples in which pragmatist constructivist interactional learning theory alleges scientific knowledge acquisition. In the first of these instances of learning, Bredo applies constructivist interactional learning theory to the learning of “traditional Newtonian properties” (p. 144). The constructivist learning claim is that Newtonian properties, like “inertia,” are “directly reflected to the organism when an object is acted upon” (p. 144). The second example of constructivist interactional learning, ostensibly leading to the definition and meaning of food, is also based on an organism’s interacting with an object. There is a third category of scientific concepts that does not seem to be amenable to an interactional approach to learning—invisible entities, like electrons, atoms, and molecules which cannot be experienced. The majority of scientific concepts which adults confront in college science courses belong to this group of concepts. These three examples of concept acquisition based on constructivist interactional learning theory, which are supported by George Herbert Mead’s philosophy, are worth examining.

In the case of students acquiring Newtonian concepts, I shall argue that such concepts cannot be learned by interacting with objects in the manner constructivist interactionism alleges. Bredo (2000) claims that Newtonian properties can be learned by interacting with objects. It is one thing to claim, as does Bredo, that Newtonian properties may be sensed by the organism, where “property” is understood, according to Webster’s, as “an effect that an object has on another object or on the senses.” But it is entirely another matter to suggest that conceptual understanding of Newtonian properties can be learned in this manner. The difference between what Bredo calls “reflected properties,”

that is, the sensation we have, for example, of “inertia,” are significantly different from the scientific meanings of such concepts. The goal of adult science education is not to provide learners merely an opportunity to gain sense impressions of objects with which they might come into contact, but to learn scientific concepts.

Turning to how constructivist learning theory and philosophy relate to the acquisition of the concept of food, Bredo (2000) specifically maintains that any “object” which reduces hunger when consumed “*really is food*” (p. 144). In accordance with Mead’s philosophy of “the act,” explicated in Chapter Three (p. 66), learning allegedly occurs as a result of an organism interacting with an “object” during some sort of problem-solving activity. In this case, a hungry organism selects an unknown object from its environment, manipulates it, and then ingests it. If this type of problem-solving activity results in satiety, then the unknown “object” the organism has consumed “*really is food*,” according to interactional pragmatist constructivism. I shall argue in Chapter Four (p. 103) two related points: (a) that this interactional constructivist conception of food based on satiety is seriously inadequate, since it does not lead to scientific understanding of the concept “food,” and (b) that pragmatist constructivist learning theory is inadequate for addressing many other food concepts.

By contrasting a more traditional concept of food as compared with that of pragmatist constructivism (Bredo, 2000), I hope to show how the constructivist conception is lacking. This argument will be bolstered by showing how Bredo’s constructivist learning theory is deficient for addressing other important food-related concepts, such as pica (the phenomenon of eating non-food items) and the hormones of

satiety and hunger. The scientific nature of these important food-related concepts that adults confront in undergraduate science courses cannot be learned in the manner alleged by pragmatist constructivist interactionism.

The third type of concepts students are required to learn cannot be experienced. Can this class of invisible, therefore theoretical, objects of science be learned interactionally, as constructivist interactionism suggests? For a variety of reasons, I shall argue in Chapter Four (p. 100) that they cannot. I aim to show this by entertaining the concept of molecular cellulose and mosquito-borne malarial parasites. By indicating why these two concepts, involving theoretical entities, are difficult for many students to learn, I hope to show why conceptual understanding cannot be achieved according to constructivist interactional learning theory.

Thus, a case is developed that will show that pragmatist interactional constructivism is not suited for learning several different kinds of scientific concepts. This includes not only sensible items, such as “blobs” that reflect Newtonian properties or that lead to the concept of “food,” but also conceptual learning involving invisible entities and processes.

*The nature and practice of science.* Realist science is based on a particular view of the world and how the world can be known. This includes particular assumptions of reality and knowledge of reality and research methods which are consistent with them. This set of basic assumptions and methods of realist science is not shared by pragmatist interactional constructivism. The manner in which science is conducted is an important consideration for science education. Graduates of science programs who will enter

science and science-related professions need to understand how science is conducted since they will be expected to apply its methods. Thus, science graduates are expected to have a basic understanding of the nature of science which includes its philosophical orientation, its methods, and manner of thinking. By analyzing examples of experimental pragmatist constructivist science provided by Mead (1938), I shall argue in Chapter Four (p. 116) that this basic combination of elements crucial to realist science is lacking. Of course, students with a philosophical bent have a right to rethink scientific methodology and the foundations of science. But part of science education is to acquaint students with an understanding of science as scientists understand it, including scientists' underlying assumptions of the nature of reality and how they think reality can be known.

One of the favored methods of science incorporates if/then/therefore thinking, commonly referred to as hypothetico-deductive reasoning (cf. Lawson, 2000, 2002). This pattern of reasoning is commonly found in the work of many scientists (Laudan, 1998b), whether or not they are consciously aware of it (Lawson, 2002). According to philosopher of science Larry Laudan (1998b), the logic of hypothetico-deductivism replaced inductivism in the natural sciences some time between 1800 and 1860. That this shift occurred Laudan claims "would be denied by no one who studies the record" (p. 151). The point here is not to debate whether hypothetico-deductivism represents *the* scientific method, or whether scientists actually employ a variety of methods. The generalized, recurring process of making observations, forming hypotheses, hypothesis testing, obtaining results, and drawing conclusions, common to hypothetico-deductivism, is a common strategy of many scientists. George Herbert Mead (1936, 1938) delineated a

version of the hypothetico-deductive method consistent with pragmatist ontology and epistemology.

Eric Bredo (2000) provides an example of Mead's scientific method worth considering. The example posits a scientific (theoretical) object, the existence of an invisible malarial parasite hypothesized to account for human malaria. The manner in which inquiry proceeds in this example bears close resemblance to the hypothetico-deductive model of realist scientific inquiry. It includes an initial observation, hypothesis formation—the positing of a scientific entity (a mosquito-borne malarial parasite)—hypothesis testing, and the drawing of a conclusion based on experimental results.

By analyzing this example of pragmatist constructivist scientific inquiry (p. 135), I hope to show how it compares with the methods of realist science, including considerations of its aims and the nature of its scientific knowledge claims. Specifically, I shall seek to determine whether this example of constructivist science lends strong support for its claim of the hypothesized malarial parasite (the aim of realist science), or whether its aim is more consistent with solving a practical problem (the aim of pragmatist science), which, in this case, is the control of malaria.

There are two related issues under consideration in this example of constructivist science. One has to do with the differing aims of realist and pragmatist science, while the other has to do with conducting what is considered good science. The second issue has direct bearing on science education, if an agreed upon goal of science education is to provide students a correct view of how science is conducted. Specifically, the question is

whether this example of constructivist science properly employs the if/then/therefore logic for testing the stated hypothesis, which is whether a mosquito-borne malarial parasite exists. The first issue, that of the differing aims of pragmatist and realist science, although more philosophically motivated than the second issue, is important, nonetheless, because it concerns the goals of science, how scientists conceive invisible objects (ontology) and what counts as scientific knowledge (epistemology). Thus, while students need not be concerned directly with philosophy of science, it nonetheless affects how scientists view the world and how they approach and conduct scientific practice. In this regard, philosophy is central to a meaningful science education.

A scientific view must incorporate philosophy with proper methods. If students are to learn and, later, properly employ scientific methods, then it does matter whether the application of the if/then/therefore thinking of hypothetico-deductivism in this situation is adequate to the stated problem, especially because it is held out as a prime example of scientific method and inquiry. One of the agreed upon goals of science education is to provide opportunities for students to learn “how scientists are thinking while engaged in scientific activity” (Lawson, 2002, p. 2). This includes how scientists view reality and how science is conducted in keeping with this view.

*Preparation for professional practice and further science education.* The question arises as to whether pragmatist constructivist interactionism is an adequate adult science education model for preparing students for professional practice in science and science-related fields. I argue in this study that it is not. The basis for my claim rests on two points that follow.

First, many learning approaches that are attributed to Deweyan pragmatism have resulted in overemphasizing the student's interests and the student's responsibility for determining the curriculum (Ryan, 1998, p. 397). Second, many learning approaches attributed to Dewey assume that conceptual learning occurs mainly inductively, so that students are able to bootstrap their way slowly to knowledge (Prawat, 2000). Richard Prawat (2000) writes that because of his inductive approach to learning, "Dewey, as is now commonly accepted, is viewed as the main proponent of what is variously termed an activity-based, hands-on, or learning-by-doing approach to teaching and learning" (p. 805). Thus, the utility of these popular learning approaches turns on whether they are based on inductive logic. Prawat contends that this question remains largely unexamined by philosophers and educators. This study seeks to address this very issue as it relates to adult science education.

Regarding the first point, the viewpoint of advocates of student-centered, interest-driven approaches to learning are consistent with the following comment by Dewey early in his career.

. . . the child's own instincts and powers furnish the material and give the starting point for all education. Save as the efforts of the educator connect with some activity which the child is carrying on of his own initiative independent of the educator, education becomes reduced to pressure from without. It may, indeed, give certain external results but cannot be truly called educative. (Dewey, 1897/1972, p. 85)

I hope to indicate the limitations of this position by showing that adult learners are not

always in a position of knowing the basic ideas in a particular discipline, why they are important, in what contexts they are applicable, or even how they are applied. This will be done by explicating specific examples of the types of knowledge graduates of science and science-related programs are expected to know but which they cannot acquire wholly on their own. An adult anatomy and physiology student, who is preparing for a career in nursing, for example, cannot be expected to “furnish the material and give the starting point for all education” based on “some activity which the” student “is carrying on of” his or her “own initiative independent of the educator.” Nor does this mean that the adult learner’s activity is reduced to pressure. Exercising free will, in accordance with their own purposes, adults desire to learn what they need to know for their professions.

Regarding the second claim, I shall argue that learning approaches that are based on induction are insufficient for learning science. That some of the currently popular approaches to learning are based on the logic of induction stems from a claim made by Dewey (1898/1972) himself: “After the conquests of the inductive method in all spheres of scientific inquiry,” Dewey writes, “we are not called upon to defend its claims in pedagogy” (p. 545).

Dewey’s argument for the use of the logic of induction in learning is as follows. The first premise is that students learn science by employing the logic of science. The second premise is that the logic of science is inductive. The conclusion drawn is that learning methods should, therefore, be based on the logic of induction. The first premise is open to question. Learning theories do not flow straightforwardly from epistemologies. But more importantly, induction is no longer considered the basic logic of science, at

least according to many philosophers (Laudan, 1998b) and scientists (cf. Campbell, Reece, & Mitchell, 1999; Lawson, 2000, 2002). Moreover, induction,

even if it is a valid form of inference, will only yield generalisations of the type “all metals expand when heated” or “in all gasses volume varies inversely with pressure.” Induction will never yield those higher generalisations we call scientific *theories*, such as the theory that matter has an atomic structure or the theory that energy can be transformed but never destroyed. (Charlesworth, 1982, p. 18, original italics)

One goal of science education is to provide future practitioners basic knowledge which they cannot derive by themselves. For graduates of health-care programs, providing proper health care is based on scientific knowledge that cannot be derived inductively but which must be learned. When nurses administer intravenous potassium solutions, for example, a physiological understanding of why this particular intervention is prescribed contributes to knowledgeable, effective, and safe health care. The same can be said of the practices of sterile technique and hand washing in health-care settings. While these last two practices are considered commonplace ideas today, the reason why is not at all intuitively obvious. They gained support only with the germ theory of disease based on the independent discoveries of a number of scientists, including van Leeuwenhoek, Semmelweis, Lister, Pasteur, and Koch. These examples are explored (p. 164) for the purpose of indicating why students are unlikely to derive this type of knowledge on their own based on their own interests and current activities.

The notion of preparing scientifically knowledgeable nurses opposes the view of nurses as “order takers” who follow orders unquestioningly and who may be incognizant of the reasons for their actions. Health care providers will no doubt gain valuable knowledge from their professional experience which augments their science knowledge. However, professional experience alone cannot supply the basic scientific (theoretical) knowledge that underpins important aspects of professional practice, making communication possible between different health-care providers, and providing a common basis for understanding and guiding medical and health-care interventions. It is highly unlikely that the scientific knowledge required in situations like these will be acquired by students following largely their own interests and constructing knowledge inductively. Rather, undergraduate science courses are designed specifically to prepare students for an array of situations so that, as informed practitioners, they are able to apply specific knowledge. Moreover, an education which provides practitioners an opportunity to learn to think scientifically will allow them to adapt better to changing health-care practices.

### *The Central Role of Philosophy in Science Education*

Constructivism has made science education a philosophical matter, not because it has drawn attention to the importance of the natural relationship of philosophy to science, but, rather, because it seeks to supplant the philosophy of scientists with its own. Because it underpins many of the issues in this chapter, a basic comparative understanding of realist and pragmatist interactional constructivist philosophy is helpful. Thus, aspects of

philosophy which are foundational to this study are found in Chapter Three of this study. The treatment of philosophy in Chapter Three, in addition to comparing and contrasting pragmatism and realism, will include applications to crucial aspects of the three arguments advanced in this study pertaining to: (a) concept acquisition, (b) scientific aims and methods, and (c) preparation for professional practice.

Many constructivists seem to treat science education as an opportunity for a discursion into philosophical speculation rather than attending to just teaching and learning. Eric Bredo (2000), a proponent of pragmatist constructivist interactionism, holds this view. “While interest in constructivism starts with how children’s knowledge develops, or how scientific knowledge has been formed,” Bredo writes, “it quickly leads to much deeper philosophical issues concerning relations between knowledge and reality” (p. 127). At the same time, these philosophical discursions on the part of constructivists result in philosophical world views which are at variance with those of scientists.

Because they contain constructivist philosophies, the adoption of constructivist learning theories has the potential for leading students away from science as understood by scientists. For example, the employment of pragmatist interactional constructivist learning theory encourages students “to redefine or discover new meanings for the objects with which they interact” such that each learner is “a potential contributor to the remaking of ‘reality’” (Bredo, 2000, p. 132). The significance of this educational aim is that it promulgates constructivist philosophy. While encouraging students both to redefine objects and to remake reality, pragmatist interactional constructivism overtly opposes not only realist metaphysics (p. 144) but realist epistemology (p. 141). Thus, there is a

conscious effort at the foundational level of much of constructivism to lead students away from traditional scientific understanding.

These same constructivist ontological and epistemological commitments surface in adult learning theories attributed to Dewey. The editors of the recent *Handbook of Adult and Continuing Education*, note constructivism's disavowal of an "objective reality" (Hayes & Wilson, 2000, p. 671) and the emphasis pragmatist constructivism places on subjective experience. Adult educator Stephen Brookfield (2000) notes that pragmatist constructivism "emphasizes the role people play in constructing and deconstructing their own experiences and meanings. Constructivism rejects universals and generalizable truths, and focuses instead on the variability of how people make interpretations of their experience" (p. 37). Educationally, this translates "into adult education's concern with helping people understand their experience, and with the field's preference for experiential methods" (p. 37).

Working scientists do not share these constructivist views about the world or how the world is known. Scientific knowledge is not derived by focusing on people's experience. Nor is it derived without first assuming the existence of a world external to the inquirer. Anton Lawson offers a contrasting view of how scientists conceive of the world and how knowledge of the world is discovered, suggesting an educational approach that is consistent with this view:

. . . learning at all levels above the sensory-motor requires that one assume the independent existence of the external world because only then can the behavior of the objects in the world be used to test subsequent higher-order ideas. In the final

analysis, ideas—including scientific hypotheses and theories—stand or fall, not due to social negotiation, but due to their ability to predict future events. . . . The primary instructional application is that science instruction should remain committed to helping students understand the crucial role played by hypotheses, predictions and evidence in learning. (Lawson, 2000, p. 577)

The manner in which scientists view the world orients them to a particular way of conducting science. I shall argue that the philosophical foundation of constructivist learning theory, because it opposes realist aims and strategies, while promoting a contrarian view of reality and knowledge, is not attuned for providing future practitioners an adequate knowledge of science.

### *Summary and Study Outline*

The educationally relevant questions this study addresses include whether pragmatist constructivist interactionism is sufficient for providing students a means of acquiring scientific concepts, learning the methods of science, or preparing them for professional practice. These arguments are advanced in Chapter Four as outlined in this chapter. Background elements of pragmatist and realist philosophy that are foundational to the issues entertained in this study are located in Chapter Three. Finally, Chapter Five contains a discussion of the conclusions of this study, a look at constructivism more generally in adult education, along with practical recommendations for educators, program planners, and administrators.

## CHAPTER THREE

### Constructivist Philosophy in Adult Education and its Relation to Realism

#### *Introduction*

The goal of this Chapter will be to provide background information in support of the items of critique of Mead's pragmatist constructivism enunciated in Chapter Two. The first item of critique concerns whether the use of pragmatist constructivism would aid learners with scientific concept acquisition. The second item concerns whether learning the scientific methods advocated by pragmatist constructivism would provide students with a modern understanding of scientific practice. The third item of critique will be to determine whether the use of pragmatist constructivist-inspired learning theories might adequately prepare students for science and science-related careers. Underpinning each of these three items of critique is a constructivist philosophical world view which opposes the world view of scientists known as scientific realism. In this Chapter, I shall introduce key philosophical concepts and positions relating to constructivism. Moreover, I shall endeavor to show that some constructivist-inspired adult learning theories are imbued with these same philosophical considerations. Lastly, I shall attempt to show that the philosophically laden adult learning theories inspired by constructivism consort with philosophical positions that are at odds with a modern, realist understanding of science and scientific practice.

### *Constructivism is a Philosophical World View*

Constructivism is introduced in the adult education literature variously as a learning orientation (Merriam & Caffarella, 1999), learning theory (Fenwick, 2000a), philosophical perspective (Merriam & Brockett, 1997), and world view (Candy, 1991). There is no inconsistency with these different modes of presentation, when one sees constructivism from the eyes of its theorists, that is, as a world view. Adult educator and constructivist theorist Philip Candy (1991), for example, envisages constructivism, not as “a single monolithic theory, but rather a cluster of perspectives united by underlying similarities in worldview” (p. 252). For Candy, epistemology is paramount for understanding constructivism, since it relates directly to issues of teaching and learning. According to Candy, constructivism involves “questioning established views about the production of and transmission of knowledge” (p. 254). In other words, constructivism not only challenges accepted philosophical theories of reality, knowledge, and how knowledge is produced, educationally, it questions whether established scientific knowledge can or ought to be communicated by the teacher to the learner (Candy, 1991; Fosnot, 1996; von Glasersfeld, 1995a, 1995b). While the question of whether scientific concepts and theories can be communicated between interlocutors is important, it is an altogether separate matter from the issues of the natures of reality and knowledge.

The questioning by constructivists of established views about the production of and transmission of scientific knowledge is laudatory. The critical examination of closely held ideas and positions is the hallmark of scholarly activity in any field. However, some constructivists are not content merely with “questioning established views about the

production of and transmission of knowledge” (Candy, 1991, p. 254). Apparently, established views about the production of knowledge and how that knowledge is to be communicated have been found to be lacking, according to some constructivists. Thus, constructivism “demands a substantial revision of ideas and perspectives” on these matters (Candy, 1991, p. 254). In support of his contrarian metaphysical and epistemological positions, adult educator Phillip Candy cites radical constructivists von Glasersfeld and Smock who call for the outright demolition of realist epistemology and metaphysics.

Revision may be too gentle a word for the kind of reorganization of ideas which . . . is indispensable for an understanding of the theory of knowledge which . . . constructivist formulations entail. It is not a question of merely adjusting a definition here and there, or rearranging familiar concepts in a somewhat novel fashion. The change that is required is of a far more drastic nature. It involves demolition of our everyday conceptions of reality and, thus of everything that is explicitly or implicitly based on naive realism. (von Glasersfeld & Smock, 1974, p. 2)

For Candy, constructivism is obviously far-ranging. Constructivism is much more than an orientation to learning. Not only does constructivism entail epistemological and metaphysical viewpoints, but we are told that these viewpoints are at variance with established views of knowledge, reality, and science. These philosophical issues need to be clarified before attention turns to issues of teaching and learning science, since the very philosophical traditions on which science rests are being challenged by

constructivists. In the following sections, I shall identify some of the metaphysical, epistemological, and methodological positions of constructivism in the adult education literature and show that they oppose a realist understanding of science.

### *Epistemological Constructivism*

Although constructivism is often presented as an approach to learning, many strands of constructivism harbor epistemological commitments that are at odds with current scientific understanding (Bredo, 2000; Candy, 1991; von Glasersfeld, 1993, 1995a). These same contrarian views advocated by constructivism are also found in the adult education literature. Hence, it is important to understand how constructivism is presented in the adult education literature, to recognize its philosophical nature, and to discern how it affects learning theory.

In the second edition of their textbook on adult education, Merriam and Caffarella (1999) introduce constructivism as a fifth orientation to learning to go along with the earlier learning orientations: behaviorist, cognitivist, humanist, and social. Hence, these two adult educators approach constructivism from the side of learning. They note that “constructivism encompasses a number of related [learning] perspectives” (p. 261). These include “experiential learning” and “self-directed learning” (p. 264). Merriam’s and Caffarella’s description of constructivism goes beyond the realm of learning into epistemology, however, when they note that the “purpose of education” from a constructivist perspective is to “construct knowledge,” where knowledge construction is seen as the “[i]nternal construction of reality by the individual” (p. 264). Hence,

according to the constructivist orientation to learning, individuals construct both knowledge and reality from a personal vantage point. Additionally, constructivism accords with experiential approaches to learning, because the “construction of meaning” is based on individual experience (p. 264). A corollary of the individual construction of reality, according to Candy (1991), “is that because no two people have had identical experiences, each person constructs a more-or-less idiosyncratic explanatory system: a unique map of the topography that we call reality” (pp. 251-252). Thus, Candy alerts us to the relativist tendencies common to many varieties of constructivism. The inherent subjectivism of constructivism is also noted by adult educators Merriam and Brockett.

What all these strains of constructivism have in common is the notion that reality can be known only subjectively (a moderate constructivist view) or that reality apart from the knower does not exist (a more radical view). Knowledge is the meaning that people make out of their experiences. (Merriam & Brockett, 1997, p. 46)

Based on these characterizations, adult educators envisage constructivism as much more than just an approach to learning. Constructivism is an epistemological doctrine.

Moreover, the inherent epistemological commitments of constructivism can be summarized.

- 1) Constructivism is not just a learning theory, it is a subjective epistemology.
- 2) The purpose of epistemological constructivism is to construct knowledge and reality, whether it is the individual or social construction of reality.
- 3) The locus of knowledge construction is the individual.

4) The basis of knowledge construction is individual experience.

5) Constructivism is a relativist doctrine.

Thus, even when it is presented as an influential learning orientation (Merriam & Caffarella, 1999) and learning theory (Fenwick, 2000a) in adult education, educators should be apprized that constructivism entails important epistemological commitments.

At this early juncture, it should be noted that the basic constructivist epistemological commitments listed above conflict with scientific realism. Contrary to epistemological constructivism, the goal of science is to learn more about a reality that exists externally to individuals. Scientists do not invent, or construct, reality based on experience. Nor is scientific knowledge reducible to personal psychology or to sociological interests (Phillips, 2000). Matthews provides a brief summary of realist philosophical commitments.

Realists believe that science aims to tell us about reality, not about our experiences; that its knowledge claims are evaluated by reference to the world, not by reference to personal, social, or national utility or viability; that scientific methodology is normative, and consequently distinctions can be made between good and bad science; that science is objective in the sense of being different from personal, inner experience; that science tries to identify and minimize the impact of noncognitive interests (political, religious, gender, class) in its development; that decision-making in science has a central cognitive element and is not reducible to mere sociological considerations . . . (Matthews, 2000c, pp. 329-330)

Constructivist epistemologies are deserving of attention, because they directly affect issues of teaching and learning science. The need for understanding constructivism as an epistemology is captured by Eric Bredo (2000), a proponent of Mead's pragmatist constructivism. Although constructivism "starts with seemingly innocuous questions about how children's knowledge develops, or how scientific knowledge has been formed, it quickly leads to much deeper philosophical issues concerning relations between knowledge and reality" (p. 127). In other words, a full appreciation of the educational import of constructivism hinges on an understanding of constructivist theories of knowledge and reality.

### *Metaphysical Constructivism*

From epistemological constructivism, attention turns to metaphysical constructivism. Metaphysical questions are important to science, because they are concerned "with the ultimate nature of reality" (Grayling, 1995, p. 183). Science and metaphysics have always been linked (Matthews, 1994). Up until the end of the 19<sup>th</sup> century, scientists were referred to as "natural philosophers" (Matthews, 2000c, p. 237). According to philosopher A. C. Grayling (1995), the primary questions of metaphysics are: "'What is there?'—that is, what exists?—and 'What is it like?'" (p. 183). Because knowledge is knowledge about something, scientists' knowledge claims are directly affected by their metaphysical views of the world. Most natural scientists are metaphysical realists who believe that unobservable entities, such as electrons, atoms, and molecules exist and that they exist independently of human minds and activities

(Musgrave, 1998). Moreover, scientists believe that one of the primary aims of science is to discover the unobservable entities and processes which are responsible for visible phenomena (Psillos, 1999).

Many constructivists do not share this objectivist metaphysical world view. Adult educator Philip Candy (1991) not only voices his disapproval of the metaphysical objectivism of realism but indicates what such a position means for education. Candy notes, “This objectivist or naive realist view has been very influential in shaping conceptions of teaching, because it implies that there is an objective reality, to which learners should be introduced” (p. 262). Candy shares many of the same views as the radical constructivist Ernst von Glasersfeld. Von Glasersfeld denies the realist metaphysical position that knowledge is about “an independent reality, a reality that exists by itself and in itself” (von Glasersfeld & Smock, 1974, p. xiv). Because Candy harbors doubts about the possibility of obtaining knowledge of a mind-independent reality, he concludes that knowledge and reality are individualistically constructed. Knowledge is an “idiosyncratic explanatory system: a unique map of the topography that we call reality” (pp. 251-252). Inevitably, according to Candy, both reality and knowledge of reality differ for each individual.

### *Methodological Constructivism*

Methodological constructivism suggests the methods by which knowledge is constructed. Although it is important to recognize that constructivist views of knowledge construction are divergent from those of realist science, it is just as important to recognize

that constructivist-inspired adult learning models are the actual embodiment of constructivist scientific methodologies for knowledge construction. In other words, experiential learning approaches, such as Mead's (1938) philosophy of the act, self-directed learning approaches, such as Candy's (1991) theory of autodidaxy, and Kolb's (1984) experiential learning model can all be seen as scientific methodologies by which knowledge is constructed. Merriam and Brockett (1997), for example, note that pragmatism promotes the "use of scientific methodology incorporating problem-solving, activity, and experienced-based approaches to instruction" (p. 35). Kolb (1984) notes that "Dewey, Lewin, and Piaget in one way or another seem to take the scientific method as their model for the learning process" (p. 32). Thus, the viability of constructivist learning theories hinges on the viability of the scientific methodologies that underpin them. Given each of the philosophical elements of constructivist philosophy—metaphysics, epistemology, and methodology—it is worthwhile to juxtapose them alongside their realist counterparts for comparison.

### *Constructivism Versus Realism*

#### *Introduction*

It is worthwhile to locate constructivism on the broad philosophical landscape. When this is done, it becomes clear why many varieties of constructivism oppose realism. In the venerable debates of science over the centuries, there have been two decidedly dominant positions which have traditionally opposed one another—realism and

empiricism. Many strains of constructivism belong to the empiricist tradition (Devitt, 1997; Irzik, 2000; Matthews, 1992a, 1992b; Musgrave, 1998; Nola, 1997; Suchting, 1992). Matthews notes,

Discussion of constructivism leads naturally into discussion of a debate that has echoed throughout the history of science: namely that between realists and empiricists. . . . What is at issue are the goals of scientific investigation and the reality or otherwise of theoretical entities and mechanisms posited in scientific theories to explain observable events and phenomena. (Matthews, 1994, p. 164)

When constructivism is seen as an empiricist doctrine, two things become clear. First, many strains of constructivism oppose realism. Second, these same constructivist strains are allied with empiricist doctrines, such as logical positivism, pragmatism, and postpositivism (Matthews, 2000a, 2004a). Because constructivism “is normally coupled with commitments to certain postpositivist, postmodernist, antirealist, and instrumentalist views about the nature of science,” it is at variance with a realist understanding of science (Matthews, 2000c, p. 328).

In opposition to empiricist views of science, realists believe that the entities and mechanisms posited by the best-supported scientific theories exist and that their existence is independent of human inquiry (Psillos, 1999). Empiricists, on the other hand, do not believe that scientific theories speak to unobservable entities of a mind-independent world. Generally speaking, empiricists believe that things which cannot be experienced do not exist. On this latter reading, scientific theories can be seen as merely aids or heuristic devices for guiding inquiry. In other words, scientific theories do not refer to the

unobservable entities and processes they name and describe. Instead of concerning themselves with the underlying unobservable entities and processes that might account for observable phenomena, empiricists attend only to the observable phenomena that are given in experience for anchoring their knowledge claims. This explains the high regard empiricists have for experience. For some empiricists, knowledge arises from experience. For others, knowledge claims are adjudicated by experience. Still, for others, experience is both the source and arbiter of knowledge claims (Grayling, 1995). Mead is a consummate empiricist. Mead asserts that experience is both the source and arbiter of scientific knowledge claims. Thus, for Mead, “Scientific knowledge is based on data gleaned from observations of this world . . .” (Baldwin, 1986, p. 16). And although Mead is regarded as a social constructivist, he nonetheless promotes a subjectivist epistemology which grounds knowledge claims in experience. Mead (1936) asserts that “the ground of authority lies in the knowledge which you yourself can in some sense grasp” (p. 11). Thus, for Mead, experience is both the fount and arbiter of scientific knowledge.

Educationally, from a Meadian constructivist perspective, students are not encouraged to learn the traditionally agreed-upon scientific definitions of objects to which they are introduced (Bredo, 2000). Instead, students should be “allowed to redefine or discover new meanings for the objects with which they interact” (p. 132). On this view, the meanings of objects constantly change, owing to the fact that objects must be seen as the objective of a response initiated from the student’s own perspective (Bredo, 2000). “What the object is, in terms of its definition or meaning, depends on how it is taken and on its functioning successfully in that way” (p. 152). In other words, objects are

approached “in a purely instrumental fashion” (p. 152). Hence, while constructivist approaches to learning are varied, “all view the learner as a potential contributor to the remaking of ‘reality’” (p. 132). However, realist understanding is not based on subjective or instrumental epistemologies, nor is it based on metaphysical or methodological empiricism.

### *Constructivist Metaphysics Opposes Realist Understanding*

Constructivists vary on the question of whether a reality exists external to the knower (Merriam & Brockett, 1997). Many constructivist positions, which deny the existence of unobservable objects posited by scientific theories, are based on metaphysical empiricism. Mead’s (1938) and Candy’s (1991) metaphysics will be briefly reviewed since they represent two prominent strands of constructivist thought in adult education.

*Mead’s metaphysics.* Mead is an able representative of pragmatism. His views had a significant impact on Dewey, his lifelong personal friend and colleague. “So intermeshed was their influence on each other that it is often impossible to determine who originated what,” notes constructivist Jim Garrison (1998, p. 43). While acknowledging the existence of observable entities, many pragmatists are antirealists concerning the existence of unobservables. Pragmatists are often accused of not defending the idea of a reality existing independently of the knower.

There has been a considerable amount of criticism directed to pragmatism, and especially to the views of John Dewey . . . a criticism to the effect that . . .

[pragmatists] have not succeeded in defending the thesis that there is a world there, whether we are aware of it or not. I suspect that much of this criticism is justified . . . (Miller, 1973, p. 95)

For Mead, objects do not exist independently of the mind, or, just as importantly, independently of instrumental activity. In this regard, it seems that Mead's metaphysics occasionally borders on idealism (Collins, 1989/1992). Philosophical idealism gives priority to the human mind, attaching lesser importance to the senses (Brown, 1998). Thus, although the world exists, it is said to be constructed by the mind. Idealism is consistent with the view that discourse creates the world (Matthews, 2000c, p. 258). Mead notes, "What is the world but a continued working hypothesis, a thought structure which is continually completing itself?" (1964, p. 332). Mead (1936, 1938) believes that reality evolves as a direct result of human inquiry. While it is one thing to state that scientific knowledge is not absolute and that it is continually evolving, it is entirely another thing to suggest, as does Mead, that the world exists as a continually changing thought structure as governed by bio-social interests. Collins (1992) criticizes what he perceives as occasional idealist tendencies in Mead's doctrine. "There are somewhat Berkeleyan overtones to Mead's argument. It is as if the world would go away when no one is acting upon it" (p. 273). Mead, himself, suggests that pragmatism draws from idealism.

If we recognize such a genuine grappling with the universe as the problem of the mind, the problem of the whole self, and further recognize the present insolubility of the problem, except as partial solutions exhibit an approach toward the

intelligibility of the universe, does not this pragmatic doctrine itself sweep us into the current of Idealism? (Mead, 1964, p. 332)

Metaphysical idealism is inconsistent with realism (Brown, 1998). Metaphysical realists do not believe that the world is created by the human mind. Instead, realists generally believe that the mind and the world are different things and that the aim of science is to try to learn more about the mind-independent world. Strictly speaking, Mead is not a consummate idealist (Collins, 1992). However, because of Mead's denial of metaphysical realism, his doctrine opposes the mind-independent existence of the unobservable entities of science, a topic that will receive greater attention in the next Chapter.

*Candy's metaphysics.* Candy (1991) objects to metaphysical realism, "because it implies that there is an objective reality, to which learners should be introduced" (p. 262). Candy's (1991) metaphysics is closely allied to that of von Glasersfeld. In turn, von Glasersfeld's (1995a) doctrine is an amalgam of Kant, British empiricism, Piaget, and others. Ernst von Glasersfeld describes radical constructivism.

Radical constructivism, thus, is *radical* because it breaks with convention and develops a theory of knowledge in which knowledge does not reflect an "objective" ontological reality, but exclusively an ordering and organization of a world constituted by our experience. The radical constructivist has relinquished "metaphysical realism" once and for all. (von Glasersfeld, 1987, p. 109, original italics)

This does not mean that Candy does not believe in the existence of an external reality.

While Candy believes that an external reality exists, he believes that we do not have direct access to it. Direct epistemic access to external reality is blocked, because cognition sullies our sensory perceptions of reality. According to this view, “What we learn in interaction with the environment is dependent upon our own [cognitive] structuring of those experiences” (Nystedt & Magnusson, 1982, p. 34). Consequently, for some constructivists, in lieu of metaphysical realism and correspondence theories of knowledge, “knowledge does not reflect an ‘objective’ ontological reality, but exclusively an ordering and organization of a world constituted by our experience” (von Glasersfeld, 1987, p. 109). This is the view to which Candy (1991) subscribes and the reason for his claim that reality is ultimately individually and socially constructed. Candy concludes with the constructivist maxim that “People participate in the construction of reality” (1991, p. 256).

The preceding argument—that because the mind is active in knowledge claims we are therefore isolated from reality—is commonplace in empiricist, including constructivist, writing (Nola, 2003). This argument is criticized by Matthews, who writes that “The one-step argument from the psychological premise (1) ‘the mind is active in knowledge acquisition’ to the epistemological conclusion (2) ‘we cannot know reality’ is endemic in constructivist writing” (2000a, p. 178). He adds that realism is untouched by this skeptical ontological argument advanced by constructivists.

. . . this conclusion only follows on the assumption that the empiricist tradition has correctly delineated the problem of knowledge. If one rejects the assumption that the problem of knowledge arises when a subject looks at an object and wonders

whether his or her mental representation corresponds to the object, then none of the skeptical conclusions of radical constructivism follow. Non-empiricist theories of knowledge are not subject to this skeptical argument. (Matthews, 2000a, p. 178)

Because Candy's philosophical world view draws heavily from von Glasersfeld's radical constructivism, it is not surprising that the world views of the two constructivists are similar on key issues. Consequently, the following criticism by Matthews (2000a) of von Glasersfeld's philosophy (VGP) can be applied equally to Candy's constructivism:

The basic problem with VGP is that it is a variant of the classic empiricist conception of knowledge which the scientific revolution discredited. All the root commitments of empiricism are preserved and endorsed in VGP: knowledge is something that individuals create and adjudicate; experience is both the raw material of knowledge claims and their arbiter; there is no immediate epistemic access to the external world; once individual cognitive activity is recognized, it is assumed that cognitive claims are compromised and knowledge of an external reality becomes impossible. (Matthews, 2000a, p. 174)

On the other hand, as metaphysical realists, scientists begin their work by presuming both the existence of a mind-independent reality and that this external reality is knowable. For example, Arizona State University biologist Anton Lawson (2000, p. 577) maintains, "Yet learning at all levels above the sensory-motor requires that one assume the independent existence of the external world because only then can the behavior of the objects in that world be used to test subsequent higher-order ideas."

Lawson proceeds to explain why the assumption of a mind-independent world is so crucial for science, when he notes that

. . . we have to assume that these entities exist so that test conditions can be imagined and predictions can be drawn. In the end we may decide that these entities do not exist. But to arrive at this conclusion, we first had to assume that they do exist. (Lawson, 2000, p. 591)

Lawson points out that this argument is not offered as a proof for the metaphysical position of realists that an external reality exists. Such a proof is not Lawson's objective. What Lawson absolutely denies, however, is the possibility of a constructivist science, or the possibility of doing anything analogous to science "without first assuming an independent reality" (p. 591).

The metaphysical debate concerning the existence of a mind-independent reality is not easily settled. Nor can it be settled here. Perhaps the best way to look at the problem is to try to discern how scientists themselves view reality. Einstein is a case in point, since both Mead and Candy have attempted to portray Einstein on occasion as supportive of their views. However, Einstein was a consummate realist. Einstein, for example, proclaimed his belief in the reality of unobservable entities. During his Herbert Spencer lecture delivered at Oxford in 1933 entitled "On the Method of Theoretical Physics," Einstein unabashedly declared, "To him who is a discoverer in this field, the products of his imagination appear so necessary and natural that he regards them, and would like to have them regarded by others, not as creations of thought but as given realities" (Einstein, 1934/1954, p. 270). Einstein (1954; Einstein & Infeld, 1938/1966) not only believed in an

objective reality but that this reality was preexistent, ordered, and knowable. Thus, Einstein's science stands in direct refutation of the constructivist position that knowledge is the "[i]nternal construction of reality by the individual" (Merriam & Caffarella, 1999, p. 264).

### *Constructivist Epistemology Opposes Realist Understanding*

*Subjectivist epistemology.* Adult educators Merriam and Brockett (1997) acknowledge that even moderate forms of epistemological constructivism are subjectivist. However, epistemological subjectivism is anathema to science. Popper (1972) maintains that scientific knowledge is not subjectivist. Popper notes that "knowledge or thought in a subjective sense . . . has led students into . . . irrelevancies: while intending to study scientific knowledge, they studied in fact something which is of no relevance to scientific knowledge" (p. 108). Hence, constructivism's widespread epistemological subjectivism would render it—in the words of Popper—irrelevant for students of science.

Scientific knowledge resides in what is known as Popper's (1972) third world. Popper's third world of scientific knowledge includes the objective theories, objective problems, and objective arguments of science. Objective in this sense refers to public as opposed to private, or subjective, knowledge. Unlike objective knowledge, subjective knowledge resides in individuals and is not therefore open to public examination. Subjective knowledge is based in personal experience. On the other hand, objective knowledge is not based in individual experience, which is to say that it is extraexperiential (Popper, 1972). Contrary to constructivism, then, scientific

knowledge does not reside in individuals but is extraexperiential; it is located within Popper's third world of objective problems, objective arguments, and objective theories.

*Experiential epistemology.* Experience is a core element of adult learning. "The idea of experience as a core aspect of adult education is so pervasive in the theory and practice of adult education that it would be difficult to find examples that do not address the role of experience" (Merriam & Brockett, 1997, p. 153). Knowles (1980) notes that experience "is a rich resource for learning" (p. 43). Dewey (1938) writes that "all genuine education comes about through experience" (p. 13). The influence of experience as a core element of the theory and practice of adult learning has led to the construction and adoption of experientially based learning models. There needs to be a clear distinction, however, between the idea that experience aids learning, on the one hand, and the idea that experience anchors knowledge claims, on the other. This distinction is important, because the former understanding of the role of experience for learning is uncontroversial, while the latter is not.

For example, when adult learning theorists (Candy, 1991; Kolb, 1984; Lewis & Williams, 1994; Merriam & Brockett, 1997) describe experiential learning models in which learners not only abstract theories from personal experience but also use experience to justify their abstracted theories, such models are inherently relativistic. According to scientific realism, experience is neither the source nor arbiter of knowledge claims.

David Kolb's (1984) experiential learning theory promulgates a philosophical empiricist view of knowledge. Kolb fashions his own learning theory after the

experiential learning theories of Lewin, Dewey, and Piaget. A central tenet of Kolb's learning theory is that learners, after having had concrete experiences, "must be able to create concepts that integrate their observations into logically sound theories" (p. 30). This process Kolb refers to as "*abstract conceptualization*" (p. 30, original italics).

Contrary to this adult education view of knowledge construction, concepts and theories cannot be abstracted from experience. According to Einstein (1934/1954), scientists erroneously thought at one time that "the postulates of physics . . . could be deduced from experience by 'abstraction'" (p. 273). Speaking specifically against the logical positivism of his day, Einstein goes on to say that "every attempt at a logical deduction of the basic concepts and postulates of mechanics from elementary experience is doomed to failure. . . [I]t is true that the axiomatic basis of theoretical physics cannot be abstracted from experience. . ." (p. 274). Thus, Einstein's epistemology directly refutes Kolb's (1984) empiricist—if not positivist—contention that learners, after having concrete learning experiences, "must be able to create concepts that integrate their observations into logically sound theories" (p. 30). Scientific concepts, including theories, are not abstracted from concrete experiences, as Kolb suggests.

In addition to the empiricist notion that scientific ideas arise from experience, some empiricists maintain that such abstracted ideas can be tested, verified, or justified by experience (Grayling, 1995). Kolb's (1984) experiential learning model represents such a position. However, just as it is impossible to abstract scientific theories from experience, it is also impossible to justify scientific theories by experience. According to Popper,

I admit, again, that the decision to accept a basic statement, and to be satisfied with it, is causally connected with our experiences—especially with our *perceptual experiences*. But we do not attempt to justify basic statements by these experiences. Experiences can *motivate a decision*, and hence an acceptance or rejection of a statement, but a basic statement cannot be *justified* by them . . .

(Popper, 1934/1959, p. 105, original italics)

Thus, Popper's view that concepts cannot be validated by experience refutes the justificatory aspect of Kolb's (1984) notion of experiential learning with "its emphasis on *here-and-now* concrete experience to validate . . . abstract concepts" (p. 21, original italics). That is, Popper's view refutes Kolb's claim that scientific ideas can be adjudicated by experience. In summary, Kolb's experiential learning model rests on two problematic empiricist practices. First, his model suggests that scientific theories are abstracted from experience. Second, it suggests that scientific theories are adjudicated by experience. Popper's view that scientific theories cannot be adjudicated, or justified, by experience also diverges from Mead's doctrine. Hans Joas (1985), a scholar of Mead, writing in the empiricist tradition, captures this aspect of Mead's empiricism when he writes: "Even the most general theory of matter presupposes the functioning of apparatuses in a world of immediate perception. Therefore, for Mead, too, as for the empiricists, experience is the final touchstone of any theory" (p. 204).

Popper captures the difference between realism and empiricism on the matter of experience as a *test* of knowledge claims, on the one hand, and experience as the *fount* and *arbiter* of knowledge claims, on the other. The former position is consistent with

scientific realism, while the latter position is consistent with empiricism. In other words, although realists believe that experience in the form of experimentation can motivate a decision to accept or reject a statement, observations themselves neither give rise to nor justify scientific statements.

Adult educators open the door to empiricism when they fashion experiential learning perspectives which accord experience epistemological status (Caffarella & Barnett, 1994; Jackson & MacIsaac, 1994). Jackson and MacIsaac (1994), for example, abdicate the notion of objective knowledge and then formulate “*definitions of knowledge*, which recognizes [*sic*] experiential knowing as an important form of knowledge for adult learners” (p. 23, original italics).

When adult educators promote experience as the arbiter of knowledge claims, it dooms experiential learning approaches for science education. The inadequacy of experience as the basis of knowledge claims as it relates to science and, by extension, science education is discussed by Matthews from a historical perspective.

[This is] why constructivist epistemology cannot give a satisfactory account of the scientific revolution and modern science. It is precisely the abandonment of experience as the arbiter of knowledge claims that distinguishes the work of Galileo and Newton from their Aristotelian and empiricist opponents. (Matthews, 2000a, p. 177)

*Relativist epistemology.* Epistemological relativism is anathema to realist scientific understanding (Musgrave, 1998). Relativism is often the result of ontological skepticism (Grayling, 1995; Nola, 2003). For example, the statement by constructivists

Nystedt and Magnusson (1982) that “the environment can never be directly known” is an example of ontological skepticism (p. 34). By denying all correspondence theories of reality, constructivists turn away from considerations of how well their ideas correspond to reality (Matthews, 2000a; McCarty & Schwandt, 2000). Constructivists are left to attend only to their experiences which stand in for reality. Ultimately, many constructivists conclude therefore that “the forms and content of knowledge are constructed by the one who experiences” reality (Nystedt & Magnusson, 1982, p. 34). Adult educator and constructivist Philip Candy (1991) captures the relativism of constructivism when he writes that one corollary of the individual construction of reality “is that because no two people have had identical experiences, each person constructs a more-or-less idiosyncratic explanatory system: a unique map of the topography that we call reality” (pp. 251-252). In other words, knowledge is not objective, but subjective. Candy states that “Knowledge does not exist outside of individual knowers; it is not a thing apart . . .” (p. 38). Candy leans toward relativism, because he believes that it is a recent trend of science.

It seems ironic that, just at the time that research in education has been striving to render itself more “scientific” (meaning more concerned with invariant laws and objective data), research in science has become more concerned with the relativity of knowledge. (Candy, 1991, p. 253)

Candy believes that the reason for the rise in self-directed approaches to learning is that “in the broadest sense [it] seems to have captured the spirit of the times—that is, to embody a number of contemporary issues that have flowed together. These include the . .

. subjective or relativistic epistemology” (pp. 46-47). Notwithstanding Candy’s claim, however, realism strongly opposes relativism (Musgrave, 1998).

### *Constructivist Methodologies Oppose Scientific Understanding*

*Methodological inductionism.* Many currently popular learning approaches stem from pragmatism. At the same time, many of these learning approaches suffer because they employ an outdated scientific methodology promulgated by Dewey early on in his career (Prawat, 2000). Dewey, “[w]ith justification, is viewed as a staunch advocate of what has been variously termed an activity-based, problem-centered, or hands-on approach to education” (Prawat, 2000, p. 805). Prawat (2000) contends that many of these approaches to learning assume the logic of induction, because at one time Dewey believed that induction represented the scientific method. In fact, Dewey (1898/1972) writes, “After the conquests of the inductive method in all spheres of scientific inquiry, we are not called upon to defend its claims in education” (p. 545).

A defense of induction as the primary method underpinning activity-based, problem-centered, and hands-on approaches to learning hinges on whether Dewey was correct in his assertion that induction represented the then current scientific method. It seems, however, that Dewey had erred. Induction was not the logic which underpinned the scientific method as Dewey had presumed. In fact, science had abandoned the logic of induction some 40-100 years prior to Dewey’s claim. Science abandoned the logic of induction sometime between 1800 and 1860, according to philosopher Larry Laudan (1998b). In short, when Dewey promulgated inductionist activity-based, problem-

centered, and hands-on approaches to learning, it was based on a mistaken notion of the logic of scientific methodology at the time. Prawat argues that Dewey was eventually influenced by Peirce to abandon his inductionist views of scientific methodology.

Notwithstanding Dewey's eventual about face on the matter of induction, Prawat argues that education, vis-à-vis its popular inquiry approaches to learning, seems not to have noticed. That is, many of the inductive approaches to learning that were initially championed by Dewey are still employed today under his name as though he would approve.

What is the logic of induction that science had abandoned long before its adoption by Dewey for education? Induction is the idea that concepts, including scientific theories, arise when subjects make generalizations based on the particulars of their experiences. In a discussion of induction, philosopher Max Charlesworth (1982) explains that induction, even if it is a valid form of inference, will only yield generalisations of the type “all metals expand when heated” or “in all gasses volume varies inversely with pressure.” Induction will never yield those higher generalisations we call scientific *theories*, such as the theory that matter has an atomic structure or the theory that energy can be transformed but never destroyed. (Charlesworth, 1982, p. 18, original italics)

Rather than surveying the environment in hopes of discerning some pattern in its particulars, scientists approach inquiry from the opposite direction, with an idea already in mind. “A moment's reflection reveals that data collection in the absence of a

hypothesis has little or no scientific value” (Schick & Vaughn, 1995, p. 191). Carl

Hempel notes:

In sum, the maxim that data should be gathered without guidance by antecedent hypotheses about the connections among the facts under study is self-defeating, and certainly not followed in scientific inquiry. On the contrary, tentative hypotheses are needed to give direction to scientific investigation. (Hempel, 1966, p. 13)

Some adult learning theories are based on the logic of induction for generating scientific knowledge. Kolb’s (1984, p. 30) experiential learning model in which learning is said to begin with a concrete learning experience, after which learners “must be able to create concepts that integrate their observations into logically sound theories,” is based on the logic of induction. Additionally, Candy (1991) urges the adoption of autodidactic learning models, some of which are based on the logic of induction. In one example, cited by Candy (1991), a lone individual is said to be able to abstract knowledge from the environment by interacting with the environment, employing inductive logic for generating scientific knowledge about pendulums.

[The learner] is not one to whom things merely happen; he is the one who, by his own volition, causes things to happen. Learning is seen as the result of his own self-initiated interaction with the world: the [learner’s] understanding grows during a constant interplay between something outside himself—the general environment, a pendulum. . .—and something inside himself, his concept-forming mechanism, his mind . . . (Rathbone, 1971, p. 100)

Rathbone concludes, “In a very fundamental way, each [subject] is his own agent—a self-reliant independent, self-actualising individual who is capable on his own of forming concepts and of learning” (p. 104). That an independent learner is capable on his or her own of forming concepts by interacting with a pendulum is quintessentially inductive. This view of concept formation is consistent with von Glasersfeld’s radical constructivism. “Knowledge is the result of an individual subject’s constructive activity, not a commodity that somehow resides outside the knower and can be conveyed or instilled by diligent perception or linguistic communication” (von Glasersfeld, 1990, p. 37).

Scientific knowledge, however, is not derived inductively. Matthews (1994) rejects the idea that an individual working in isolation can learn the laws of pendulum motion proceeding inductively. Matthews contends that the language and concepts required for hypothesis development cannot be learned independently of social interaction and participation in language communities as many constructivists suppose. Further, Matthews denies both that scientific concepts can be formed by abstraction from particulars and that the scientific method is inductive. In sum, “Galileo’s discovery of the laws of pendulum motion have illustrated the deficiency of all the foregoing claims” (Matthews, 1994, p. 147).

*Methodological instrumentalism.* One way of framing the longstanding debates between realists and empiricists is to approach empiricism from the side of instrumentalism. Instrumentalism is consonant with many empiricist (including constructivist), but not realist, positions. Hence, instrumentalism is often referred to by

philosophers of science as *antirealism* (Curd & Cover, 1998). “Instrumentalism is the doctrine that theories are merely instruments, tools for the prediction and convenient summary of data” (Curd & Cover, 1998, p. 1300). In other words, scientific theories do not refer to unobservable entities and processes. Moreover, the unobservable entities posited by scientific theories do not exist. Realists, on the other hand, object to instrumentalist accounts of unobservable entities and processes. The instrumentalist aspect of many empiricist positions is discussed by Matthews.

There are many ways of posing the realist/empiricist distinction. The fundamental distinction is that empiricists wish to confine the claims of science to what we can experience, saying that any claims that go beyond experience have to be treated only as aids, tools, models or heuristic devices for coordinating sensory or observable phenomena. For empiricists, the theoretical, as distinct from observational, terms of a theory do not refer, and are not meant to refer to the existing entities. (Matthews, 1994, p. 164)

Hence, instrumentalists treat scientific theories, not as referring to the entities which they posit, but as aids to order observable phenomena. The instrumentalist view of scientific theorizing is consonant with the empiricist claim that knowledge is based in experience. “Empiricism is the doctrine that knowledge is confined to the world of experience or phenomena, and that the aim of science is to produce theories that predict phenomena and connect economically—usually mathematically—items of experience” (Matthews, 1994, p. 163). On the other hand, realists

believe that the point of science is to postulate theoretical entities and to test the accuracy of these postulates. Realists are not so naive as to believe that all of what science postulates at any one time is accurate, but they do believe that science strives to uncover the hidden nature of reality. (Matthews, 1994, p. 164)

Instrumentalism is important to the present discussion, because pragmatists—Dewey and Mead—are instrumentalists, as are both Candy and von Glasersfeld.

Consistent with their instrumentalism, Dewey and Mead both adopt an agnostic, or skeptical, view of the unobservable entities of science posited by scientific theories (Bredo, 2000). For example, Mead (1938) does not believe that a real entity stands behind the scientific concept of cellulose. Cellulose is merely a convenient way of describing woody things whose woodiness is fully reducible to experience. This corresponds to Mead's anti-realist metaphysics which refuses to account for the invisible objects of science. According to Mead, scientific objects are not regarded on their own terms as real, existing entities. Instead, scientific objects must be thought of only in terms of useful aids for guiding human activity directed at solving some practical problem. In the pragmatist tradition, an object's objectivity and meaning are fully reducible to efficacious problem-solving activity based in experience. This view is often referred to as the pragmatic criterion of meaning and closely resembles positivism's verificationism (Phillips, 2004).

*Summary of Philosophical Considerations of Constructivism for Adult Science Education*

Constructivism is an important learning orientation in adult education. It encompasses a number of approaches, including experiential and self-directed learning

(Merriam & Caffarella, 1999). Some of the constructivist-inspired learning models found in adult education, such as Kolb's (1984) experiential learning model, and Candy's (1991) autodidactic learning model, are reminiscent of philosophical empiricism, because they place experience at the very center of knowledge claims. Kolb's learning model derives in part from pragmatism (after the influence of Dewey), while Candy's model derives in part from British empiricism (after the influence of the radical constructivist Ernst von Glasersfeld). The learning methods promulgated by both of these learning models deviate from a modern understanding of science, because students are said to construct theories inductively by abstracting them from the particulars of concrete experiences before justifying them experientially. The presumption on the part of constructivists is that, because scientists create knowledge in this empiricist manner, students should be able to create scientific theories this way as well (Osborne, 1996). However, this manner of scientific knowledge creation assumes that scientific theories are generated and verified in this manner. This is not the case, however. Constructivism has thus become a vehicle for resurrecting and then substituting outdated philosophies of science for current realist understanding (Matthews, 1994).

Some constructivists encourage educators to look to George Herbert Mead for guidance (Bentley, 1998; Bredo, 2000; Garrison, 1998). For Bentley (1998), "constructivism has become a major philosophical referent for the reform of science education. . . an umbrella term covering diverse interpretations" (p. 237). In making Mead's constructivism a referent for the reform of science education, the adoption of certain metaphysical and epistemological positions are advocated. Thus, for Bentley,

constructivism is not just a view of learning, just as Mead's doctrine is not just a learning theory. Constructivism purports to tell us how scientific knowledge is constructed. Bredo (2000) describes the metaphysical and epistemological positions of Mead's philosophy, noting their departure from realism. For example, Mead's pragmatism dissolves the metaphysical object of realism and disavows all correspondence theories of knowledge (Bredo, 2000).

The claim by proponents of Mead's doctrine that "constructivism has become a major philosophical referent for the reform of science education" (Bentley, 1998, p. 237), should be taken seriously. In this Chapter, I have endeavored to outline key philosophical issues involving constructivist-inspired learning theory. Additionally, I have attempted to show how key elements of constructivist philosophy inherent in some adult learning theories oppose current scientific understanding. In the next Chapter, I shall endeavor to show that, contrary to Bentley's assertion, Mead's pragmatism is not a viable "philosophical referent for the reform of science education." It is my intent to show in the next Chapter that pragmatism was as out of step with the science of its day as pragmatist constructivism is out of step with the science of our day and what this means for science education.

## CHAPTER FOUR

### Pragmatist Constructivism and its Viability in Science Education

#### *Introduction*

In this Chapter, I shall seek to determine whether the use of Mead's pragmatist constructivism might guide adult learners to scientific understanding. For the purposes of this study, scientific understanding is used in a broad sense. It includes: (a) scientific concept acquisition, (b) learning the methods of science and how they are employed in the proper settings, and (c) preparing students for careers in science and science-related fields, but also for science literacy. There will be a section in this Chapter devoted to each of these three themes.

#### *Scientific Concept Acquisition*

##### *Introduction*

Conceptual understanding is obviously important to science education. Constructivists and realists differ, however, not only on how scientific concepts are acquired but on what constitutes valid scientific knowledge. In Chapter Three it was noted that constructivist-inspired experiential learning models are the embodiment of scientific methodologies. I shall argue in this Chapter that Mead's scientific method—which doubles as a learning model—determines not only the manner in which scientific concepts must be acquired but also what constitutes valid scientific knowledge.

Many of the empiricist themes addressed in the preceding Chapter resurface here in consideration of Mead's pragmatist constructivism. It is useful to review these themes as well as determine on what side of the realist-empiricist divide Mead sought to locate himself. While Mead's pragmatist philosophy was certainly unique, it fits squarely within the empiricist camp.

### *Empiricist Themes in Mead's Philosophy*

*Mead's metaphysics.* Mead opposed metaphysical realism (Bredo, 2000). "In fact, a careful reading of his Carus Lectures—the first four chapters of *The Philosophy of the Present* [1932]—reveals that they are nothing but a polemic against a metaphysical interpretation of modern science" (Burke, 1992, p. 35). In addition to the Carus Lectures, Mead explicated much of his empiricism as it relates specifically to the natural sciences in *The Philosophy of the Act* (1938). Mead's antirealist metaphysics manifests itself several ways.

For example, contrary to metaphysical realism, Mead did not believe in a mind-independent, preexistent reality. Mead (1938) writes that

. . . current scientific views of the world do assume physical objects, which are stated in terms of mass and energy occupying space and possessing inertia . . . but which are conceived of as entirely independent of perceiving individuals. . . . I have called this current and perhaps I should add, popular scientific view of the world, "uncritical." (Mead, 1938, pp. 284-285)

Reality, for Mead (1938), was not something given to be discovered. Rather, humans are

seen as co-creators of reality as they problem-solve in meeting their bio-social needs. Prior to organismic interaction with an object, such as an apple, the object does not have meaning in any traditional sense, either everyday or scientific. Rather, “an object’s definition and meaning” are “dependent on how it is used” by the organism (Bredo, 2000, p. 144). Not only is an object’s “meaning” usage-dependent, but an object’s objectivity is also usage dependent. In other words, what most people would call an object—such as an apple sitting on the table—does not really fall into any such ready-made concept of an apple. Under Mead’s doctrine, we do not think of an object in itself but how it is used to solve a practical problem. Mead’s doctrine rejects the idea that the apple is an object with the meaning of apple, unless it is used in such a way that it is subsequently determined to be an apple-object. It may turn out, however, that the object which most people take to be an apple will not be an apple-object. Instead, it may be a projectile, if it is used instrumentally in this way. Thus, there are no antecedently agreed-upon meanings for objects, according to Mead. In explicating this aspect of Mead’s doctrine, Bredo (2000) uses various synonyms for object—“things” and “existences”—in an attempt to convey Mead’s position that “objects” and their meanings do not exist prior to their being used instrumentally in satisfying bio-social needs. Bredo explains what an object is as follows:

What it “is” for an organism depends on what is done with it. This is not to say that nothing exists prior to action, only that such unknown “things” or “existences” are not objects. Making an object’s definition and meaning (its consequences when acted upon) dependent on how it is used may seem to make it unsubstantial or unreal . . . (Bredo, 2000, p. 144)

Thus, one of the consequences of Mead's act is that scientists are held hostage to doing, that is, instrumental activity. Mead's interactional approach gives "priority to *doing* rather than *knowing*" (Bredo, 2000, p. 141, original italics). Because Mead does not recognize either objects or their meanings prior to problem-solving instrumental activity, scientific objects and their meanings as normally conceived by scientists cannot enter into Mead's act. Instead, objects and their meanings arise only concomitantly with problem-solving activity, because Mead has arbitrarily mandated—solely for the sake of the act—that an "object's definition and meaning (its consequences when acted upon)" are "dependent on how it is used" (Bredo, 2000, p. 144).

Mead's atheoretical view of scientific objects and how their meaning arises stands in sharp contrast to contemporary views of science. Scientists believe that the objects of their inquiry exist prior to activity and that their meaning has already been determined by the work of earlier scientists and pre-existing theoretical systems, not by satisfying an organism's bio-social needs (Murphy, 1939). The last stage of Mead's act, the satisfying of an organism's bio-social needs, which is a necessary requirement for an object's meaning and objectivity, is referred to as "consummation" (de Waal, 2002; Mead, 1938; Murphy, 1939). Consummation "is satisfaction and, if you like, happiness" (Mead, 1938, p. 136).

Additionally, Mead's (1938) metaphysics does not allow for the existence of invisible entities posited by scientific theories. This is because "scientific objects are also to be understood functionally rather than metaphysically" (Bredo, 2000, p. 149). Thus, when it encounters the unobservable objects reported by science, Mead's doctrine must

completely reconceptualize them in a manner that does away with, or “dissolves,” these objects (Bredo, 2000, p. 144). Mead’s “approach dissolves the traditional metaphysical object, the object that is assumed to be given prior to activity, and makes both boundaries and properties dependent upon activity” (Bredo, 2000, p. 144). Mead (1938) did not accept the mind-independent existence of such things as cellulose or the malarial parasite discovered by science. Rather, Mead (1938) thought of these things as nothing more than principles of organization which aided problem solving (p. 250). Mead’s principles of organization, such as the concept of cellulose, are merely convenient ways of thinking about and grouping things that are comprised of wood. Mead (1938) was adamant that there was no ontic entity in back of the various instantiations of woody things to which the term “cellulose” refers (pp. 249-251).

The educational implication of Mead’s metaphysics deserves explication. When Mead methodically “dissolves” the unobservable objects discovered by science, he is inviting students of science to become metaphysical agnostics and thus oppose the metaphysical beliefs held by scientists generally. But there is also a question—taken up in the second section of this Chapter—as to whether Mead’s doctrine successfully makes the objects of science “reappear.” In other words, can Mead’s doctrine give an adequate account of traditional scientific concepts by indicating how they arise? For example, can Mead’s scientific method account for concepts, like the Newtonian concepts of mass and inertia, or cellulose, and the malarial parasite?

In arriving at his philosophy of the act, Mead (1938) claims to have borrowed ideas from a notable contemporary, Albert Einstein. But it is important to distinguish the

metaphysics of Mead from that of the eminent scientist. This is because Mead is said to have adopted a “questionable interpretation of Einstein’s theories of relativity” (Burke, 1992, p. 34).

Einstein’s metaphysics do not coincide with Mead’s metaphysics. Einstein believed in an ordered, preexistent, mind-independent reality and that scientific theories are capable of describing such a reality. Mead believed in none of these things. Einstein (1930/1954) noted, “The belief in an external world independent of the perceiving subject is the basis of all natural science” (p. 266). Furthermore, Einstein (1918/1954) believed that the mind-independent world possesses a “pre-established harmony” (p. 226). Moreover, Einstein believed “that it is possible to grasp the reality with our theoretical constructions . . .” (Einstein & Infeld, 1938/1966, p. 296). In fact, according to Einstein, “the only justification for our mental structures is whether and in what way our theories form such a link” (Einstein & Infeld, 1938/1966, p. 294). It is important to note that Mead did not share any of these metaphysical views. Unlike Einstein, because Mead did not believe in the existence of unobservables, he did not believe that scientific theories ultimately pertain to such entities.

*Mead’s epistemology.* Although it was a unique doctrine in many ways, Mead’s (1932, 1938) philosophy of science fits squarely in the empiricist camp. By the turn of the 20<sup>th</sup> century, all of the natural sciences had adopted the concept of the scientific object (Laudan, 1998b, p. 151). This did not mean that everyone committed to their existence. Empiricists routinely spoke of scientific objects—electrons, atoms, and molecules—without committing to their existence. Thus, when realists and empiricists

spoke of scientific theories, which posited the existence of scientific objects, they usually meant two entirely different things. Stathis Psillos (1999) provides a historical synopsis of the basic differences between realists and empiricists regarding the question of how to interpret the theoretical discourse of the two camps:

There are two broad theoretical traditions—an empiricist and a realist tradition—each with an answer to this question. Broadly speaking, the empiricist tradition aims to show that theoretical discourse may be so constructed that it does not commit to the existence of unobservable entities. The realist tradition, on the other hand, aims to show that a full and just explication of theoretical discourse in science requires commitment to the existence of unobservable entities. (Psillos, 1999, p. 3)

Mead's (1938) answer to the question of unobservable entities was that they did not exist. However, the very notion of unobservable entities created a dilemma for empiricists. Empiricists were forced to account for scientific discourse, which routinely posited hypothetical entities, while simultaneously maintaining that no such entities existed. As an instrumentalist, Mead (1938) maintained that the unobservable entities posited by scientific theories were nothing more than "principles of organization" which aided problem solving (p. 250). As an empiricist, Mead attempted to account for the unobservable entities of science by reducing them to the observable objects of experience. At one point, Mead (1938) characterized his own empiricism by writing, "seeing is believing" (p. 32). If the unobservable entities of science could be reduced to, that is, stated fully in terms of observable objects, then the unobservable entities could be

dismissed. Hence, there was no reason to believe in their existence. This was the strategy of reductive empiricism (Psillos, 1999).

Thus, although Mead's pragmatist doctrine was unqualifiedly unique, it is important to appreciate its thoroughgoing empiricism. In fact, Mead (1938) employed several empiricist methods common to his day for reducing theoretical talk into the observable objects of experience. What was unique about Mead's anti-realist doctrine was not that he attempted to reduce so-called theoretical knowledge to the observables of everyday experience. What was unique was the manner in which theoretical knowledge was reduced to experience. Mead's doctrine, known as "the act," claimed that knowledge arose from the instrumental use of objects during problem-solving *activity* as an organism attended to its bio-social needs. Mead made "an object's definition and meaning (its consequences when acted upon) dependent on how it is used" (Bredo, 2000, p. 144). The problem with this epistemological position is that it flies in the face of both scientific and common-sense understandings of objects and how they are defined. Mead's epistemology does not even begin to address the theoretical nature of science, that is, how scientists conceive of causal mechanisms involving unobservable objects and how these theoretical ideas might be tested. In fact, Mead seeks to sidestep theoretical understanding completely. When scientists cogitate and plan experimental protocols hopefully designed to ascertain the causal effect of one variable on another, such intellectual activity involves and is dependent upon a vast network of prior theoretical understanding. In other words, in traditional science, the objective meaning of oxygen, for example, can be taken as given prior to its use in inquiry or for any use to which it might be put. This is not the

case, however, with Mead's science. Mead's science cannot accommodate antecedent knowledge, particularly antecedent theoretical knowledge. Nor can Mead's science, based on the act, accommodate preexisting objects of any sort, whether they be subatomic particles or falling apples. Objects are not objects (nor do they have meanings) before they enter the act (Bredo, 2000). Moreover, what we know—and all that we can know—of Einstein's physics, for example, must be stated in terms of meeting an organism's bio-social needs, if Mead's act is to work (Murphy, 1939).

*Mead's Alternative Reading of the Scientific Revolution and Newtonian Concepts*

In what can certainly be considered an ambitious goal, Mead sought to provide a better account of Renaissance science than the one offered by Newton and his followers (Miller, 1973). Mead sought to recast the mind-independent scientific objects of the scientific revolution in empiricist terms. While Renaissance science introduced idealization, including model building which involved theoretical objects and theoretical systems, Mead sought to recast such mind-independent objects, anchoring them in experience. Mead's goal was to “offer an adequate account of how we become aware or conscious of, or how we arrive at the concept of, the physical object” (Miller, 1973, p. 104). Miller (1973) writes that, although Mead thought that “Newton and his followers had the correct conception of the physical thing, they did not offer an adequate account of how through *experience* we arrive at the conception” (p. 104, italics added).

Miller's statement is revealing in that it indicates the huge divide between Mead's empiricism, on the one hand, and the scientific revolution, on the other. Mead's goal is to

offer a completely new interpretation of the scientific revolution from a unique empiricist perspective. In fact, one of the chapters in Mead's (1938) *The Philosophy of the Act* is entitled "Experiential Basis of Natural Sciences." However, one of the lessons of the scientific revolution is that scientific knowledge is not based in experience.

Before turning to Mead's doctrine as an alternative account of the scientific revolution, it is important to understand the significance of the scientific revolution. Lombardi (1999) refers to the "epistemological rupture," resulting from the scientific revolution.

Only a naive epistemological perspective permits us to ignore the role that idealization plays in physics since Galileo: the semantical reference of physical theories is not constituted by the objects perceived by direct perception, but by ideal objects which, in their reciprocal links, form the so-called "physical models." (Lombardi, 1999, p. 222)

Mead's disenchantment with science is purely metaphysical. Mead is simply not a realist. Mead (1938) writes that "current scientific views of the world" in which "physical objects . . . are stated in terms of mass and energy occupying space and possessing inertia . . . but which are conceived of as entirely independent of perceiving individuals. . . . I have called . . . 'uncritical'" (pp. 284-285). Contrary to the science of Galileo and Newton, Mead seeks to secure knowledge by placing it firmly in observational and tactile experience.

In arguing that Newtonian concepts are ultimately derivable from experience, Mead begins by stating: "It was the particular advantage of Newtonian mechanics that the

fundamental concept of mass was so closely correlated with the weight and volume of contact experience” (Mead, 1932, p. 37). On the one hand, Mead’s statement is entirely true. Based, however, on his commitment to provide a pragmatist account of Renaissance science, Mead is implying that the concept of mass is derivable from experience. Earlier, for example, Mead (1982) had claimed more generally that “[r]eality reduces to possible contact experiences” (p. 118). But this is hardly the case.

Before Newton’s time, mass and weight were considered one and the same thing. The question—raised by Mead—is whether the concept of mass is derivable from experience. Michael Matthews (2000c) provides a brief historical backdrop of the concepts of weight and mass:

Jean Richer’s . . . 1671 Cayenne voyage for the first time made the relationship of mass and weight problematic. When his Paris seconds pendulum clock lost about 2½ minutes per day at Cayenne, Huygens, Newton, and others realized that a fundamental conceptual problem had been unearthed. (Matthews, 2000c, p. 194)

Thus, although Mead is certainly correct in asserting that mass and weight are correlated, his assertion that mass can be easily abstracted experientially from weight is not true. Matthews (2000c) alludes to the inherent problem of conceptualizing mass when he notes “Newton used the pendulum to flesh out the troublesome concept of ‘mass,’ and its relation to ‘matter’ and ‘weight’” (pp. 193-194).

In addition to the concept of mass, Mead (1932) held that other Newtonian concepts were derivable from contact experience. Mead (1932) writes that “it has always been easy for us to imagine this subdivision of perceptual objects into mass particles, and

to translate inertia, force, and momentum into the effort of which contact experience calls out . . .” (p. 37). In other words, the fundamental concepts of Newtonian physics, according to Mead, can be abstracted easily from experience. One proponent of Mead’s doctrine provides a nice summary of this claim. “Traditional Newtonian properties like extension, mass, and inertia are directly *reflected* to the organism when an object is acted upon” (Bredo, 2000, p. 144, original italics).

Although the claim that Newtonian properties can be abstracted from experience would surely promote Mead’s doctrine, there is no historical scientific support for such a claim. In fact, the history of mechanics directly refutes such a claim. Einstein (1934/1954) stated that “every attempt at a logical deduction of the basic concepts and postulates of mechanics from elementary experience is doomed to failure” (p. 274). In fact, the “fundamental concepts . . . of physics [cannot] be deduced from experience by ‘abstraction’” (p. 273). Thus, contrary to Mead’s (1932, p. 37) assertion, Newtonian properties do not arise as a matter of abstraction from “contact experience.” Matthews (2000c) writes that “Classical mechanics is not only not verified in experience, but its direct verification is fundamentally impossible” (p. 252). The historian E. J. Dijksterhuis (1986) makes the same point another way by describing an aspect of idealization involved in the science of mechanics, when he notes that

one cannot indeed introduce a material point all by itself into an infinite void and then cause a force that is constant in direction and magnitude to act on it; it is not even possible to attach any rational meaning to this formulation. (Dijksterhuis, 1986, p. 30)

One of the Newtonian concepts that both Mead (1932) and Bredo (2000) allege can be abstracted from experience is “inertia.” Fermi and Bernardini (1961) argue that this is not the case. They report that the law of inertia “required a great insight” which was hidden from experience.

In formulating the “Law of Inertia” the abstraction consisted of imagining the motion of a body on which no force was acting and which . . . would be free of any sort of friction. This abstraction was not easy, because it was friction itself that for thousands of years had kept hidden the simplicity and validity of the laws of motion. In other words, friction is an essential element in all human experience: our intuition is dominated by friction. . . . To see the essence of motion beyond the complications of friction indeed required a great insight. (Fermi & Bernardini, 1961, p. 116)

The realization that Newtonian concepts cannot be derived from everyday experience is placed in an educational context by Matthews (2000a) who writes that

People do not build up meanings from sensory inputs: they learn meanings and they may learn them more or less accurately and well. We push against an object and receive various sense inputs. None of this converts to ideas of pressure, elasticity, force, stress, or strain—until we learn the words and how they are defined. (Matthews, 2000a, p. 171)

At this point it is helpful to summarize Mead’s position vis-à-vis the scientific revolution and what it means for science education. Mead’s claim that his doctrine can provide an alternative account of concept acquisition, different from that of the scientific

revolution, is unsupported. In short, Newtonian concepts are neither derivable from nor confirmable by personal experience. If one assumes that Einstein is correct in his understanding of the history and philosophy of the science of mechanics, this presents a serious difficulty for gaining theoretical understanding for science education.

Constructivists hold that theoretical concepts can be abstracted from personal experience and, moreover, that they can be confirmed by experience. To varying degrees, some constructivists also hold that scientific ideas cannot or ought not be communicated (Candy, 1991; Fosnot, 1996a; von Glasersfeld, 1995a, 1995b). However, if it is true that scientific concepts cannot be derived from personal experience and that scientific concepts cannot or should not be communicated, then adult learners are indeed in dire straits.

Allowing Mead the benefit of the doubt against his contemporary Einstein, which is the implied assumption of pragmatist constructivism, the following discussions explore the possibility of Mead's constructivist science providing an adequate account of traditional scientific concepts. The two concepts that I shall explore vis-à-vis Mead's science are cellulose and food. The question that I shall attempt to answer is whether Mead's science is able to communicate to us a conceptual understanding of cellulose and food, which Mead claims is derivable as a result of problem solving in meeting each student's bio-social needs.

### *The Scientific Concept of Cellulose*

The concept of cellulose is described completely differently according to contemporary science, on the one hand, and Mead's doctrine, on the other. The concept of cellulose poses a dilemma for Mead's doctrine. Although Mead asserts that the concept of cellulose can be extracted from experience, at the same time he maintains that cellulose is not a real entity. Mead's description of cellulose provides a vignette of his philosophy of science. Two versions of cellulose—that of traditional science and that of Mead's science—are explored.

Cellulose—as described in a popular introductory college biology text book by Campbell, Reece, and Mitchell (1999)—is a major constituent of plant cell walls, and it is the most abundant organic compound on earth (p. 63). Cellulose is a polymer of glucose, which means that it is composed of many glucose molecules linked together. Cellulose is a straight-chain polymer. In plant cells, these straight chains not only lie alongside each other but the regularly occurring hydroxyl groups of one chain tend to form hydrogen bonds with the hydroxyl groups of adjacent, parallel strands thus forming *microfibrils* (p. 63). These microfibrils or “cables are a strong building material for plants—as well as for humans, who use wood, which is rich in cellulose, for lumber” (p. 63).

Several things should be noted from this depiction of cellulose. First, cellulose is recognized as a mind-independent, molecular entity. Second, reference is made to cellulose's specific chemical bonding patterns both in terms of its constituent subunits and cross-molecular formation of cable-like microfibrils. In addition to these molecular and chemical reactivity references, it is noted that cellulose “is a major constituent of

plant cell walls” and that because of its special bonding patterns, cellulose makes wood “a strong building material for plants” and “humans.”

On the other hand, when Mead describes cellulose, he does not do so in realist terms. For purposes of comparison, we can set aside differences of science’s understanding of cellulose in Mead’s day as compared to today, because this is not the issue. The issue is more fundamental. Mead neither recognizes nor treats cellulose on its own terms as a real physical entity that exists apart from the mind or organismic activity. In short, Mead’s scientific version of cellulose is not the cellulose of contemporary chemists or biologists. Rather, cellulose, for Mead (1982) must be reducible “to possible contact experiences” (p. 118). Thus, whereas the above description by Campbell, Reece, and Mitchell (1999) depicts cellulose on its own terms—in which the biologists mention, almost as an afterthought, that cellulose is found in wood—Mead, on the other hand, must make wood the central issue so that cellulose can be reduced to woody objects for the sake of the act. Not only will cellulose and wood become synonymous in Mead’s act, but cellulose will become a vacuous ontic concept. Mead (1938) does this by dissolving the metaphysical object—the cellulose molecule of science—and recasting it as a useful “principle of organization” (p. 250). Specifically, Mead states that cellulose is “not so much a thing” as it is “a principle of organization from which a number of different objects may be deduced” (p. 250). But even in reference to the number of different objects to which the organizing principle, cellulose, refers, there is no object in back of each of these many references. Mead (1938) states that “there is no such world that is there back of the objects in the different sets, or situations” (p. 251). Thus, the organizing

principle—cellulose—has no ontic standing. On the other hand, chemists tell us that cellulose exists and that they have much theoretical and empirical evidence for its existence.

This is a wonderful example of Mead's reducing the unobservable objects of contemporary science to tangible, or sensible, objects. In true empiricist fashion, cellulose is not accepted on its own terms as a legitimate ontic entity but is reduced to woody objects. "Both the food of the termite and the physical and chemical structure of the stuff are referred to the stick of timber that is there," writes Mead (1938, pp. 250-251). Henceforward, to know wood is to know cellulose, and to know cellulose is to know wood. The conflation of "cellulose" and "wood" is intentional, because it allows reductive empiricists, like Mead, to subordinate theory along with the unobservable theoretical entity that is posited by scientific theories. Once theoretical entities have been stated in terms of observable objects by Mead, they are henceforward superfluous "principles of organization."

However, there are some problems here. Contrary to Mead's science, wood and cellulose are in no way synonymous. Wood is comprised of many other chemical compounds besides cellulose. Further, non-woody things, such as herbaceous plants and fungi, contain cellulose. Moreover, cotton contains almost twice the percentage of cellulose of most trees, yet cotton is not considered woody! And although cellulose is indigestible to humans, it forms the very important part of our diet known either as roughage or fiber. If cellulose were not considered by science as an entity in its own right, none of these examples would make much sense, because cellulose is not reducible to

wood. Furthermore, none of these things can be learned by being shown wood with which we subsequently interact in our own personal way.

Educationally, the problem Mead's empiricism poses is that the chemistry of cellulose cannot be learned by interacting with woody objects, that is, by abstraction or induction. A chemical understanding of cellulose neither derives from nor reduces to experience. Students cannot learn "the chemical structure of the stuff" scientists call cellulose by being "referred to the stick of timber that is there," as Mead suggests. Nor does one need to know anything about cellulose in order to know that wooden objects are constituted of wood. Mead's science does not account for either of these distinctions, the first of which has to do with scientific thought, the second with common sense understanding. Mead's science fails to distinguish not only between the objects of contemporary science, on the one hand, and the objects of experience, on the other; but how the two relate to each other. Specifically, Mead's doctrine does not provide students of science a mechanism for either acquiring the concept of cellulose or understanding it as it is understood by scientists.

### *The Scientific Concept of Food*

In this section, I shall show that the concept of food poses several challenges for Mead's (1938) doctrine. According to Mead's act, the entirety of what we can know about an object can be stated in terms of satisfying a bio-social need during efficacious problem-solving activity at a particular point in time. An object is not an object prior to the act. And only during the act is an object's meaning determined. An object's

objectivity and meaning arise together at a particular moment in time as the solution to a particular problem. Because an object's objectivity and meaning are restricted to the act, both are relative to the act. Once consummation is achieved, the object and its meaning are no more. Consequently, there is no such thing as antecedent knowledge. An object's objectivity and meaning change according to each problem. When an organism confronts a new problem, old objects take on new meanings (Bredo, 2000). Stated in this manner, Mead's act defies both common sense and scientific understanding of objects and their meanings. This is because objects are not objects unless and until they are used instrumentally to solve a problem as adjudicated by an organism's bio-social needs. This raises two sorts of problems for the act, both of which are related—one involves antecedent knowledge and one involves scientific knowledge. Science relies on antecedent theoretical knowledge which cannot be reduced to the bio-social needs of organisms.

Something as simple as a person checking to see whether there is an apple in her pocket to eat later when she is hungry, is something that Mead's doctrine cannot accommodate. For the alleged apple in this case is not an "object," much less a food object, according to Mead, unless and until it is used to satisfy someone's hunger. The act completely ignores the fact that scientists and non-scientists alike approach objects and use them based on previous knowledge. When farmers plant seeds for a later food harvest, and when people shop for food they do so with definite preconceived ideas and expectations which neither arise from nor are dependent upon immediate consummatory behavior. Therefore, the first problem with Mead's act is that it cannot account for

antecedent knowledge. Instead, because Mead assumes that hypotheses are generated as the direct result of problem solving *during* inquiry, the act necessarily relies on abstraction and induction. But scientific theories cannot be abstracted or induced as generalizations based on the particulars of the environment (Charlesworth, 1982). Scientists do not begin inquiry without some guiding principle already in mind. Scientific inquiry is not atheoretical as is suggested by pragmatism (Scheffler, 1974).

Antecedent knowledge is extremely important to science as indicated by the cold-fusion fiasco. When two University of Utah scientists—Pons and Fleischmann—reported to the world press that they had observed cold fusion in March 1989, physicists largely ignored the report which bypassed the normal review process, because what was “described would violate widely accepted principles of nuclear physics” (Curd & Cover, 1998, p. 469). Scientists’ suspicions were confirmed. Once “rigorous controls were instituted” and the experiments were repeated, “the effects disappeared” (Curd & Cover, 1998, p. 469). Antecedent theory indicated what the proper controls should be. Mead’s act cannot account for the fact that scientists rely heavily on antecedent theory for guiding inquiry and interpreting results, even to the point of sometimes rejecting observational results, when they do not coincide with theory, as the cold-fusion fiasco suggests. The point is that scientists rely heavily on antecedent theoretical knowledge.

The second sort of problem Mead’s act encounters is that scientific knowledge cannot be reduced to bio-sociality, which is required if the act is to work. Food is defined functionally by Mead. According to Mead’s doctrine, “For something to function as food, it has to reduce hunger; if it does so, it *really is* food” (Bredo, 2000, p. 144, original

italics). Physiological hunger reduction is the sole adjudicator as to whether a particular object is food. Given this purely utilitarian definition of objects and meanings imposed by the act, food and food concepts reduce to nothing more than a combination of an organism's perception of and physiological response to hunger. As such, Mead's doctrine cannot provide scientific conceptions of food, such as *essential nutrients*, which are not reducible in this manner. Humans are certainly not aware, unless they are told, whether or not a particular meal is nutritious.

A proponent of Mead's philosophy, Eric Bredo (2000) at the University of Virginia, describes how Mead's act reduces the concept of food to the personal feeling of satiety. Bredo attests that an object is indeterminate prior to the act and only becomes a food object as a result of the act, if the object is used in a very prescribed manner:

[Mead's] approach dissolves the traditional metaphysical object, the object that is assumed to be given prior to activity, and makes both boundaries and properties dependent upon activity. The same blob may be smeared around the table like finger-paint or put in one's mouth like food. What it "is" for the organism depends on what is done with it. . . . Mead was careful to suggest, objects are not defined unilaterally. They are effectively partners in the act and must function in the requisite way for an act to succeed. For something to function as food, it has to reduce hunger; if it does so, it *really is* food. (Bredo, 2000, p. 144, original italics)

This conception of food is not only inconsistent with common-sense understanding but it has nothing to do with scientific understanding. The problem is that for Mead to satisfy the requirements of the act to which he is bound, he must not only forfeit antecedent

knowledge but deny that objects are objects except as a result of the act. Scientists normally take antecedent knowledge of the objects of inquiry from which they form hypotheses and then conduct experiments in order to test their hypotheses. Knowledge does not arise solely from doing as the pragmatists presume (Scheffler, 1974). Knowledge also arises from theorizing, and theorizing is not entirely dependent on doing (Scheffler, 1974). Scientists conduct experiments to test the feasibility of their preformed ideas (Popper, 1934/1959). Thus, Mead's rendition of how theoretical knowledge arises deviates significantly from that of common scientific practice (Murphy, 1939).

What most people consider to be food objects would not qualify as food objects, according to Mead's act. What most people take to be an apple, for example, would not qualify as an "object" with Mead's doctrine, much less a food object, unless: (a) the organism is hungry, (b) the object is consumed, and (c) consumption results in satiety. After satiety is achieved, Mead would say, however, that the same object is no longer an "object," much less a food object, since there is no problem to solve. That is, we classify objects only as needs, and their objectivity changes as our needs change. Consequently, what most people consider to be food objects are not food objects in and of themselves. Rather, the concept of food is not only relative to but reduces to the current physiological state of an organism. However, such a conception of food is meaningless to science, since it fails to address the inherent qualities of food which allow it to be called food, such as essential nutrients. Even worse, such a functional definition includes objects which, although they may reduce hunger, are not only not food objects but objects which may pose serious health threats if consumed.

According to Mead, humans conjointly determine food objects based on successful consummatory activity (Bredo, 2000). Such a position gives the impression that a scientific understanding of food is consonant with hunger reduction as determined by the organism itself. On the other hand, a scientific understanding of food is not based on satiety. Satiety is a convenient way for instrumentalists to define food and food objects, because satiety is an observable phenomenon, and food can be reduced to observational experience. Nutritional science, however, does not address food in terms of observable phenomena. Instead, nutritionists seek to determine the underlying unobservable entities and the causal processes in which they are involved which allow something to be called food. These underlying factors include considerations of energetics and nutrition, for example. These factors also involve Mead's notion of hunger reduction but at deeper levels of understanding, such as the psychological, nervous, biochemical, and hormonal correlates of hunger and satiety. In other words, scientists seek to answer basic questions, such as What is food? and How does food work? Such questions give meaning to the comment made by one biochemist, Harold Draper, for example, who states that "there are no essential foods—only essential nutrients" (Gadsby, 2004, p. 50). These kinds of basic scientific questions simply cannot be addressed at the bio-social level as Mead suggests. While Mead is correct to suggest that much of the time food does lead to satiety, even the scientific concept of satiety is not straight forward. That is, physiologists and other scientists are not just concerned with feelings of fullness but with the underlying causal mechanisms responsible for satiety, which involve an interplay of factors: hormonal, chemical, nervous, psychological, for example. Our

scientific conception of food cannot be based on satiety for the convenience of fulfilling the requirement of Mead's theory of the act.

Moreover, Mead goes too far when he suggests that if something reduces hunger, then it is food. That Mead's (1938) science must reduce conceptual understanding to contact experience is not a virtue but a vice of the act. Food cannot be functionally defined simply as something that reduces hunger. While such a working definition of food might satisfy the act, it does not qualify even as a common sense definition of food. In fact, such a definition of food can be dangerous to one's health. There are many things that reduce hunger but which cannot be considered food.

For example, both alcohol and cocaine have been used by some, particularly women, expressly for the purpose of appetite suppression and weight control (Cochrane, Malcolm & Brewerton, 1998). Another example of an eating behavior that serves to satisfy cravings but has nothing to do with food is known as *pica*. Pica is the practice of humans consuming non-food items, such as dirt, clay, chalk, starch, cigarettes, paper, and coins, among other things. Mineral deficiency has been implicated as a reason for pica behavior, although not proven (Reilly & Henry, 2000). Even if eating dirt is a means of attempting to correct mineral deficiencies, the minerals consumed by geophagists (dirt eaters) may not be absorbed by the body (Johns & Duquette, 1991). Moreover, serious health problems may arise as a direct result of consuming non-food items. Groups with the highest rates of pica activity include young children (Calabrese, Stanek, James & Roberts, 1997), the mentally retarded (Kumar & Jazieh, 2001; Rose, Porcerelli & Neal, 2000), and pregnant women (Simpson, Mull, Longley & East, 2000). During pregnancy,

women who engage in pica experience cravings for non-food items. There may be adverse consequences for pica activity during pregnancy for both mother and fetus.

Effects on the mother could include dental injury, constipation, intestinal obstruction, dysfunctional labor due to fecal impaction, parasitic infections, toxemia, interference with the absorption of minerals, lead poisoning, and hyperkalemia. Possible effects on the fetus include prematurity, perinatal mortality, low birth rate, irritability, decreased fetal head circumference, and exposure to chemicals such as lead, pesticides, and herbicides. (Simpson, Mull, Longley, & East, 2000, p. 21)

Simpson and colleagues (2000) state that pica is practiced around the world, including the US. They note that some cultural groups are at greater risk than others. The researchers recommend that in these groups pregnant women “should be screened for pica and educated about the potentially serious effects on the fetus and mother” (p. 20). This group of public-health physicians and educators note “that pica behavior is probably underreported because the ingestion of nonfood items may be seen as either shameful or merely unimportant and ‘normal’” (p. 20).

To state, as does Bredo (2000) in reference to Mead’s doctrine, that if something which is ingested reduces hunger, then “it *really is* food” (p. 144, original italics)—is overly simplistic. Mead’s act dismisses science’s attempt to determine why some substances are food—the role they play in terms of energy, molecular and cellular building blocks, and good health. Both the causes of hunger and hunger reduction are extremely complex issues that are not fully understood, even by science. Hunger and

satiety involve a complex interplay of social, psychological, educational, physiological, hormonal, and nervous factors.

For example, if one were to consider for a moment just some of the known hormonal influences on eating, then one meets a dizzying array of substances (Druce, Small, & Bloom, 2004). For example, *leptin* (Bouret & Simerly, 2004) and *peptide YY3-36* (Coll, Challis, & O’Rahilly, 2004) are appetite suppressants, while *ghrelin* (Tschoè & Smiley, 2000) and *neuropeptide Y* (Wren et al., 2000) are potent appetite stimulants. All of a sudden, we come face to face with substances affecting hunger and satiety but which are far removed from observable experience. Just as with cellulose discussed in the previous section, realists believe that leptin, for example, exists. In fact, scientists have not only identified but isolated and synthesized leptin and observed its effects on satiety in controlled settings (Heymsfield et al., 1999).

Ghrelin, which has been referred to as the hormone of hunger, is produced by the stomach. Levels of ghrelin are higher in the blood between meals and are lower just after eating. However, there is not always a direct correlation between eating and satiety as mediated by ghrelin. In many obese people, food intake fails to suppress ghrelin levels; thus, ghrelin has been hypothesized to be the hormone of obesity, contributing to overeating (Druce, Small, & Bloom, 2004). In particular, individuals with Prader Willis syndrome have abnormally high ghrelin levels, the possible cause of their overeating. On the other hand, researchers have noted abnormally high levels of ghrelin in people suffering from anorexia nervosa which is the reverse of what might be expected (Cuntz et al., 2002; Broglio et al., 2004). Anorexia is a condition in which people do not eat

sufficient amounts of food and eventually waste away. One group of researchers hypothesizes that although anorectics produce ghrelin, the receptor cells which normally respond to the hormone may be desensitized. Whether this is true or not remains to be seen. What is important, however, for the present discussion is that Mead's science is not generally equipped to test for the existence of hypothetical entities posited by scientific theories, a topic that will be addressed in the next section relating to the hypothetical malarial parasite. For now, it is sufficient to note that Mead's science cannot test for the hypothetical ghrelin receptors because they cannot be reduced to observable objects in a bio-social setting required by the act.

Unlike ghrelin, leptin reduces food intake (Druce, Small, & Bloom, 2004). Leptin plays a long-term role in maintaining the body's energy stores and thus food intake and body weight (Sahu, 2004). There is some evidence to suggest that the neural circuitry of the brain can be affected nutritionally around the time of birth such that it is not as receptive to leptin, leading to changes in the circuit's regulation of feeding, thereby affecting body weight in the direction of obesity in later life (Bouret & Simerly, 2004; Sahu, 2004).

In addition to leptin, there are other polypeptide (protein) hormones that work in various ways to produce satiety. These satiety hormones include *glucagon-like peptide-1* (GLP-1), *oxyntomodulin* (Oxm), *peptide YY* (PYY3-36), *cholecystokinin* (CCK), and *pancreatic polypeptide* (PP), all of which are produced by the human digestive system (Druce, Small, & Bloom, 2004). Each of these substances appears to be released as a result of eating. As hormones, they are released into the blood stream where they travel to

and affect the brain. The release of peptide YY, for example, is stimulated by ingestion of carbohydrates and lipids, leading “to a sensation of fullness and satiety” (p. 2662). That there are several possible unobservable hormonal appetite suppressors is not an idea that Mead’s science is equipped to address. Pragmatist science is unable to differentiate between two or more unobservable causal mechanisms which, although they may act independently of each other, nonetheless produce the same observable results. This criticism of Dewey’s and Mead’s pragmatism will be revisited at the end of this section.

Based on the preceding topics, it seems that there is not always a straightforward link between food consumption, satiety, and what we consider and do not consider food. Mead’s model, which equates food with satiety, fails to distinguish such things as the nutritional aspects of food, pica, the overproduction of the hunger hormone ghrelin or the undersecretion of appetite suppressor peptides. With pica, the items that individuals ingest to curb their cravings are not food items. For individuals who produce too much ghrelin, consuming larger than normal quantities of food fails to quell hunger. This is not a critique of Mead’s science based on what science now knows in relation to Mead’s day. The point is that there is a fundamental difference between Mead’s empiricism which seeks to reduce all theoretical knowledge about unobservables to sensory experience, on the one hand, and realism, on the other, which seeks to establish underlying causal mechanisms for such things as satiety and hunger, or why some things qualify as food.

Pragmatism, in general, is not equipped to arbitrate between competing theories that are all reducible to the same observable phenomena. Dewey (1929) stated that scientific ideas, or theories, are always “integral with the course of experience itself, not

imported from the external source of a reality beyond” (p. 139). If this is the case, then food and food concepts must be always reducible to experience, in this case satiety. And there is no way of sorting out the various underlying causes of hunger reduction under pragmatism. Under Mead’s doctrine, there is no differentiating between the underlying causal mechanisms of activities, such as eating what is traditionally considered to be food, participating in bouts of pica, or receiving leptin injections, because each of these activities may result in the same observable phenomenon—hunger reduction. This runs against realist sensibilities. For the realist, each of these activities requires a different explanation far removed from experience. Contrary to Dewey’s (1929, p. 139) metaphysics and epistemology, the idea that hormones might be involved in satiety *is* beyond “the course of experience itself,” and it *is* an idea that is “imported from the external source of a reality beyond.” Moreover, the possibility of more than one unobservable entity affecting satiety is an idea that is also beyond Dewey’s and Mead’s pragmatism. There may be several different underlying mechanisms responsible for what appear to be the same observable phenomena, such as satiety. These underlying mechanisms may be unrelated to each other. Scheffler (1974) comments on this aspect of Deweyan pragmatism in particular.

Theories with the same observational content are not, in general, identifiable with one another, for they may differ in a wide variety of other relevant features, among the most important of which are the postulations employed to systematize and explain observable phenomena. (Scheffler, 1974, p. 205)

The educational ramifications of this are important. Students need to learn the underlying

mechanisms responsible for, and which explain, observable phenomena. It is not enough to learn about satiety based on their own and other students' consummatory behaviors.

Mead's science circumvents the view of food held by traditional science which seeks to learn at a fundamental level what makes something food. Instead, Mead attempts to explain natural scientific understanding by reducing it to his own brand of social behaviorism (Joas, 1985) and bio-sociality (Murphy, 1939). The answers science seeks at the cellular and biochemical levels of understanding are not translatable in this fashion. They involve theoretical ideas that are beyond experience and which are antecedent to the act. Food energetics, for example, is dependent on a panoply of biochemical, physical, and cellular processes far removed from experience. The role of science education should be to introduce students to this rich source of knowledge and to aid them to learn, when appropriate, how it was derived, and how it can be applied. Too much is at stake to leave science education to pragmatist theorists who maintain that scientific knowledge is immediately accessible, that it arises primarily from doing and is reducible to observables. Expectant mothers are not aware unless they are told that their developing fetuses need folate (a B vitamin) and iron for proper nervous system development and which food items are rich sources of these nutrients. Examples like these are the proper topics of nutrition education which is not reducible to possible "contact experience."

## *Learning and Applying the Methods of Science*

### *Introduction*

Mead's (1938) philosophy of the act is not only a learning theory, which is the way it was approached in the previous section, but also a scientific methodology. One can consider Mead's act from either of these two viewpoints which, in practice, overlap. In other words, students learn science by employing Mead's learning theory, while scientists do science by employing Mead's scientific method. It is this second usage that is of greater interest in this section, because one of the commonly agreed upon goals of science education is for students to learn how scientists conduct science.

In practice, Mead makes no distinction between the two usages just described. In fact, because Mead maintains that learning science and doing science center on problem solving based in consummatory activity, even animals can do science! Mead (1936) writes that "The animal is doing the same thing the scientist is doing. It is facing a problem, selecting some element in the situation which may enable it to carry its acts through to completion" (p. 346). The Meadian scholar Cornelis de Waal (2002) comments on this aspect of Mead's science. "In short, the scientific method, which is often considered the pinnacle of human thought, is not something specifically human, but is found throughout the entire animal kingdom. Even unicellular protozoans practice it" (p. 6).

The purpose of this second section of the present chapter will be to analyze Mead's scientific method in terms of how it accords with traditional science, utilizing the

examples of Copernicus's rotating earth hypothesis and the scientific discovery of the malarial parasite. It is important to see Mead's science in action, given that it is being held out to educators as a suitable, if not preferable, alternative to the scientific methods from the time of the scientific revolution.

### *The Rotating Earth and Hypothesis Generation*

*Introduction.* Copernicus's rotating earth hypothesis poses several challenges for Mead's empiricism. Mead claims that the rotating earth is a fact of immediate experience. Two episodes in the history of the rotating earth hypothesis refute Mead's claim that the earth's rotation is a fact of immediate experience. The first episode occurs in the 1730s involving the Paris Académie des Sciences which sponsored scientific expeditions to Peru and Lapland in an attempt to resolve a dispute between one group which believed that the earth rotated on its axis and another group which held that the earth was stationary. The second episode involves Foucault's pendulum which enjoyed immense notoriety during 1851 both in Europe and the U. S. There are three points to be made regarding Foucault's pendulum that relate to the history and philosophy of science.

First of all, when Foucault demonstrated his pendulum, the theory of the rotating earth was already firmly established and in no need of any sort of further defense or proof. Astronomers, physicists, and other scientists had been convinced that the earth rotated on its axis some three centuries prior to Foucault's demonstration in 1851 of his marvelous pendulum in Paris. Newton, for example, assumed the rotating earth hypothesis of Copernican predecessors in building his system of mechanics. Moreover,

the rotating earth was again supported in the early 18<sup>th</sup> century by the Cartesian-Newtonian debates concerning the shape of the earth mentioned above. However, there was a felt need on the part of scientists and lay people alike for a dynamical, visual demonstration of the earth's rotation. There is always something satisfying about such elegant demonstrations. Moreover, science always looks to new evidence either in support or in opposition to its theories. In this way, scientific knowledge is always at risk, since new evidence can help modify, if not—in some cases—overturn well-established theories. Conversely, theories which are able to explain many different kinds of unrelated phenomena and predict novel events are held highly by scientists (Laudan, 1998a). Foucault's pendulum represented a wonderful opportunity for scientists and non-scientists to become involved in a very personal way with science by reading about and attending demonstrations of Foucault's pendulum.

The second point relating to the history and philosophy of science suggested by Foucault's pendulum is that there is no direct connection between the scientific significance, or meaning, of the swinging pendulum, on the one hand, and personal experience, on the other hand. That is, one could observe the swinging pendulum, as thousands of people did, and still not understand how it demonstrated the earth's rotation. An appreciation of why Foucault's pendulum was a dynamic demonstration of the earth's rotation is something that is not mediated by personal experience but by theory.

Third, even if we entertain for a moment the notion that personal experience is sufficient for allowing concept acquisition, as many empiricists—including pragmatists—suppose, there is still a problem. Individual experience is incapable of

capturing all of the individual experiences of all the scientists who contributed in some way to our current understanding of celestial mechanics. On the other hand, unlike most students in introductory science courses, Foucault was aware of some of the experiences of the Copernicans, Galileans, and Newtonians. Very few of those who observed Foucault's pendulum in 1851 would have been versed in these astronomical and mechanical traditions. However, Mead maintains that the rotating earth is a fact of immediate experience to all intelligent people of his day.

For most intelligent people of the day it may be fairly said that the earth turning on its axis is a fact of immediate experience. The passage of the sun from its rising to the going-down thereof has become a revolution of the earth in the contrary direction. (Mead, 1938, p. 33)

In other words, the idea that the earth is rotating is so well established that it has become a fact which is verified in immediate experience. There is no need for further evidence.

*The rotating earth hypothesis.* The idea of a rotating earth arose during the 5<sup>th</sup> century B. C. with the Greeks (Kuhn, 1957) and again during the 3<sup>rd</sup> century B. C. with Aristarchos of Samos (Tobin, 2003). After that, "Copernicus revived the idea, and Galileo defended it against the opposition of the church and Aristotelian physicists. Newton assumed it and built a physics upon the assumption" (Matthews, 2000c, p. 208). The first proof of the earth's rotation was obtained "with measurements of polar flattening in Lapland by Maupertuis in 1736-37 and of the equatorial bulge by La Condamine and Bouguer in Peru in the 1740s" (Tobin, 2003, p. 137). Followers of the celestial mechanics of Copernicus, Galileo, and Newton reasoned that a spherical, rotating earth should bulge

at its equator (Todhunter, 1962). This hypothesis opposed that of some natural philosophers from Aristotle through Descartes who maintained that the shape of the earth should be “a uniform sphere or a sphere elongated along the polar axis” (Laudan, 1998a, p. 341). Although scientists who were sympathetic to the stationary earth hypothesis conducted the investigation, taking the necessary agreed-upon measurements of the earth’s circumference, it was they who determined that the results did not support their own theory (Laudan, 1998a). Thus, it was determined “that the diameter of the earth at its equator was significantly larger than along its polar axis” (Laudan, 1998a, p. 341). Although the results of these experiments sponsored by the Paris Académie des Sciences were important in lending empirical support to the rotating earth hypothesis, there is another underlying issue here as it relates to Mead’s empiricism. That is, it is important to realize that there was even a disagreement among scientific-minded people during the first half of the 18<sup>th</sup> century as to whether the earth rotated. If the earth’s rotation were a fact of immediate experience, as Mead suggests, then the Paris Académie des Sciences which “organized a series of elaborate expeditions to Peru and Lapland to collect the appropriate data” (Laudan, 1998a, p. 341) would not have needed to become involved in the debate.

*Foucault’s pendulum and the rotating earth hypothesis.* In addressing the inadequacy of Mead’s empiricism as it relates to the rotating earth hypothesis, it is useful to describe some of the history relating to Foucault’s pendulum. Because Foucault’s pendulum has been described as the best dynamical proof of the earth’s rotation (Conlin, 1999; Dugas, 1988; Tobin, 2003), it would seem to be a very likely candidate for

supporting Mead's claim that the rotating earth is a fact of immediate experience. On the contrary, Foucault's pendulum does not support Mead's empiricism. In the discussions that follow, I hope to show that Foucault's pendulum is a wonderful example of the science of mechanics in the tradition of Copernicus, Galileo, Newton, and Einstein. Finally, I shall show that the historical account of Foucault's pendulum speaks directly to adult science education, since tens of thousands of Americans were caught up in what Michael Conlin (1999) has referred to as "pendulum mania" due to newspaper accounts and demonstrations of the earth's rotation (p. 195).

Prior to Foucault's pendulum demonstrations in 1851 in Paris, scientists had already accepted the rotating earth hypothesis. Five decades prior to Foucault's demonstrations, Laplace wrote that "Although the rotation of the Earth is now established with all the certainty available in the physical sciences, a direct proof of the phenomenon would nevertheless be of interest to mathematicians and astronomers" (Laplace, quoted in Tobin, 2003, p. 137).

Additionally, the history of Foucault's pendulum is of great interest to adult science educators, since it helps divine the differences between Mead's science, on the one hand, and the realist tradition, on the other. Although the pendulum represents perhaps the best visual demonstration of the earth's rotation, the observer cannot understand how it "proves" the earth's rotation without theory. Although thousands attended demonstrations of Foucault's pendulum in the United States, and although tens of thousands read accounts of the pendulum's motion, they "did not understand how it revealed the earth's rotation" (Conlin, 1999, p. 197). Historian of mechanics René Dugas

(1988) comments that “however brilliant it may have been, Foucault’s experiment remained rather mysterious to the general public. . .” (Dugas, 1988, p. 382). An appreciation of the meaning of Foucault’s pendulum captures the realist understanding that much theory is needed in relating how the oscillating pendulum demonstrates the earth’s rotation, theory which is not provided by reading off of immediate experience.

In America, the “experiment provoked reactions ranging from admiration to incredulity to scorn” (Conlin, 1999, p. 195). One person wrote a letter to a newspaper editor requesting an explanation of Foucault’s pendulum from a scientist “in a manner adapted to the understandings of those who . . . have more zeal for science than capacity for imbibing it” (Conlin, 1999, p. 196). Thus, the general public’s understanding of Foucault’s pendulum does not seem to support Mead’s scientific empiricism. If, as Mead (1938) writes, “seeing is believing” (p. 32), then there would be no need to explain how Foucault’s pendulum demonstrated a rotating earth. Moreover, there would be no need even for a Foucauldian pendulum, since Mead (1938) claimed that “[f]or most intelligent people of the day it may be fairly said that the earth turning on its axis is a fact of immediate experience” (p. 33). This is because Mead (1934, p. 247) held that “[o]ur environment exists in a certain sense as hypotheses” and that “[a] question . . . as to the actual happening carries it back to the experience of the individual who reports it, and its actuality is reduced to his experience” (p. 33-34). For Mead, hypothesis generation and adjudication are anchored in experience as the result of observing naturally occurring phenomena. The history of Foucault’s pendulum suggests otherwise.

As it relates to science education, Foucault's pendulum indicates that there is no reading off of personal experience as to the way the world is. Science education, then, must provide students an explanation of what they experience. And such explanations involve the experiences of many people who have preceded them.

In 1851, Léon Foucault was a young French experimental physicist who constructed a pendulum that would bear his name. The pendulum was not that complex. But its enormity, supported by an astounding idea, captured the imagination of thousands of spectators who flocked to pendulum demonstrations on both sides of the Atlantic. For, “[i]t was Foucault, with apparatus no more complex than a weighty ball swinging on a wire, who finally produced the long-sought proof in 1851” that the earth rotates on its axis (Tobin, 2003, p. ix).

There were two Foucauldian pendulums. The more famous is the one that awed the crowds at demonstrations. The other is the idealized pendulum that was originally conceived, constructed, and tested entirely by Foucault as a thought experiment in the Galilean tradition. Foucault wrote about Galileo's idealized pendulum: “the pendulum is one of physics' most precious instruments, one of Galileo's most beautiful conceptions” (quoted in Tobin, 2003, p. 139). In true realist fashion, Foucault's pendulum began with theory. Newton had theorized that an ideal pendulum once placed in motion would continue to swing in the same plane indefinitely, the “only forces on the bob being the tension in the cord, and its weight directed vertically downward” (Matthews, 2000c, p. 210). Borrowing Newton's idealized pendulum, Foucault placed it directly over the north pole in his own thought experiment. The cord and bob were suspended in such a manner

that they were free to rotate without interference at the point of attachment to the support. The pendulum was then set in motion. Once Foucault set the pendulum in motion, it continued swinging indefinitely in the same plane, while the earth continued to rotate beneath it from west to east. To an earthbound individual, the ground beneath the pendulum would appear stationary, but the plane of the swinging pendulum would slowly rotate in a clockwise fashion. Foucault reasoned that the plane of oscillation of a pendulum positioned above the north pole would make one complete turn in a twenty-four hour period, the time it takes the earth to rotate on its axis. René Dugas (1988) describes the experimental apparatus as Foucault imagined it at the north pole.

The motion of the Earth, which forever rotates from west to east, will become appreciable in contrast with the fixity of the plane of oscillation, whose trace on the ground will seem to be actuated by a motion conforming to the apparent motion of the celestial sphere. And if the oscillations can continue for twenty-four hours, in this time the plane will execute a whole revolution about the vertical through the point of suspension. (Dugas, 1988, p. 380)

Foucault's pendulum at this stage was an idealized model, working perfectly within the Galilean-Newtonian theoretical system, not hampered by real-world exigencies. However, Foucault (1851) was well aware that idealized pendulums do not operate ideally in the real world. Foucault wrote:

Passing from theory to practice, the physicist must expect disappointments; and, in the present case, he must think himself very happy if with a real pendulum he is

able to obtain an unequivocal deviation in the expected direction. (Foucault, 1851, quoted in Tobin, 2003, p. 155)

No pendulum behaves perfectly in the real world, and Foucault's pendulum was no exception. Pendulums can experience "damping," or slowing down, due to air resistance; "looping" due to the bob being lopsided; and "ellipsing" which "can easily mask the slow clockwise veering due to the Earth's rotation" (Tobin, 2003, pp. 155-160). In reference to the behavior of Foucault's real-world pendulum in action, Chester Lyman, an American astronomer, contended that the "wonder is, not that the experiments exhibit some discrepancy in results, but that they show so little" (Conlin, 1999, p. 200).

Foucault faced yet another real-world challenge with his pendulum demonstrations. Foucault realized that his pendulum would not behave at lower latitudes like it would at the north pole. He correctly intuited that the period of planar oscillation would take longer than 24 hours to complete a circle in Paris, for example. The problem that Foucault foresaw can be imagined as follows. At the south pole, the direction of pendulum rotation would be the reverse of that at the north pole. Consequently, as one traveled with the pendulum from one pole toward the other, at some point the pendulum would have to reverse itself. That point would lie approximately half-way between the poles, or near the equator. At the equator, the pendulum's planar oscillations would not rotate. Foucault reasoned as follows as to the behavior of his pendulum at different latitudes in the Northern hemisphere, for example, in Paris,

. . . when our latitudes are approached, the phenomenon becomes complicated in a way that is rather difficult to appreciate. To the extent that the Equator is

approached, the plane of horizon has a more and more oblique direction with respect to the Earth. The vertical, instead of turning on itself as at the pole, describes a cone which is more and more obtuse. From this results a slowing down in the relative motion of the plane of oscillation. This becomes zero at the Equator and changes its sense in the other hemisphere. (Dugas, 1988, p. 381)

Foucault devised an equation that would account for the time it would take a pendulum's plane of oscillation to complete a circle based on the location of the pendulum. Foucault reasoned that the time for a complete rotation at the north pole was 24 hours. On the other hand, the pendulum would never complete a rotation at the equator. Said differently, as one proceeds south from the north pole towards the equator, the time necessary for the planar rotation to complete a full circle increases from 24 hours to infinity. Based on this realization, "Foucault intuited the relation between latitude and 'rotation' of the plane of oscillation" (Matthews, 2000c, p. 211). He developed the equation:  $T^1 = T/\sin b$ , in which  $T^1$  is the time it takes the pendulum plane to rotate  $360^\circ$ ;  $T$  is the period of rotation of the earth (24 hours); and  $b$  is the latitude in which the experiment is conducted (Matthews, 2000b, p. 211). At the north pole, where  $\sin 90^\circ = 1$ ,  $T^1 = T$ , and it takes 24 hours for the pendulum plane to rotate  $360^\circ$ . At the equator,  $T^1 = \infty$  (since  $\sin 0^\circ = 0$ ), and there is no apparent planar rotation. At the latitude of Paris,  $49^\circ$  N, it should take Foucault's pendulum 31 hours and 47 minutes to make a complete  $360^\circ$  rotation (Tobin, 2003, p. 143).

Foucault's thought experiment and intuited sine equation were prefatory to the pendulum that was assembled and displayed in the Panthéon in Paris, demonstrating the

earth's rotation. In the Panthéon, Foucault's pendulum was enormous. The bob, a brass shell 17 cm in diameter, had been filled with 28 kg of molten lead, and it hung at the end of a 67 meters long wire (Tobin, 2003). For those who wanted immediate indication of the planar rotation of the pendulum, a "stylus screwed to the underside of the bob widened breaches in piles of damp sand by an easily perceptible 2.3 mm progression at the extremity of each swing" (Tobin, 2003, pp. 147-148).

Pendulum mania resulted from public demonstrations of Foucault's pendulum (Conlin, 1999; Tobin, 2003). Tobin recounts some of the interest generated by Foucault's pendulum.

By early June a pendulum was under trial in the Radcliffe Library in Oxford.

Others swung in Bristol, Dublin, Liverpool and York. In France pendulums were set up in Rennes and in the cathedral in the royal city of Rheims, while others were erected in Rome by the Vatican astronomer Father Angelo Secchi, in Geneva by some of de la Rive's colleagues, in Cologne, in Florence, in Brussels, Columbo, in Rio de Janeiro and doubtless many other places. Pendulum mania even extended to the United States, where the experiment was repeated in at least twenty five cities and towns during the summer of 1851. (Tobin, 2003, pp. 148-149)

Conlin (1999) has recounted pendulum mania in the United States, including the many confusions that arose regarding the pendulum's meaning from newspaper accounts and public demonstrations.

The two major questions that arose as a result of pendulum mania were “how the pendulum oscillated independently of the earth’s rotation if its point of suspension was attached to the earth” and why at latitudes in the United States it took up to thirty-four hours for the pendulum’s plane of oscillation to trace a complete circle (Conlin, 1999, p. 195). In his analysis of pendulum mania, Conlin reports that the newspaper accounts were not scientifically very informative.

Even as they reprinted accounts of demonstrations of the Foucault pendulum, editors of several newspapers—the *Providence Journal*, the *Trenton Star Gazette*, the *Scioto Gazette*, and the *Friends’ Weekly Intelligencer*—confessed that they did not understand the experiment. Their readers did not understand it either. (Tobin, 2003, pp. 195-196)

At least one newspaper, the *Albany Argos*, understood the important link between what had been seen, on the one hand, and the need for a scientific (i.e., theoretical) explanation for what had transpired, on the other. Conlin notes:

“Notwithstanding the many explanations of the French experiment which renders visible the rotation of the globe on its axis,” the *Albany Argos* observed, “there is a good deal of misapprehension” regarding the “*modus operandi* and the theory of it.” (Conlin, 1999, p. 197, original italics)

It is at this point that Mead’s empiricism comes face to face with the realist tradition that highlights theoretical understanding. When the *Albany Argos* observes that Foucault’s pendulum “renders visible the rotation of the globe on its axis,” the editor is not speaking as an empiricist, such as Mead, who maintains that “seeing is believing” (Mead, 1938, p.

32). Instead, the editor implies that it is the mediating role of theory that “renders visible the rotation of the globe on its axis” when one observes Foucault’s pendulum. For realists, theoretical and observational understanding are complementary, while for empiricists, theoretical understanding is not only subordinated to but derives from observational understanding. It is the realist theoretical tradition which allowed Foucault to build his real-world pendulum in Paris after first imagining it in an idealized state and “seeing” it perform in an idealized setting above the north pole where it behaved perfectly, according to theory.

Foucault’s pendulum does not sit comfortably with Mead’s act in a number of areas. Each of these differences is worthy of comment, because they speak to the unresolvable gulf that exists between empiricist and realist science.

First, the pragmatists—both Dewey and Mead—insisted that scientific hypotheses or theories are generated from within experience as a result of activity. Realists, on the other hand, do not believe that scientific objects, hypotheses and theories derive directly from experience.

It seems that the human mind has first to construct forms independently before we can find them in things. Kepler’s marvelous achievement is a particularly fine example of the truth that knowledge cannot spring from experience alone but only from the comparison of the inventions of the intellect with observed fact.

(Einstein, 1930/1954, p. 266)

For Einstein, theory generation is a creative interplay between the intellect and experience. In the pragmatist tradition, however, theories come directly from experience.

That is, contrary to Einstein's view of hypothesis generation, Dewey (1929) insists that experience "generates them within its own procedures and tests them by its own operations" (p. 138). Scheffler (1974) criticizes Dewey's position on this matter.

. . . Dewey's view that ideas in science are "generated within" scientific procedures, as well as tested by scientific operations, is too strong. *Testing of ideas through scientific operations is certainly an important function of such operations. But there are no scientific procedures that capture the processes by which theoretical ideas are generated. These creative processes remain independent of routines and procedures; they can hardly be adduced as a reason for saying that "ideas and meanings" are "integral with the course of experience itself, not imported from the external source of reality beyond."* (Scheffler, 1974, pp. 204-205, original italics)

Mead's view of hypothesis generation is closer to Dewey's than it is to Einstein's. Mead (1934) insists that the world exists as hypotheses which are given in experience: "Our environment exists in a certain sense as hypotheses" (p. 247). Moreover, for Mead, humans are able to abstract these hypotheses from nature. Mead (1934) writes: "The physical object is an abstraction which we make from the social response to nature" (p. 184).

Contrary to the empiricist accounts of theory generation offered by pragmatists, which insist that theory arises always during active inquiry, the theory Foucault tested was not only antecedent to any data collection, but it was antecedent to the construction of his real-world pendulum. Foucault's real-world pendulum was designed specifically to

test Copernicus's three-centuries old theory. Moreover, in a move that anticipated one of Einstein's favorite methods, Foucault conceived of and initially tested his pendulum as a thought experiment, predicting the pendulum's behavior.

In Mead's science, on the other hand, theory does not antedate inquiry. Theory arises as a result of conflicted problem solving, that is, during the act. Scheffler criticizes the pragmatist claim that theory derives largely from experience.

The process of theorizing is a creative process. It is not just a matter of cataloguing the functional relations among phenomenal changes, nor is it, in any plausible sense, generated out of experience. The theorist is free to invent, simplify, postulate, categorize, extrapolate, idealize . . . to back away from the detail of phenomenological change and practical urgency in order to strive to "see through" to underlying elements and patterns. (Scheffler, 1974, p. 251)

The difference between Foucault's and Mead's understanding of theory derivation is important to adult science education, because scientific theories and concepts are not abstractions from experience as Mead contends. Just as Foucault based his pendulum on the theories of Galileo and Newton, students need to be provided Galilean-Newtonian theoretical understanding if they are to grasp the science of mechanics (Carson & Rowlands, 2003; Lombardi, 1999). Students therefore need to be introduced to the "epistemological rupture" between observation and theory that gave rise to this axiomatic system" which is our current science of mechanics (Carson & Rowlands, 2003, p. 716). This is because, "every attempt at a logical deduction of the basic concepts and postulates

of mechanics from elementary experience is doomed to failure” (Einstein, 1934/1954, p. 274).

Second, Foucault’s pendulum did not seek to order the phenomenal world, but spoke to a physical process that is not experiential, namely that the earth rotates. Mead’s science, on the other hand, seeks to order or construct the phenomenal world based in experience. It does not seek to find the underlying causes of observable phenomena, because, ultimately, there are no entities in back of observable phenomena (Mead, 1938). Ultimately, for Mead (1982), “[r]eality reduces to possible contact experiences” (p. 118).

Third, pragmatists hold that “experimental science is a mode of doing” (Dewey, 1929, p. 102). In the hands of Mead, truth derives from activity aimed at helping “us cope with our environment” (de Waal, 2002, p. 17). And “since the sole aim of all thought is to solve a problem, truth is synonymous with the solution to a problem” (de Waal, 2002, p. 17). According to the pragmatic definition, truth “is whatever solves the problem” (de Waal, 2002, p. 17). Thus, for pragmatists, doing (as it relates to experience) and truth are inextricably associated. Truth cannot be had without doing.

But is experimental science reducible to doing, that is, reducible to experience derived from activity? The events surrounding Foucault’s pendulum would seem to suggest that this is not the case. Léon Foucault conceived his pendulum as a thought experiment, employing existing theory, creating an idealized model, and testing his model in an idealized setting before he ever constructed a real-world model. This is in opposition to Mead’s kinesthetic, instrumentalist model of knowledge (Miller, 1974), which has influenced adult learning theorists, for example, Eduard Lindeman. Lindeman

(1961/1989) writes that “Intelligence performs its function in relation to actualities, not abstractions” (p. 6). On this reading, knowledge is readily ascertainable from our actions. Lindeman adds that “Experience [is] the stuff out of which education is grown. . . . Experience is, first of all, doing something; second, doing something that makes a difference; third, knowing what difference it makes” (p. 87). Moreover, this actual versus abstract knowledge is local.

Experience, the stuff out of which education is grown, is after all a homely matter.

The affairs of home, neighborhood and community are vastly more important educationally than those more distant events which seem so enchanting.

Experience is, first of all, doing something. (Lindeman, 1961/1989, p. 87)

Léon Foucault did not follow this pragmatist-inspired recipe of education which generates knowledge from experience, that is, doing based on “actualities, not abstractions.” Moreover, Foucault was not interested in local knowledge but knowledge that literally had the earth turning on its axis. Borrowing Newton’s theory of pendulum motion, Foucault envisaged his own idealized pendulum operating successfully at the north pole. Thus, contrary to pragmatism, the only activity Foucault engaged in while creating and testing his idealized pendulum was largely the activity of reasoning based on antecedent theory and knowledge of trigonometry. More importantly, Foucault did not build his pendulum only to begin his scientific investigation by generating data and attempting to abstract theory, after the empiricist fashion, from visible phenomena.

Thus, Foucault’s science is diametrically opposed to Dewey’s (1929) empiricism in which the latter insists that scientific ideas are generated within activity rather than

being “imported from the external source of a reality beyond” (p. 139). Speaking in opposition to Dewey’s notion that scientific theorizing reduces to doing, Scheffler (1974) writes:

I believe, that to conceive “experimental knowledge” as a “mode of doing” is to overstate the case. Experimental knowledge is born both of doing and of theorizing, and theorizing is itself independent of the constraints of activity or observation at the level of practice. (Scheffler, 1974, pp. 205-206)

Fourth, Foucault’s real-world pendulum, contrary to Mead’s (1938) science, did not satisfy an immediate physiological need. Scientific theorizing and conceptualizing is not reducible to bio-social understanding through the fulfilment of satisfying bio-social needs as is required by Mead’s act. Speaking to Mead’s act as it pertains to science, philosopher Arthur Murphy (1939) states that the only consummatory goal of problem solving in physics ought to be to obtain “an adequate knowledge of the physical world” (p. 101). According to Murphy, the only way that the bio-social requirement of the act can be meaningful in physics is if its primary goal is “in discovering the invariant laws of physics” (p. 101). Consequently, scientific understanding, on the one hand, and Mead’s bio-social understanding, on the other, are two completely separate ways of viewing the world, and they are incongruous.

In conclusion, Mead’s act has called into question traditional science’s manner of creating its scientific objects. Mead (1938) contends that scientific objects are not mind independent, that hypotheses exist as part of the environment, and that they reduce to common experience. This leads Mead to claim “that the earth turning on its axis is a fact

of immediate experience” (p. 33). These aspects of Mead’s science are unsupported by the example of Foucault’s pendulum which provides evidence for the rotating earth hypothesis. Thus, Mead’s act provides no mechanism for generating scientific hypotheses involving unobservables. This fact should weigh heavily in determining the suitability of Mead’s doctrine as a referent for adult science education.

*Mead’s Scientific Method and the Discovery of the Malarial Parasite*

*Introduction.* A study of Foucault’s pendulum in the previous section allowed us to compare Mead’s doctrine to realism in terms of the roles of hypotheses and idealization in science. In this section, the history and science of the discovery of the malarial parasite will allow us to compare the experimental side of Mead’s science with realism. Specifically, Mead’s act will be analyzed in terms of the sufficiency of its experimental design for testing the hypothesis that a mosquito-borne entity is the human malarial parasite. Such a comparison is useful, since Mead’s science is being held out to science educators as a suitable alternative to traditional realism (Bredo, 2000). One of the goals of adult science education is for students to learn scientific methods and their correct application.

*The discovery of the malarial parasite.* Roughly a quarter of a century before Mead enunciated his scientific method, scientists had not only discovered parasites transported by mosquitoes but showed that they were the causal agents in human and avian forms of malaria. The discovery of the malarial parasite in 1898 was a huge affair celebrated world wide. The malarial parasite, *Plasmodium*, is carried by both *Anopheles*

and *Culex* mosquitoes which inject the parasite into human and bird hosts, respectively. Ronald Ross, a British army surgeon, who in 1898 showed that the *Plasmodium* parasite transmitted by *Culex* mosquitoes was the causal agent of malaria in birds, received the Noble Prize in 1902. The Italian researcher Giovanni Grassi “completed the picture of the life cycle of *Plasmodium* in birds and man when in 1898 he demonstrated a special capacity of the genus *Anopheles* to transmit malaria from man to man by carrying *Plasmodium* in its digestive tract” (Poser & Bruyn, 1999, p. 44).

Details of the science and ensuing discovery of the human malarial parasite suggest insufficiencies with Mead’s doctrine. In spite of the demonstrated existence of the malarial parasite and its causative role in human malaria by traditional science a quarter century before Mead’s doctrine, Mead’s personal metaphysics would not allow him to accept the parasite as a mind-independent object of reality. For Mead, the malarial parasite is not a real entity but “an abstract entity that helps in causal reasoning and, by extension, practical problem solving” (Bredo, 2000, p. 148). Mead claims that “scientific objects are . . . to be understood functionally rather than metaphysically” (Bredo, 2000, pp. 148-149). Thus, “The role of the scientific object, such as a possibly invisible parasite, in this process is to aid problem solving. It is an abstract entity that helps in causal reasoning and by extension, practical problem solving” (Bredo, 2000, pp. 147-148). Thus, whereas Einstein (1934/1954) took the unobservable scientific objects posited by scientific theories “as given realities” (p. 148), Mead, on the other hand, asserted that “scientific objects are . . . not metaphysical givens” (Bredo, 2000, p. 148).

Thus, Mead sought to dissolve the traditional metaphysical objects of science. Bredo explains that Mead's act "dissolves the traditional metaphysical object . . ." (p. 144).

Mead provides an empiricist account of the derivation of the malarial parasite hypothesis. Mead (1938) maintains that hypotheses are "placed in individuals' minds with individuals' experiences" (p. 47). Mead goes on to describe the genesis of the malarial hypothesis, according to the act.

The incidence of the diseases are now observed and recorded by physicians and health officers who are seeking to discover the mechanism of the spread of the infection. . . . In so far as these data are embedded in the lives of individuals, they are personal but hard facts. But, in so far as the experience suggests what is known of the relation of the mosquito to malaria and a possible parasitic organism . . . we are in the presence of an idea and of what we will call "subjective."

(Mead, 1938, pp. 46-47)

From this it is quite clear that Mead believes that the malarial-parasite hypothesis stems from direct experience. Mead's claim that the malarial-parasite hypothesis stems from experience is in direct opposition to the realist view which is consistent in this case with the hypothetico-deductive method of inventing hypotheses whole cloth independently of experience and data gathering. In fact, according to the hypothetico-deductive method, hypotheses must precede data gathering; otherwise, scientific inquiry would be blind information gathering. The same can be said on behalf of malarial science. What was needed in the search for the causative agent of malaria was not more subjective experiences but a guiding theory.

Poser and Bruyn (1999) provide a detailed account of the history of malarial science. They trace the development of malarial science from its ancient beginnings. One of the consistent themes in their account is that malarial science was impeded by experience and that malarial science was aided when new theories were invented whole cloth.

Poser and Bruyn (1999) write that “The doctors who put together testable hypotheses from observed associations of mosquitoes and fever had few facts to go on” (p. 37). Consequently, rather than experience guiding researchers in their search for the causative agent of malaria, they “had to invent cause-and-effect linkages out of whole cloth” (p. 37). In fact, according to Poser and Bruyn, personal experience often got in the way when researchers sought to account for malarial contagion. What was needed was a powerful new way of looking at contagion, a new theory. “It took the brilliant, albeit completely theoretical exposition of Jacob Henle in 1840 to establish the classic concept of the *contagium vivum*” (Poser & Bruyn, 1999, p. 26). Not until a theory of contagion that implicated living organisms was imagined could malarial investigators begin looking for what had been there all along. This captures nicely Einstein’s (1930/1954) claim “that the human mind has first to construct forms independently before we can see them in things” (p. 266).

The importance of the role of antecedent theory holds a central place in malarial science. Laveran had already seen the parasites responsible for malaria in 1880 through his microscope; however, the small organisms were meaningless (Poser & Bruyn, 1999).

Without a malarial-parasite theory, the tiny organisms that many others had already viewed seemed to be without significance.

As was pointed out by Smith and Sanford, in the mid-1880s the problem was obviously one of interpretation of what was observed under the microscope. For example, Frerich's illustrations, which were published in Virchow in 1858, indicated that he had actually seen plasmodia without realizing their significance. The Italians, Colin and Laveran, were all seeing the same things on differently prepared slides and interpreting their observations in different ways. (Poser & Bruyn, 1999, pp. 29-30)

Much to his later chagrin, even the eventual discoverer of the malarial parasite Ronald Ross had discounted earlier reports of flagellates found in human blood as having anything of scientific value (Poser & Bruyn, 1999). However prescient the idea that a malarial parasite might be found in human blood, it did not have many converts.

Experience, rather than leading researchers to the discovery of the malarial parasite, was an impediment that had to be overcome. Even those who had seen blood-borne parasites could not believe what they had seen. For example, William Osler, who was "America's leading clinician and internationally recognized expert on the microscopic study of blood challenged . . . Laveran's and the Italian's interpretation of what was observed" (Poser & Bruyn, 1999, p. 31). Osler would eventually become a convert to Laveran's thesis that flagellates could be found in blood. Osler noted that his conversion was due to theoretical considerations that went "against all past experience" (Poser & Bruyn, 1999, p. 31). Poser and Bruyn quote Osler on the matter.

When I first read Laveran's papers nothing excited my incredulity more than his description of the ciliated bodies. It seems so improbable and so contrary to all past experience that flagellate organisms should occur in the blood. The work of the past six months has taught me a lesson on the folly of skepticism based on theoretical conceptions, and of preconceived notions drawn from limited experience. (Poser & Bruyn, 1999, p. 31)

Although many researchers were guided by what became known as the "germ theory of disease," the climactic discovery of an organismal causal agent of malaria in 1898 could not have been predicted even a few years earlier, due to the inherent skepticism surrounding the notion of a blood-borne parasite. Earlier in the century, John Crawford's suggestion that malaria was caused by "microscopic worms" was considered one of "the wildest of philosophical vagaries" (Poser & Bruyn, 1999, p. 27).

The same incredulity was directed at Patrick Manson on the very eve of the discovery of the malarial parasite. Patrick Manson contributed immensely to the discovery of the malarial parasite. Manson hypothesized that there was a connection between mosquitoes and malaria. Yet, as late as 1898, his theory was received with incredulity by many. Poser and Bruyn (1999) write that Manson became defensive about his mosquito theory.

I have been stigmatized as a sort of pathological Jules Verne, and hinted at as being governed by "speculative considerations" and as being "guided by the divining rod of preconceived ideas." It seems to me that the theory I enunciated was a logical outcome of the relationship of these facts and the most likely

explanation of the relationship of these facts to each other and the most promising guide to fresh facts. (Poser & Bruyn, 1999, p. 43)

Manson's comments indicate his realist attitude. Manson's theory was derived independently of experience, and it was used to guide inquiry. Manson goes on to explain the important role his theory had in guiding Ross's Nobel Prize winning work. "This speculation in question has certainly guided Ross to further important facts, all of which point to the conclusion I ventured to indicate. After three years of incessant labor on the mosquito theory, Ross firmly believes in it" (Poser & Bruyn, 1999, p. 43).

Mead's account of hypothesis generation deviates significantly from that of the history of the science of malaria as recounted by Poser and Bruyn. While Mead contends that hypotheses were generated from individual experience, Poser and Bruyn (1999) provide historical evidence from the actual investigators that hypotheses were developed "whole cloth." Poser and Bruyn allege that personal, even professional, experience hindered researchers. The idea of a blood-parasite contradicted all past experience, and it seemed wildly speculative at the time. When Ronald Ross designed his crucial experiments showing the causal role played by *Plasmodium* in malaria transmission, no doubt he was influenced by Manson's "speculative considerations" or theories (Poser & Bruyn, 1999, p. 43). Ross's belief in Manson's "speculations" enabled him to discover the mosquito-borne malarial parasite.

Mead's account of the derivation of the causal agent of malaria from experience does not accord with the historical record. Not until malarial researchers went against

prior experience and invented hypotheses whole cloth did they make critical headway in the discovery of the malarial parasite.

*Mead's scientific method and the malarial parasite.* Mead's scientific method deviates from traditional science in terms of experimental design and hypothesis testing. For Mead, hypotheses derive from the experience of individuals. As such, they do not address the underlying invisible causes of observable phenomena. Hence, in spite of the fact that Mead's science accepts the malarial-parasite hypothesis, it cannot entertain it from a realist perspective. In a word, Mead's science cannot *test* the malarial-parasite hypothesis. Instead, Mead's science must turn to some observational phenomena that can be measured. Since Mead's science is aimed at reporting observable change rather than testing theory, it cannot address the very thing that is of greatest interest to scientists—the issue of the malarial parasite's existence. Thus, Mead sidesteps the whole issue of the malarial parasite's existence. Mead's science is fashioned to solve a practical problem that can be assessed and interpreted solely in terms of observable change. The question then is what, if anything, does Mead's science add to our understanding of malarial science?

Bredo (2000) describes Mead's malarial-parasite experiment. For convenience of later analysis, I have numbered each of the sentences describing Mead's experimental science, its rationale and protocol:

[1] The hypothesis that malaria is caused by a certain parasite posits a “scientific object” as the cause. [2] If the parasite is found to be transmitted by mosquitoes who thrive in lowland swamps yet are able to live in a host at higher altitudes,

then the anomaly is resolved, at least hypothetically. [3] The theory based on a mosquito-borne parasite can be tested to see if the elimination of mosquitoes reduces the incidence of disease. [4] The role of the scientific object, such as a possibly invisible parasite, in this process is to aid problem solving. [5] It is an abstract entity that helps in causal reasoning and, by extension, practical problem solving. (Bredo, 2000, p. 148)

The following analysis will show that Mead's experimental method turns malarial science on its head. What was a discovery of traditional science—the malarial parasite—Mead seeks to downplay. In other words, what is important for Mead is not the *existence* of the malarial parasite so much as it is the *idea* of the malarial parasite which aids problem solving. Speaking of scientific objects, Bredo (2000) notes that “Their *scientific* role is to be tools of inquiry” (p. 149, original italics). Their “function is to guide action and inquiry in an instrumental fashion so that different observers may produce similar results from similar manipulations” (Bredo, 2000, p. 149). Again, pragmatist constructivists are concerned only with observable changes at the phenomenal level, not with their underlying causes. This means that when experiments are conducted, what matters is that the same results are obtained by all (Bredo, 2000). A consideration of the many competing explanations as to why particular results were obtained does not matter.

The realist hypothesis that posited the existence of an organismal cause of malaria, antedated Mead's doctrine by several decades. Moreover, *Plasmodium* had already been firmly established as the malarial agent in both birds and humans. Oddly, Mead's doctrine seeks to downplay this scientific discovery. Bredo (2000) captures

Mead's anti-realist metaphysics in the very first sentence of his explanation of Mead's method provided above. The placing of quotation marks around *scientific object* implies that its objectivity is in question. What occurs next is a shift away from the malarial parasite to something that is readily observable and to which the parasite can be reduced or made synonymous. Bredo (2000) accomplishes this when he writes that "The role of the scientific object is to focus attention on certain aspects of the situation, such as *vectors* by which a parasite might be transmitted. . ." (p. 148, italics added). Bredo makes the reduction when he substitutes vectors, that is, mosquitoes which carry parasites, for the parasites themselves. Now attention has been diverted completely away from the hypothetical entity to something which is observable. Henceforth, all considerations turn to mosquitoes and incidences of malaria which are both observable and measurable. In the language of the philosophy of science, the malarial parasite has thus been reduced in empiricist fashion to observables. Subsequent activity centers on observables rather than on the existence of a malarial parasite. Consequently, Bredo has turned entirely away from testing the original, realist hypothesis which posited a scientific object—the existence of a malarial parasite. In sum, what began as the positing of a hypothetical malarial parasite, will subsequently digress into a discussion of mosquito populations and incidences of malaria.

The second sentence, which leads up to the experimental testing of the hypothesis, is circular, because it already assumes the discovery of the malarial parasite. For if, as Bredo states, the malarial "parasite is found to be transmitted by mosquitoes," then there is no reason to test the malarial-parasite hypothesis, because the malarial parasite has

already been discovered. If this is the case, then Mead's science has nothing to add to our knowledge of malarial science. However, there is a downside to Mead's science, because not only does it not commit to the unobservable entities already established by traditional science, it seeks to dissolve them.

The experimental protocol, which is the topic of the third sentence, is not designed, as in realism, to determine whether or not there is such a thing as a malarial parasite. Instead, the proposed experiment seeks to establish only a link between mosquitoes and malaria. In this cause and effect design, the elimination of mosquitoes is the independent variable, while the incidence of malaria is the dependent variable. Assuming that the experiment is a success and that there is a reduction in both the number of mosquitoes and cases of malaria, such results would suggest only that mosquitoes *may* be linked somehow to malaria. Such results, though favorable, do not rule out other possible causes of malaria. There may have been another non-mosquito swamp-related factor responsible for malaria. Ironically, these favorable results are even less suggestive of a mosquito-borne parasite being responsible for malaria. What still needs to be proved is that mosquitoes actually carry a human parasite capable of causing malaria. Thus, Bredo's claim that the "theory based on a mosquito-borne parasite can be tested" by draining swamps stands in stark contrast to science's discovery a quarter century earlier of the malarial parasite in 1898.

In the last two sentences above, Bredo explains that the role of the scientific object in Mead's instrumentalism is to aid problem solving by promoting causal reasoning. Thus, in true instrumentalist fashion, the scientific object is to be "understood

functionally rather than metaphysically” (Bredo, 2000, p. 149). For Mead, one need not commit to the existence of the malarial parasite in order to be able to solve practical problems. Mead’s point deserves consideration.

The immediate question is whether pragmatism, as opposed to realism, has the upper hand in solving practical problems. By focusing on the underlying causes of observable phenomena, realist science does not lose out to instrumentalist science in leading the charge to solve practical problems. After all, realists posited the existence of the malarial parasite and then devised an experimental protocol for testing the theory. Further, realists can argue that it was the discovery of the malarial parasite which provided a sound scientific reason *why* the draining of swamps by pragmatists might actually reduce the incidence of malaria. Realists can further argue that it was the discovery of the malarial parasite, *Plasmodium*, that helped open new avenues of malarial research at levels even further removed from experience, that is, at the cellular, subcellular, and molecular levels. This ultimately leads back to the question of what Mead’s doctrine has contributed to our understanding of malarial science. Mead’s science causes us to lose sight of the hypothetical object and to concentrate solely on phenomenal changes rather than to their underlying causes. From an educational viewpoint, one must consider whether Mead’s scientific method coincides with traditional scientific understanding. Not only are the history and science surrounding the discovery of the malarial parasite, which predated Mead’s doctrine, ignored by Mead, but Mead’s account differs substantially from traditional understanding. Thus, science educators are asked to

choose between Mead's malarial science and the actual scientific understanding both before and after Mead's day.

Mead's science cannot adjudicate between competing hypotheses which posit different scientific objects. Before the discovery of the malarial parasite, the parasite hypothesis was not the only causative explanation vying for attention. The history of malarial science shows that there were many competing hypotheses as to the cause of the disease (Poser & Bruyn, 1999). The term "malaria," as its etymology suggests, means "bad air." The bad air issuing from swamps was said to have several putative origins. The bad-air hypothesis which circulated during the 17<sup>th</sup> and 18<sup>th</sup> centuries was persistent. Even as late as 1880, it still had reputable adherents, one of whom was Léon Colin, France's leading authority on malarial fever. Colin wrote: "In my view, indeed, the fever is caused most of all by the vegetative power of the soil whenever that power is not called into action, when it is not exhausted by plants sufficiently to use it up" (Poser & Bruyn, 1999, p. 29). The different putative causes of malaria would come to be called "miasmas." Speaking to the possible causes of miasmas, Carl Friedrich von Heusinger in 1844 wrote, for example, that

Miasmas are of different kinds, so that their characteristics could naturally be very different: one could consist of a poisonous gas, another of a small animal, a third of fungi. As we discover the characteristics of miasmas, we will cease to call them so and will attribute their effects to the poisons or the parasites, or to a discovered general influence such as electricity or heat. (Poser & Bruyn, 1999, p. 26)

Other causes of malaria were advanced from time to time. John Bell of Philadelphia, who

was highly critical of the several hypotheses for malaria advanced by Josiah Nott, wrote that the latter

has been bold enough to deny the very existence of malaria in any shape and has contended that meteorological changes and radiating or absorbing qualities of soils and plants, of dews, etc., are sufficient alone to explain the occurrence of those diseases, commonly attributed to malaria. (Poser & Bruyn, 1999, p. 27)

Some attributed malaria to venomous fluids injected by insects. “Louis Beauperthuy, a French physician living in Venezuela, wrote in 1854 that he believed that yellow fever and malaria ‘are produced by a venomous fluid injected under the skin by mosquitoes like poison injected by snakes’” (Poser & Bruyn, 1999, p. 27). Although Robert Koch, the famous bacteriologist, believed that malaria was spread by mosquitos, he thought that the organisms were deposited by the mosquito on a person’s skin (Poser & Bruyn, 1999). Given the many conflictive hypotheses of the cause of malaria, it is difficult to see how Bredo’s (2000) strategy of draining swamps is able to discriminate between them.

The discoverers of the malarial agent in 1898 created experimental settings and protocols that allowed them to test their hypothesis in controlled settings. Thus, they were able to show that the *Plasmodium* responsible for malaria in one host was transported by a mosquito to a malaria-free host which subsequently contracted malaria. The draining of swamps to test the mosquito-borne malarial hypothesis not only fails to establish a direct link with malaria and mosquitoes but with malaria and a mosquito-borne parasite. Mead’s insistence that scientific knowledge derives from human activities in reference to observable changes prevents him from dealing directly with the objects posited by

scientific theories. Even after the scientific world community agreed that parasites responsible for malaria in birds and humans had been discovered, for metaphysical reasons, Mead could not, in general, accept the existence of unobservable entities. Instead, Mead sought to provide a different account of malarial science, one which did not necessitate a commitment to the mind-independent existence of the parasites themselves.

### *Preparation of Adult Learners for Professional Practice and Further Science Education*

#### *Introduction*

One of the goals of tertiary science education is to prepare adults for science and science-related careers, and for graduate study in science, as well as to provide a more general foundation for science literacy. A pertinent question, then, is whether the adoption of a pragmatist constructivist view of course design and implementation would be adequate for preparing students for these options. I shall argue in this section that the pragmatist constructivist view of course design and implementation would not adequately prepare students for professional practice in science and science-related fields, or for science study at the graduate level. The basis of my claim rests on the following two points.

First, many learning approaches stemming from Deweyan pragmatism have overemphasized the student's interests and student's responsibilities for determining the curriculum (Prawat, 2000; Ryan, 1998, p. 397). In adult education, the assumption is not

only that adults are in a position to conceive, design, implement, and assess courses but that this approach is preferable to more teacher-centered approaches.

Second, many learning approaches attributed to Dewey are based on inductive notions of learning (Prawat, 2000). Inductive logic assumes that students can acquire conceptual understanding by abstracting theoretical knowledge from the particulars of their learning experiences inductively. In this manner, students are thought to be fully capable of bootstrapping themselves to knowledge (Prawat, 2000).

### *Are Students' Interests Sufficient Determinants for Course Design?*

*Introduction.* The philosophical debates between realist and constructivist understanding are really independent of many of the educational issues regarding teaching and learning. Philosopher Robert Nola (1997) maintains that “Constructivists in science education often wrongly assume that the debate can tell us something about the teaching and learning of science” (p. 57). However, many constructivists have championed the use of experiential approaches to learning, basing them, in fact, on constructivist philosophy. It is because of this that issues of teaching and learning deserve our attention.

Early in his career, Dewey argued for student-centered, interest-driven, activity-based approaches to learning (Prawat, 2000). Dewey maintained that these types of approaches were truly educative, while educational approaches in which topics were initiated by the educator were not. Dewey (1897/1972) writes:

the child's instincts and powers furnish the material and give the starting point for all education. Save the efforts of the educator connect with some activity which

the child is carrying on of his own initiative independent of the educator, education becomes reduced to pressure from without. It may, indeed, give certain external results but cannot be truly called educative. (Dewey, 1897/1972, p. 85)

Dewey's admonition has been applied to adult education. Its current embodiment is found in the words of Caffarella (1993) who writes that

Greater learner control means that learners are given the time and opportunity to think about what they want to learn (that is, what is useful and meaningful to them), how they want to go about learning (techniques, resources needed, location, and pacing), and which criteria will be used, and in what ways, to determine whether the learning experience was satisfactory and worthwhile. (Caffarella, 1993, p. 30)

The confluence of several factors in adult education supports the notion of student-centered, interest-driven, course design. The history of adult education, which stems from progressivist ideals, supports student-centered learning. In more recent times, andragogy has been instrumental in leading the way. Knowles (1975) maintains that adults take the lead "in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (p. 18). Empirical support for the idea of self-direction comes from studies which suggest that the majority of the learning activities that adults normally engage in are primarily designed, implemented, and evaluated by the learners themselves (cf. Tough, 1971/1979). The idea that adults are self-directing is perceived by some, however, as a tautology (Collard,

1985). That is, “adult” and “self-directing” are used to define each other. In other words, based on the premise that “Adults are self-directed learners,” some conclude that “Adults are self-directed learners, because they are adults.” Eventually, there was a push to institutionalize self-directed approaches to learning based on the rationale that, if adult students are normally self-directed, then they ought to be self-directed in formal learning settings as well (Caffarella, 1993). Obviously, such a view would disrupt fundamental thinking of traditional learning approaches in formal settings. “Fundamental changes in attitudes and beliefs of both teachers and learners about what constitutes formal instruction are needed for learner self-direction to become a major part of an institution’s education program” (Caffarella, 1993, p. 31). Some have concluded that self-direction, even in formal settings, has become an end in itself (Pratt, 1993). On this view, what began as an andragogical ideal has since evolved into an educational mandate. In adult education, student-centered approaches to learning are embodied in notions of experiential and self-directed learning perspectives.

Another factor contributing to the popularity of experiential and self-directed approaches to learning is the belief that adults value both practicality and immediacy. As active learners, adults value learning activities that relate most directly to their lived worlds. Merriam (2001) writes that one of the assumptions of Knowles’s work is that the adult learner “is problem-centered and interested in immediate application of knowledge” (p. 5). Indeed, Knowles (1989) wrote that “adults are life centered (or task centered or problem centered) in their orientation to learning” (pp. 83-84). Moreover, allowing adult learners to focus on practical problems is said to aid learning. Jones (1994) states that,

according to pragmatism, “adults learn most naturally when they have a problem solving experience with relevant, real-life issues” (p. 23). In sum, the notion of student-centered learning seems to flow from a number of andragogical and pragmatist principles that support each other, such as experience, self-direction, immediacy, relevancy, and practical problem solving. What remains is a teaching-learning approach by which these student-centered ideals can be realized.

Constructivism is seen by many adult educators as providing the mechanism by which andragogical principles can be applied to teaching and learning (Merriam & Caffarella, 1999). According to adult educator Philip Candy (1989), constructivism allows learners to give meaning or “make sense out of the perplexing variety and constantly changing texture of their experiences” (p. 98). Caffarella and Barnett (1994) apply Candy’s constructivist viewpoint to teaching and learning, when they write that students are able to construct conceptual knowledge by “negotiating meaning” that is “embedded in the multifaceted realities that students bring with them to the learning experiences” (p. 37). Here, Caffarella and Barnett make their claim that experience is foundational to concept construction. Indeed, some adult educators maintain that experiential knowledge is a legitimate form of knowledge on equal footing with traditional classroom knowledge (Caffarella & Barnett, 1994; Jackson & MacIsaac, 1994). Hence, for some adult educators, there are two definitions of knowledge, formal and experiential (Caffarella & Barnett, 1994). In fact, “the learner’s experience as part of the knowledge base has been promoted in adult learning programs for decades. . .” (Caffarella & Barnett, 1994).

*Critique of student-centeredness as a basis of course design.* There is much to be said for student-centered ideals for learning. Almost everyone would agree that students' active engagement in their own education not only aids learning but ensures relevance. Most would also agree that students' prior experiences play an important role in furthering subsequent learning. Moreover, most would agree that education should be meaningful to students. However, one can ask whether these considerations are the exclusive domain of self-directed approaches to learning and whether a student-centered approach to learning is preferential in all cases. It seems that even in learning situations which are not deemed self-directed, students can actively plan, monitor, and assess their learning goals as they learn and begin applying fundamental disciplinary principles. It seems, however, that there may be significant limitations to self-directed learning that deserve serious consideration, especially as they relate to adult science education.

First, although many adult learners conceive, design, implement, and assess self-directed learning projects completely on their own, there are many instances when adults not only prefer but choose more teacher direction. In fact, many adults are anything but self-directed learners (Pratt, 1988). Some adults tend to be more self-directed in some contexts and less so in others (Slusarski, 1994). Adults seem to be more self-directive in environments in which they have some measure of expertise. Conversely, they tend to be less self-directive in situations where they have little or no expertise. In practical terms, this includes adult learners who are returning to college, because they are seeking either a career change or employment. Thus, even a professional with lots of education and experience in a non-science area may feel inclined to want more teacher direction in a

science-related discipline. When attention turns specifically to the topic of learning science, itself, this seems to be the case; many adult learners prefer teacher direction (Slusarski, 1994). Candy (1991) notes that

despite the idealized image of the self-directed learner lightly and easily pursuing his or her own interests, the very complexity and rapidity of change—both social and occupational—may baffle and perplex the individual learner, leaving him or her confused, anxious, and far from confident about *how to best to proceed or what to learn*. (Candy, 1991, p. 59, original italics)

This points to a second problem associated with student design of courses. Even if students are able to identify recent trends in a particular discipline, this does not mean that they will be able to identify the important underlying disciplinary principles by which the latest trends can be understood, applied, or evaluated. Introducing disciplinary knowledge by current events may be a powerful pedagogical tool but only if students are able to understand these current events as they are understood by representatives of the very same disciplines. Current events are understood as they relate to established disciplinary principles. Paradoxically, both an awareness of the basic principles of a discipline and how they are applied presumes a foreknowledge of that discipline. Disciplinary foreknowledge also relates directly to issues of course design, implementation, and evaluation. For example, most students enrolled in community college physiology courses may not be aware at the outset that physics applies to physiology even though the same etymological root, *phys-*, is shared by both terms. In spite of the fact that physics informs cardiovascular and pulmonary function, for example,

most community college students have never had a course in physics. The point is that unless students are aware that physics applies to physiology, they are not likely to include it in a course design as something that is important for understanding physiology. And even if students are aware of the importance of physics for understanding physiology, their understanding of physics and how it might apply to physiology may be limited. The same thing can be said for chemistry and its importance for understanding human physiology. In short, physiological principles depend upon physical and chemical principles which have to be learned before they can be applied. This raises yet another important consideration for adult science education—prerequisite knowledge.

Some adult educators resist the notion of prerequisite knowledge, because it implies that not all knowledge is immediately apprehendable or directly applicable. One of the debates surrounding the demarcation of andragogy from pedagogy, for example, has been the idea that children learn knowledge that will be applied later, while adults learn knowledge that is practical, immediate, and makes a difference in their lived world. Knowles (1980) wrote that “There is a change in time perspective as people mature—from future application to immediacy of application. Thus the adult are more problem centered than subject centered in learning” (pp. 44-45).

This view of knowledge suggested by andragogy which stems from pragmatism presents a slippery slope as it relates to scientific understanding. The pragmatists, Dewey (1929) and Mead (1938) in particular, held that theoretical knowledge arises from activity. Dewey suggests “that the import of theory can be wholly encompassed within the sphere of action and observation” (Scheffler, 1974, p. 204). If this is the case, then

learners can induce the necessary theories they need to solve problems during those same problem-solving activities. On this view, there is no need to encumber adult learners with antecedent scientific theory. Instead, education should proceed by allowing adult learners to discover the theories they need on the way to solving what they themselves consider to be practical problems.

First, the temporal aspect of immediacy needs to be addressed. Hundreds of thousands of adults embark each year in formal programs of study at the college level cognizant that their professional careers in their chosen area of study will be delayed until they graduate and, in some cases, delayed until they pass licensing exams. Thus, all knowledge is not immediate in this sense. Second, students of science need to learn the underlying concepts and principles of a discipline even if it means learning to solve the important problems that have already been solved (Bereiter, 1994; Kuhn, 1970). Particularly, for health-science students, it is better to learn some things prior to professional practice.

One can argue, that there are some things that pre-professional nursing students should learn prior to professional practice, even if it means that the material needs to be transmitted to them rather than individually constructed. According to many constructivists, the transmission of knowledge, or didactic pedagogy, should be avoided. This position is considered extreme, even by some constructivists. The problem, according to constructivist Paul Cobb (1994), is that pedagogies “derived from constructivist theories frequently involve a collection of questionable claims that sanctify the student at the expense of . . . scientific ways of knowing” (p. 4). Even if teachers

merely make suggestions to students, it violates a canon of constructivist thought, which holds that students are to construct their own scientific ways of knowing individually (Cobb, 1994). Such a strict constructivist prohibition may not even be what the pragmatists intended. “As John Dewey observed, it is then but a short step to the conclusion that teachers are guilty of teaching by transmission if they do more than stimulate students’ reflection and problem solving” (Cobb, 1994, p. 4). While it is certainly true that Dewey did not want to make students passive receptacles of information by lecturing to them, Dewey, himself, was certainly not averse to lecturing. In fact, a former student describes Dewey’s hour-long lectures at Teachers College, which are characterized as a methodical, painstaking elaboration of ideas (Larrabee, 1959). As a student, “One rarely left the classroom without the conviction that something intellectually and practically had been said” (Larrabee, 1959, p. 54). Dewey (1933/1986) thought that it was the teacher’s duty to take charge “at the critical junctures where the experience of pupils is too limited to supply just the material needed” (p. 334). This is because Dewey did not believe “that, out of due respect for the mental freedom of those taught, all suggestions are to come from them” (p. 334). Dewey believed that it was the teacher’s responsibility to make sure that the ideas entertained in the classroom honored the disciplines and the students’ efforts to learn them (Prawat, 2000). The confusion surrounding Dewey’s intent as to whether learning should start with the student’s own ideas or from the ideas offered by the various disciplines, no doubt stems from some of his early writing. Dewey (1897/1972) writes that “the child’s own instincts and powers furnish the material and give the starting point for all education” (p. 85). Otherwise,

“education becomes reduced to a pressure from without. It may, indeed, give certain external results but cannot be truly called educative” (p. 85).

Sometimes very specific information needs to be conveyed to students. This would include information that students cannot, or should not, construct on their own. One area in which precise information is important is in the administration of prescribed medications. Pre-nursing students not only learn why particular medications are administered under very specific conditions but also of the dangers of these same medications if administered under inappropriate conditions. Thus, a nurse who is knowledgeable of (a) his or her patient’s current medical condition, (b) how this condition relates to medications that have been prescribed, and (c) how the patient should respond to the medications, is better able to provide for that patient’s welfare. This is an example of the kind of knowledge students should learn prior to their professional careers. A nurse who questions, for example, an order for the administration of an intravenous solution of potassium chloride to a patient who already has a higher than normal blood potassium level, is acting on prior learning. The student may recall from his or her previous education that either too much or too little blood potassium is lethal. Just as parents transmit certain prohibitions to their children, warning them of potential life-threatening dangers, important information can be transmitted to nursing students as well. Thus, it is hard to imagine how the transmission of subject matter can be deemed unimportant in all cases. Nonetheless, in order to cast aspersions on all forms of didacticism, some constructivists employ a rhetorical device which is to ascribe didactic pedagogy to philosophical positivism.

Once some position is identified as “positivist,” then it can be dismissed; such identification is basically the end of any argument. It is difficult to think of any term in the educational lexicon so laden with negative connotations as “positivism.” (Matthews, 2004c, p. 7)

However, as noted above, neither realist nor constructivist philosophy has really anything to do with pedagogical issues of teaching and learning. The same is true of philosophical positivism. Nonetheless, one constructivist maintains that an “[e]mphasis on subject matter stems from the positivist tradition of transmitting knowledge from instructors to students” (Baxter Magolda, 1999, p. 103). Notwithstanding the pejorative connotation of positivism ascribed by some constructivists to certain pedagogical issues, such as the transmission of ideas, there are many educators who believe that some ideas are not only worth conveying to students but that some important knowledge cannot be constructed by students on their own.

The subordination of prerequisite knowledge surfaces in other ways as well. For example, it is implied when pragmatist constructivist Eric Bredo (2000) maintains that truly constructivist pedagogies allow students the opportunity to contribute to the “remaking of ‘reality,’” as they interact with objects (p. 132). In this sense, knowledge is immediate, both in terms of its derivation and application. Each time a learner interacts with the environment the environment is said to be reconstructed. On this reading, there is no need to consider how others who have gone before have conceived of the same objects. In fact, according to pragmatist constructivism, objects only become objects during their current instrumental usage (Bredo, 2000; Mead, 1938).

Adult educator and constructivist Philip Candy (1991) implicitly rejects the notion of prerequisite knowledge through his denial that an objective reality can be known and thus communicated to students. Candy (1991) writes that the “‘objectivist’ . . . view has been very influential in shaping conceptions of teaching, because it implies that there is an objective reality, to which learners should be introduced” (p. 262). Candy agrees with the radical constructivist Ernst von Glasersfeld, that the “‘constructivist perspective differs significantly from the view of knowledge as deriving from a process of copying or replicating” (p. 263). Although Candy is correct to maintain that scientific knowledge is not an exact mirror of reality, he goes too far when he dismisses all correspondence theories of truth. This leaves no room either for scientific knowledge, as it is envisaged by scientists, or for scientific methodologies. Thus, Candy is left with the idea that “[t]eaching is not a process of transmitting knowledge intact to learners, but a matter of negotiating meanings” (p. 278). There are two problems with this view. First, scientific knowledge is not negotiated by learners in classroom settings (Lawson, 2000). Second, there are demonstrated cases of prior science knowledge being beneficial to adults’ later academic success (Higgins, 2003).

Scientific knowledge is not negotiated by college students. Arizona State University biologist Anton Lawson (2000) states: “In the final analysis, ideas—including scientific hypotheses and theories—stand or fall, not due to social negotiation, but due to their ability to predict future events” (p. 577). Lawson applies this to education. “The primary instructional application is that science instruction should remain committed to helping students understand the crucial role played by hypotheses, predictions and

evidence in learning” (p. 577). The reason for this is that an understanding of the knowledge structure of science aids in the acquisition of scientific concepts of a theoretical nature. Lawson and his science colleagues (Lawson et al., 2000) explicate this idea, when they write that

Evidence has been obtained consistent with the view that some students, perhaps fewer than one third . . . develop thinking skills associated with hypothesis testing when the hypothesized entities are unobservables. As has been found in previous studies, these thinking skills appear to facilitate the acquisition of knowledge about, and the understanding of, scientific concepts. (Lawson et al., 2000, p. 1011)

Students must learn to think scientifically, both as an end in itself and because it furthers scientific concept acquisition—“many, if not, most of the concepts that fill the syllabi of college courses are of the hypothetical and theoretical nature. . .” (p. 1011). This leads to an important educational point. Unless the knowledge structure of science is somehow communicated to students, they will not discover it on their own. Matthews (1994) writes that “Western science is not natural, it does not automatically unfold as children either confront the world, or participate in culture” (p. 161). Lawson (2000) argues that the ability of “thinking in theoretical concepts” speaks to the reason for “the difficulty that many adolescents and adults experience” with science (p. 595). Thus, even the ability to think scientifically represents a form of prerequisite knowledge that aids further learning, and it must be passed from teacher to students. It is not negotiated.

When adult educators maintain that adult learners should play a primary role in determining course content, they overlook the value of prerequisite knowledge,

knowledge that is learned prior to its application, oftentimes by learners who might not fully appreciate its value until later. On the other hand, many adult educators understand the importance of prerequisite knowledge as it relates to student success. This includes prerequisite scientific knowledge.

Because an understanding of scientific concepts is considered crucial to student success in the health sciences, many community colleges have implemented tests of scientific understanding to gauge students' potential for success. Cape Fear Community College in North Carolina assesses students' science knowledge in preadmission tests for various health-science curricula.

This part of the test determines a person's accumulated information of the Natural Sciences on a *fundamental* level. Knowledge of the Natural Sciences (biology, chemistry, health safety, etc.) is important to the course of study of [*sic*] Nursing and Allied Health program. There are certain concepts that are related to Natural Sciences, which must be understood as essential . . . (Cape Fear Community College, 2004, original italics)

One study at a community college in Texas found that science knowledge is essential both for nursing program completion and for passing the national registered-nursing (RN) licensing exam (NCLEX-RN) (Higgins, 2003). Preadmission testing allows educators to implement remediation for students who are at-risk and to identify students who have the greatest potential for success. Regardless of how the test is used, there is widespread agreement that scientific understanding is crucial for student success. In trying to determine success predictors for nursing program completion and NCLEX-RN exam

passage, Higgins (2003) looked at several variables which were divided into three categories. The three categories were academic (courses in English, biology, chemistry, psychology), preadmission test scores (verbal, math, nonverbal, spelling, science, vocational adjustment index, reading), and demographic descriptors (age, gender, race). The results of the study indicate that the following variables were statistically significant predictors for nursing program completion: academic (biology), preadmission test scores (math, science, reading), and demographic descriptors (none). With regard to subsequent passage of the RN licensing exam, the significant predictive variables were: academic (biology), preadmission test scores (science), and demographic descriptors (none).

The important notion of prerequisite knowledge enlarges our understanding of adult education's notions of immediacy, relevancy, and self-direction. Scientific concepts are not relevant because they are immediately apprehendable, or because they can be applied immediately or directly to practical problem solving. They are relevant, because they are foundational to aspects of nursing education and practice that can neither be obtained from nor verified by experience. Hand washing is a case in point. Not until the germ theory of disease, which surfaced during the mid-nineteenth century, did health-care professionals devise measures for controlling the spread of microbial infection, such as hand washing. Unfortunately, even today "a lack of hand washing by hospital staff and physicians, even in developed nations, ranks as a major mechanism for disease transmission from patient to patient" (Pommerville, 2004, p. 16). If the reason for hand washing arose from experience in the form of practical problem solving or was verified in experience, then the practice of hand washing would continually reinforce itself. This is

not the case, however. In educational settings, it is only because of the germ theory of disease that the problem of disease transmission is even recognized. The germ theory of disease which gives rise to our understanding of the necessity of hand washing is something that must be learned. And in order for it to be learned, it must be taught. But it cannot be taught unless it is deemed worthy of being taught. And this recognition comes from an understanding of the basic scientific principles and the problems in a particular field and how they apply to professional practice. Consequently, when health-care professionals practice something as simple as routine hand washing, they are applying prerequisite, theoretical scientific knowledge. Henceforward, theoretical knowledge can be rightly thought of as prerequisite knowledge, since it guides scientists and students alike in their professional activities.

At the bottom of the debate regarding the strength of student-centered approaches to learning are the two definitions of knowledge raised earlier, traditional and experiential (Caffarella & Barnett, 1994). On the one hand, science educators from a realist perspective maintain that scientific knowledge does not arise as a result of social construction or negotiation (Lawson, 2000; Phillips, 2000a). On the other hand, adult educator Philip Candy (1991), working from a social constructivist position, maintains that “[c]ommonly accepted categories of understanding are socially constructed,” meaning “that many aspects of a person’s knowledge are actually shared with others, being influenced by factors such as age, gender, class, and cultural background . . .” (pp. 256, 278). While Candy is correct in his assertion that sociological considerations may influence the scientific enterprise, they are not significant determinants of its knowledge

claims (Phillips, 2000a). In her study of nursing student success factors, a study which included 213 students, Higgins (2003) reports that none of the demographic descriptors—age, gender, race—were statistically significant indicators either for nursing program completion or for licensing passage, albeit an understanding of science was significant in both instances, and the only significant indicator in the second instance.

When adult educators place students at the center of the process of knowledge construction by (1) according experiential knowledge epistemological status (Jackson & MacIsaac, 1994; Caffarella & Barnett, 1994); by (2) asserting that knowledge is “influenced by factors such as age, gender, class, and cultural background” (Candy, 1991, p. 278); and by (3) asserting that knowledge is a “matter of negotiating meanings” (Candy, 1991, p. 278), they set the stage for leading students away from scientific understanding. Phillips (1973) notes:

Certainly, a teacher must think it worthwhile listening to what his pupils say, but the relationship between the teacher and what is said must be a critical one and it is in terms of intellectual criticism that a distinction appears between what is said and what is worth saying. Without such a distinction, there can be no academic standards and hence no deep inquiry into any subject. (Phillips, 1973, p. 140)

*Is Theoretical Knowledge Inductively Abstracted from Experience?*

Induction is the idea that generalizations can be abstracted from the particulars of experience. The issue is whether scientific theories can be derived inductively. The

question arises because some experiential learning models in adult education that stem from Dewey are based on inductive logic.

Dewey presumed that conceptual understanding arises as students abstract generalizations from their experiences (Prawat, 2000). A little more than a century ago, Dewey (1898/1972) wrote: “After the conquests of the inductive method in all spheres of scientific inquiry, we are not called on to defend its claims in pedagogy” (p. 545).

Adult educators call attention to experiential learning models which presume that not only can learners abstract generalizations from concrete learning experiences but that, after reflection and the consideration of different perspectives, learners are able to develop theories which can then be tested in real-world settings (Lewis & Williams, 1994; Merriam & Brockett, 1997). Both the logic of induction and its latent manifestation in some adult learning perspectives deserve attention.

There are two points to be made regarding the logic of induction as it relates to science and, subsequently, science education. The first point is that, “by the late nineteenth century this methodological orientation had largely vanished from the writings of major scientists and methodologists” and that “most of the traditional rules of inductive reasoning had been superseded by the logic of hypothetico-deduction” (Laudan, 1998b, p. 151). Philosopher of science Larry Laudan (1998b) argues that, although it is difficult to set an exact date of when this occurred, “probably no scholar would quarrel with the claim that it comes in the period from 1800 to 1860” (p. 151). Allowing that this change occurred as late as 1860, Dewey’s 1898 assertion regarding “the conquests of the inductive method in all spheres of scientific inquiry,” was behind the times by some 40

years. Although Dewey would later abandon his view regarding the logic of induction as foundational to both science and education in general, many in education today still view Dewey as an inductionist and the champion “of what has been variously termed an activity-based, problem-centered, or hands-on approach to education” (Prawat, 2000, p. 805). The second point to be made regarding the logic of induction is why it was abandoned by science. The logic of induction fell out of favor once scientists began positing unobservables as part of its theorizing. Induction simply does not lead to higher order ideas in science, such as theories. Max Charlesworth (1982) explains that induction, even if it is a valid form of inference, will yield generalisations of the type “all metals expand when heated” or “in all gasses volume varies inversely with pressure.” Induction will never yield those higher generalisations we call scientific *theories*, such as the theory that matter has an atomic structure or the theory that energy can be transformed but never destroyed. (Charlesworth, 1982, p. 18, original italics)

The practice of positing unobservable objects represents a watershed both for science and science education. Realists contend that the unobservable entities and processes posited by scientific theories do not arise from experience either by abstracting or generalizing. Einstein (1934/1954) wrote that “it is true that the axiomatic basis of theoretical physics cannot be extracted from experience. . .” (p. 274). This realist view opposes experiential learning models in adult education which maintain that theories can be abstracted from learners’ concrete experiences.

Experiential learning is enormously popular in adult education (Merriam & Brockett, 1997). Merriam and Caffarella (1999) cite Dewey (1938) who once wrote that “all genuine education comes through experience” (p. 13). David Kolb’s (1984) experiential learning model is popular in adult education (Merriam & Caffarella, 1999). It was influenced in part by Deweyan pragmatism (Kolb, 1984). The immediate question regarding Kolb’s experiential learning model is whether it is inductionist. Lewis and Williams (1994) describe David Kolb’s (1984) model as a four-part process:

- 1) Learners have concrete experiences;
- 2) [T]hen they reflect on the experiences from a variety of perspectives.
- 3) From these reflective observations learners engage in abstract conceptualization, creating generalizations or principles that integrate their observations into theories.
- 4) Learners then use these generalizations as guides to engage in further action, called active experimentation, where they test what they have learned in other more complex situations. This leads to another set of concrete experiences and another round of learning at a more sophisticated level. (adapted from Lewis & Williams, 1994, p. 6)

If one follows the logical progression of events—concrete experience, reflection on the concrete experience, abstract conceptualization, creating generalizations that integrate observations into theories—they epitomize classical empiricism. Further, that adult learners “test what they have learned in other more complex situations,” exemplifies the instrumentalist verificationism of logical positivism adopted by the pragmatists and

reformulated as the pragmatic criterion of meaning. Kolb (1984) captures both the verificationist aspect of his learning model and its broader empiricist framework when he notes: “Two aspects of this learning model are particularly noteworthy. First is its emphasis on *here-and-now concrete experience* to validate and test abstract concepts” (p. 21, original italics). Educationally, when learners abstract theories from concrete experiences and then validate them in the “here-and-now” experiential world, they are following Mead’s empiricism.

Adult learners are presented a formidable task when they are asked to abstract scientific theories from concrete experiences. But this is exactly what some experiential learning models require of them. Philosopher Wallis Suchting (1992) describes the difficulty of abstracting what might seem like an easy concept, the color red.

Abstraction theories in general are essentially circular because the alleged process of abstraction already presupposes the concept which is supposed to be formed as the result of that process. . . . I must already have a rudimentary command of the concept intended if I am to realise what is meant. (Suchting, 1992, p. 239)

In the absence of any guidance that would clue adult learners as to what to construct or how it should be constructed, educators, students, and anyone else who is concerned with science education can rightly ask the same question: What are students constructing? Students’ discussions of data in science classes may not necessarily be linked with scientific theories (Brickhouse, Ford, Kittleson & Lottero-Perdue, 2003). Therefore, one of the tasks of the teacher is to introduce theoretical ideas to students (Brickhouse, Ford, Kittleson & Lottero-Perdue, 2003).

Experiential learning models in some cases are not the answer to adult science education. This is true when the assumption is made that students are best served when they, themselves, determine the topics to be studied. The problem with this approach is that it presupposes several things of which students are not likely aware. These include disciplinary knowledge, a discipline's knowledge structure, what the discipline deems as tractable problems, and how these problems are approached and solved. In science education contexts, students do not gain this type of knowledge necessarily as the result of following their interests. Moreover, students cannot, as some adult experiential learning models suggest, abstract scientific theories from concrete experience. Finally, when experiential learning models follow inductionist and abstractionist theories of knowledge and employ empiricist epistemologies and methods, this suggests that they may be alien to contemporary scientific realism and, hence, scientific understanding.

## CHAPTER FIVE

### Study Conclusions, Constructivism in Adult Education, Educational Implications, and Recommendations

#### *Introduction*

In this chapter, I shall discuss the main conclusions of my study of constructivism, how the findings relate more generally to constructivism in adult education, and make recommendations for future study of constructivism as it relates to adult and science education. These discussions will incorporate the main themes of each of the chapters of this study, which include: (a) introduction of pragmatist constructivism as an influential and potential science education learning orientation for adult learners (Chapter One), (b) methods for assessing constructivism as a science education referent (Chapter Two), (c) characterization of Mead's constructivist philosophy of natural science (Chapter Three), and (d) assessment of pragmatist constructivism as a science education referent for adult learners (Chapter Four).

In the first section of this final chapter, "Findings in the Context of Current Topics in Adult Education," I shall relate the general findings of this study to adult science education. In spite of the narrow focus of my study, the question arises as to how it might relate to constructivism in adult education more generally. In order to understand the epistemological influence of constructivism on adult education, it is necessary to be able to (a) recognize the presence of constructivism in adult education, (b) identify its epistemological origins, and (c) recognize its current epistemological nature. Thus, in the second section of this Chapter, "Constructivism in Adult Education," I shall show how

constructivism is currently manifested in adult education. Although constructivism is considered a “prevalent and influential adult learning theory,” (Fenwick, 2000a, p. 248), it is also a theory of teaching (Caffarella & Barnett, 1994) and an epistemology (Brookfield, 2000; Candy, 1991). It is the epistemological dimension of constructivism that is of greatest concern for adult science education, because it often affects theories of teaching and learning. In “The Origins of Constructivism in Adult Education,” I shall briefly discuss the three major historical epistemological strands of constructivism that influence adult education, namely those which stem from Piaget, Dewey, and Kuhn. In addition to its early historical influences, constructivism in adult education has been affected more recently by postpositivist philosophy of science and postmodernist philosophy. In some cases, constructivism is an amalgamate of all three—pragmatist, postpositivist, and postmodernist—influences. Consequently, in “The Nature of Constructivism in Adult Education,” I shall identify the epistemological dimension of pragmatist, postpositivist, and postmodernist forms of constructivism in adult education and discuss how each relates to natural scientific understanding. Finally, in “Recommendations for Adult Graduate Education, Educators, and Further Research,” I shall make suggestions, as the heading suggests, based on the findings of this study.

#### *Findings in the Context of Current Topics in Adult Education*

This study focused on pragmatist constructivism as a referent for adult science education. This was in keeping with pronouncements by social constructivists that pragmatist constructivism is a viable referent for science education (Bredo, 2000;

Bentley, 1998) and with the general importance of pragmatist constructivism generally in adult education (Brookfield, 2000; Merriam & Brockett, 1997). Because of the strong influence of pragmatist constructivism in adult education, this study sought to determine specifically whether the employment of George Herbert Mead's (1938) philosophical doctrine known as "the act" would (a) enable students to acquire scientific concepts, (b) adequately portray the methods of science, and (c) prepare students for careers in science and science-related fields.

As a science education referent, pragmatist constructivism is much more than just a pedagogical theory of teaching and learning. It is also an epistemology; and, "as an epistemology, constructivism speaks to the nature of science" (Bentley, 1998, p. 243). However, pragmatist constructivism is incompatible with the way a large majority of scientists understand their own work. Pragmatist constructivism incorporates instrumentalist scientific methodology, anti-realist metaphysics, and subjectivist epistemology—all of which are incompatible with contemporary scientific understanding. The problem is not just that pragmatist constructivism and scientific realism are incompatible. Part of the problem is that constructivist learning theories often become the instantiations of constructivist philosophy. However, learners simply cannot read scientific meaning off of their immediate experiences, as is suggested by pragmatist constructivist learning theory.

Consequently, this study does not support the thesis that pragmatist constructivism is a viable referent for science education. This determination was made on the basis of the ability of pragmatist constructivism to aid learners in (a) scientific

concept acquisition, (b) learning the methods of science, and (c) preparing for careers in science and science-related areas. Mead's science opposes not only the realist account of the scientific revolution in terms of acquiring Newtonian concepts, such as force and mass; it also opposes the realist account of the science of mechanics of Mead's own day as depicted in the work of Einstein. In terms of scientific method, Mead's instrumentalist science is not adaptable to controlled experimentation, a method which is designed to test for the existence of unobservable, hypothetical objects that may be responsible for observable phenomena. As this study indicates, Mead's science sits uneasily with the protozoan malarial parasite, which was discovered a quarter-century before Mead articulated his doctrine. As for the preparation of future scientists and professionals in science-related areas, it seems that there are several sorts of problems for constructivism aside from the aforementioned difficulties associated with concept acquisition and scientific methodology. The constructivist practice of encouraging learners to envisage, design, implement, and assess their own science courses may be problematic for several reasons. First, when it comes to learning difficult subjects such as science, many adult learners desire more teacher direction (Ellsworth, 1992; Slusarski, 1994). Second, some adults may wish to spend their time learning science rather than designing, implementing, and evaluating courses. Designing, implementing, and assessing science courses is time consuming. Often it is an iterative process that precedes and extends beyond any one academic term. Furthermore, because the subject-matter content of some curricula is in some cases largely constrained by various external licensing and accrediting agencies, many of the basic components of curricula are predetermined. Third, paradoxically, the

designing of science courses requires a foreknowledge not only of science but of what is important to learn and why. Students in need of science courses do not have such foreknowledge. Pre-nursing students, for example, who have never been exposed to physiology will not necessarily demand to learn chemical, biochemical, cellular, and physical principles that are foundational for understanding human physiology. Similarly, not all students are necessarily aware of the importance of mathematics for physics. The importance of mathematics in physics is described by physicist Richard Feynman in a letter to a high school student.

To do any important work in physics a very good mathematical ability and aptitude are required. Some work in application can be done without this, but it will not be very inspired. If you must satisfy your “personal curiosity concerning the mysteries of nature” what will happen if these mysteries turn out to be laws expressed in mathematical terms (as they do turn out to be)? You cannot understand the physical world in any deep or satisfying way without using mathematical reasoning with facility . . . (Feynman, 2005, p. 47)

If curriculum design becomes the responsibility of the learners, then the first activity students would need to engage in would not be learning science but designing curricula. This seems, however, like a digression from learning. Setting aside the matter of whether adult learners should design their own curricula, the question can be asked whether the implementation of such a curriculum, which entails self-direction, is always beneficial. In other words, does the adult learner gain a learning advantage by virtue of having designed

a particular course? Brookfield's (1985) answer to the question is no. Brookfield notes that it may be

possible to be a superb technician of self-directed learning in terms of one's command of goal setting, instructional design or evaluative procedures, and yet to exercise no critical questioning of the validity or worth of one's intellectual pursuit as compared with competing, alternative possibilities. (Brookfield, 1985, p. 29)

Just because adult learners elect to relinquish some aspects of the teaching and learning situation does not mean that they become passive participants in the educational process. Candy (1991) notes that "the fact that a learner does not choose to exercise control in a particular educational setting cannot be taken as evidence that he or she lacks personal autonomy in the broader sense" (p. 21). In other words, autonomy means having the ability to exercise more or less personal control as one perceives the need. Paradoxically, then, the notion of student autonomy must be extended to include the desire on the part of some students to be taught. On this view, Candy writes that

anyone who is unfamiliar with a subject or topic may well choose to submit to being taught, at least at the beginning. This does not necessarily imply any pathological lack of [personal autonomy], but rather an acknowledgment that the best way to master the rudiments of a new area is to be taught by an expert. (Candy, 1987, cited by Candy, 1991, p. 21)

Shulman (1986) describes what he considers to be a key component of good instruction, which is referred to as pedagogical knowledge that a teacher must possess.

Within the category of pedagogical knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that makes it comprehensible to others. (Shulman, 1986, p. 9)

The fact that some adult learners choose to be taught in some settings is something that seems to be overlooked in some constructivist discourse. Geary (1995) recognizes that much constructivist thought results from educators imposing an agenda on science, not necessarily in conformity with how scientists view their own discipline.

In sum, constructivism is largely a reflection of current American cultural beliefs and, as such, involves the development of instructional techniques that attempt to make the acquisition of complex mathematical skills an enjoyable social enterprise that will be pursued on the basis of individual interest and choice. (Geary, 1995, p. 32)

Mead's constructivism was out of favor with the realist tradition which both preceded and followed him. Consequently, if students learn science by emulating Mead's science, then they come away with an understanding of both the knowledge structure of science and its methods different from that of practicing scientists. The problem with Meadian-inspired approaches to education is its conflation of scientific method and pedagogy. On this view, adults construct knowledge based on immediate, individual experience. However, scientists and philosophers alike note that scientific knowledge is not anchored either in observation or in experience. Historian Alexandre Koyré notes that

observation and experience—in the meaning of brute, common-sense observation and experience—had a very small part in the edification of modern science; one could even say that they constituted the chief obstacles that it encountered on its way. . . . the empiricism of modern science is not *experiential*; it is *experimental*.  
(Koyré, 1968, p. 90, original italics)

The primacy of experience and observation stems from Aristotle, and it is preserved by 20<sup>th</sup> century logical positivists and logical empiricists. The positivists “were also Aristotelian as regards the primacy they accorded observation, and observation statements in their logic of science” (Matthews, 2000c, p. 265). On the one hand, constructivism represents in some ways a return to pre-Renaissance science. On the other hand, it shares several basic commitments of positivism (Matthews, 2004c). Ernest Nagel, whom Matthews describes as a representative of positivist philosophy, notes the roles of observation and experience in positivist science.

Scientific thought takes its ultimate point of departure from problems suggested by observing things and events encountered in common experience; it aims to understand these observable things by discovering some systematic order in them; and its final test for the laws that serve as instruments of explanation and prediction is their concordance with such observations. (Nagel, 1961, p. 79)

This emphasis on experience is important to an understanding of both pragmatism and constructivism. There are striking resemblances between positivism and pragmatism (Phillips, 2004), on the one hand, and between positivism and constructivism (Matthews,

2004c), on the other. These will be discussed in the section “The Nature of Constructivism.”

Some experiential learning theorists in adult education recognize experientially derived knowledge (that is, knowledge derived from learners’ own experience, not from the work of scientists) as a legitimate form of knowledge, which they place on the same level as disciplinary knowledge. In their discussion of the conceptual foundations of experiential learning, adult educators Jackson and MacIsaac (1994), for example, promote “*definitions of knowledge*, which recognizes [*sic*] experiential learning as an important form of knowledge” (p. 23, original italics). Referring to the work of adult-learning forebears Kidd and Knowles, adult educators Caffarella and Barnett (1994) note that “the learner’s experience as part of the knowledge base has been promoted in adult learning for decades” (p. 35). It is here that Caffarella and Barnett contend that experiential knowledge in adult education is on the same plane as disciplinary knowledge: “Other forms of knowledge as legitimate in formal settings, and more specifically experiential knowledge, have been discussed by a number of authors” (p. 35).

The legitimization of experiential knowledge, along with the call for constructivist teaching (Caffarella & Barnett, 1994), is one thing. However, when attention turns to science education, the question arises as to how adult learners are to construct, for example, important concepts which simply cannot be derived from experience, such as the Newtonian concepts of inertia, force, and mass, or the Galilean concept of acceleration. Many of the scientific concepts that adults meet in freshman college science courses are highly abstract, cannot be experienced, and are counter intuitive.

Many science educators are interested in finding out how, on constructivist principles, one teaches a body of scientific knowledge that is in large part abstract (depending on notions such as velocity, acceleration, force, gene), that is removed from experience (propositions about atomic structure, cellular processes, astronomic events), that has no connection with prior conceptions (ideas of viruses, antibodies, molten core, evolution, electromagnetic radiation), and that is alien to common-sense, and in conflict with everyday experience, expectations, and concepts? Teaching a body of knowledge involves not just teaching the concepts, but also the method, and something of the methodology or theory of method. How all of this is to be taught, without teachers actually conveying something to pupils, is a moot point. (Matthews, 2002, p. 129)

The constructivist discourse in teaching has oftentimes valued what students bring to the learning setting in terms of their own experiences (Caffarella & Barnett, 1994). “The constructivist discourse, along with andragogy, has represented another movement away from content and teacher-centered education, to learner and learner-centered education” (Pratt & Nesbit, 2000, p. 121). On this view, constructivist teaching allows learners to give meaning or “make sense out of the perplexing variety and constantly changing texture of their experiences” (Candy, 1991, p. 98). “The aim of teaching from this [constructivist] framework is not just transmitting knowledge, but negotiating meaning embedded in the multifaceted realities that students bring with them to learning experiences” (Caffarella & Barnett, 1994, p. 37). When constructivism aims to challenge students’ “ways of thinking” and help them construct “more desirable ways of knowing”

(Pratt & Nesbit, 2000, p. 121), few educators would disagree with these educational aims. However, some science educators would strongly disagree with the manner constructivists propose to reach these aims, which calls for a “movement away from content and teacher-centered education, to learner and learner-centered education” (Pratt & Nesbit, 2000, p. 121). It seems that in the process of moving away from so-called teacher-centered education, constructivists create another dualism by overemphasizing student-centered education. Furthermore, to downplay disciplinary knowledge—by sidelining educators who are knowledge experts—in favor of “negotiated meaning” which is “embedded in the multifaceted realities that students bring with them to learning experiences,” misses the point of science education. Scientific knowledge is not anchored in students’ experiences. Nor is scientific knowledge the result of social negotiation (Lawson, 2000). Although Dewey is considered to be a major force behind constructivist views of education, there is evidence to suggest that Dewey would question some of the practices that have been ascribed to him (Prawat, 2000). Deweyan scholar Alan Ryan (1998) describes the excesses of progressivism which Dewey detested but which bear great resemblance to some constructivist ideals.

“Progressive education” later came to be a label for an educational theory that *overemphasized* the importance of teaching what interested the child, and *overemphasized* the child’s responsibility for what went on in school. Dewey was utterly hostile to progressive education so described. He feared that his emphasis on the need to take the child’s abilities and interests seriously had been taken as a license to abandon teaching entirely. “Child-centered” education had come to

mean that it did not matter what the teacher did. For any such view he had complete contempt. His views were “teacher centered.” (Ryan, 1998, p. 397, original italics)

If constructivism could provide students a way of acquiring a body of knowledge based on personal interests and personal experiences, then constructivism would have a lot to offer science education. However, the prominent British science educator Joan Solomon (1994) notes that “Constructivism, in the sense that it is used within science education . . . has always skirted round the actual learning of an established body of knowledge” (p. 6). Constructivist thinking evolved such that “no hard line could be drawn, it seemed, between the ideas held by the learning child and those of practising scientists” (p. 10). “Thus, it became politically correct to accord to children’s ideas all the deference and respect that one would give to scientific theories” (p. 10). On the other hand, many adults who enroll in college science courses do not labor under the notion that they are experts in science. Many adults enroll in college science courses with the expectation that not only will they be taught by subject-matter experts but by teachers who can answer their questions regarding (a) the material at hand, (b) how the material relates to their experiences, and (c) how the material relates to future practice.

Certainly experience is important to science. But experience is not the overriding factor in the determination of its knowledge claims. Scientific knowledge results from an interplay between theory and highly “significant experiences” in which theory is tested in highly controlled situations against nature (House, 1991, p. 5). House describes the

interplay of antecedent theory, significant experiences, and the need for controlled experimentation in science.

Experiences are not necessarily significant. Rather, one must work to produce significant experiences, and scientists sort out significant from insignificant experiences through antecedent knowledge. By prior substantive knowledge, the experimental scientist tries to exclude external influences and to trigger the causal entity under study so that entity acts in relative isolation. (House, 1991, p. 5)

Students do not learn science only by practical inquiry. Students must also learn what scientists consider as reputable knowledge (Solomon, 2000). The idea that students are somehow able to learn science largely by inquiry ignores the many struggles of past generations of scientists whose ideas and empirical findings are foundational to current understanding. When Léon Foucault, for example, conducted his thought experiment in which he set into motion an idealized Newtonian pendulum oscillating above the North Pole, it was based on the previous theorizing, methods, and experiences of Copernicus, Galileo, Newton, and countless others. Thus, it seems that

learning science involves being initiated into the culture of science. If learners are to be given access to the knowledge system of science, the process of knowledge construction must go beyond personal empirical inquiry. Learners need to be given access not only to physical experiences but also to the concepts and models of conventional science. (Driver, Asoko, Leach, Mortimer, & Scott, 1994, p. 6)

### *Constructivism in Adult Education*

Over the past few years, the influence of constructivism has been increasingly recognized in adult education (Brookfield, 2000; Caffarella & Barnett, 1994; Candy, 1991; Deshler & Grudens-Schuck, 2000; Fenwick, 2000a; Hayes & Wilson, 2000; Jackson & MacIsaac, 1994; Merriam & Brockett, 1997; Merriam & Caffarella, 1999).

One adult educator refers to constructivism as a “prevalent and influential adult learning theory” (Fenwick, 2000a, p. 248). The multi-dimensional aspect of constructivism is recognized by adult educators. That is, constructivism is recognized in adult education as a theory of teaching (Caffarella & Barnett, 1994; Candy, 1991; Jackson & MacIsaac, 1994), a learning orientation or learning theory (Askov, 2000; Candy, 1991; Fenwick, 2000a; Lee & Caffarella, 1994; Merriam & Caffarella, 1999), as well as an epistemology (Brookfield, 2000; Candy, 1991; Merriam & Brockett, 1997).

Although there are occasional references to epistemological constructivism in adult education, there are also references of an epistemological nature that are not identified as such. It is therefore important that educators be able to recognize the epistemological dimension of constructivism and to separate it from its teaching and learning dimensions. This is not always easy to do in practice as Matthews notes.

Unfortunately the different dimensions of constructivism [are] often treated as a package deal, whereby being a constructivist in learning theory is deemed to flow on to being a constructivist in all the other areas, and being a constructivist in pedagogy is deemed to imply a constructivist epistemology and educational theory. (Matthews, 2002, p. 124)

In determining the influence of epistemological constructivism in adult education, it is useful to document some of the overt references to epistemological constructivism found in the literature but also to provide some of the more subtle allusions to epistemological constructivism. In this section, some of the epistemologically related claims found in the adult education literature will be noted. The nature of the claims and their constructivist origins will be discussed more fully in the following sections.

In describing “constructivist views of knowledge and self” that relate to prudent action, Hayes and Wilson (2000) write that “knowledge is socially constructed rather than linked to any kind of ‘objective’ reality” (p. 671). That knowledge is socially constructed is a truism, an idea that is readily accepted by realists and non-realists alike. This does not mean, however, that knowledge communities are free to construct whatsoever they wish. Realists believe that nature constrains our knowledge constructions. The further constructivist claim by Hayes and Wilson, that knowledge is not linked to any kind of objective reality, is open to various interpretations. On the one hand, to state that knowledge is not an exact copy of reality, or that it does not mirror reality, is true. The real world and our theorizing about it are separate things. Scientific knowledge of an object, for example, is not the same thing as the object itself. On the other hand, the claim that knowledge does not in some way refer to a mind-independent, external reality is a dismissal of correspondence theories of truth. The realist asks: If our knowledge claims do not refer in some way to the real world, then to what do they refer? And, if our knowledge claims do not refer to an independently existing reality, what means do we have for evaluating our scientific knowledge claims? To the extent that constructivists

claim “that reality apart from the knower does not exist” (Merriam & Brockett, 1997, p. 46), they are consorting with the discredited philosophy of idealism.

Care must be taken to distinguish claims regarding the social construction of social knowledge, on the one hand, and the social construction of natural scientific knowledge, on the other hand. Oftentimes when adult educators discuss social issues, they are referring to the former rather than to the latter. Most philosophers would have no problem with the idea, in this case, that social realities—languages and traffic laws, for example—are socially constructed, though there is a famous theory in linguistics that language structure, in important ways, is in us innately. When attention turns to the social construction of natural scientific knowledge, however, scientists and philosophers alike balk at the suggestion proposed by some social constructivists that disciplinary knowledge “*can be fully explained, or entirely accounted for, in sociological terms*” (Phillips, 2000a, p. 8, original italics). Phillips writes that

on this view what is taken to be knowledge in any field has been determined by sociological forces including the influence of ideologies, religion, human interests, group dynamics, and so forth. To repeat the point made earlier, this group of thinkers wishes to deny that so called knowledge is in any sense a reflection or copy of the “external reality” that the community in question is investigating. (Phillips, 2000a, pp. 8-9)

Phillips quotes philosopher David Hull, who provides a dissenting view.

The most extreme constructivists seem to hold that all of us, scientists included, are helpless victims in the maws of our societies. We all believe what our

societies force us to believe. On this extreme view, the appeals that scientists make to reason, argument, and evidence are merely so much show to cover the social origins of our beliefs. (Hull, cited by Phillips, 2000a, p. 5)

Phillips's and Hull's comments can be juxtaposed with an editorial comment made by the co-editors of *Adult Education Quarterly*, Wilson and Hayes (2002a). The editors write that "Many practitioners of disciplinary inquiry are keenly aware (even as many others remain clueless) that there is nothing objective or neutral about knowledge production" (p. 5). Here, Wilson and Hayes hit upon several theses reminiscent of postpositivism. As they relate to scientific understanding, these theses call into question both the objective nature of scientific knowledge and the objective progress of science. However, many scientists and philosophers do not accept the far-ranging claims made by postpositivist philosophers regarding scientific knowledge and the scientific enterprise (Curd & Cover, 1998; Devitt, 1997; Laudan, 1998a, 1998b; McMullin, 1998), a topic that will be taken up in a subsequent section.

A contemporary interpretation of pragmatist constructivism is offered by adult educator Stephen Brookfield (2000). Brookfield's pragmatist constructivism is not restricted to the modernism of Dewey or Mead but entails several postmodernist themes. Brookfield notes that pragmatist constructivism "emphasizes the role people play in constructing and deconstructing their own experiences and meanings. Constructivism rejects universals and generalizable truths, and focuses instead on the variability of how people make interpretations of their experience. . ." (p. 37). The postmodernist elements of Brookfield's pragmatist constructivism will be discussed later. In addition to its

postmodernist elements, Brookfield's constructivism entails several postpositivist elements.

[T]he epistemology of pragmatist constructivism is subjectivist. Knowledge is viewed as malleable, and experience is open to multiple interpretations. Knowing in pragmatist constructivism, is individually, culturally, and socially framed.

There is no fixed reality waiting to be discovered by diligent analysis. Experience is interpreted in various ways and different people experience the same events in wildly divergent, yet internally coherent ways. (Brookfield, 2000, p. 39)

One of the qualities of constructivism, which has been referred to as a "Broad Church" movement (Matthews, 2002; Phillips, 1995), is its ability to harbor conflictive sects (Phillips, 1995). Brookfield, however, takes this to a new level in that he is able to incorporate both modernist and postmodernist views—some of which are conflictive—within his own brand of pragmatist constructivism. Some of the views of Dewey and Mead do not jibe, however, with postmodernist views of science, a topic which will be discussed in a subsequent section.

### *Origins of Constructivism in Adult Education*

In primary and secondary mathematics and science education, the two modern constructivist pillars are Jean Piaget and Thomas S. Kuhn (Matthews, 2002). In addition to Piaget and Kuhn, constructivism in adult education has been greatly influenced, if not more so, by the pragmatists. The pragmatists have influenced generations of thinkers in adult education, including such notables as Lindeman, Kidd, Knowles, Schön, and Kolb.

### *Piaget, von Glasersfeld, and Candy in Adult Education*

Jean Piaget's work is embodied more recently in the radical psychological constructivism of Ernst von Glasersfeld (1995a, 1995b). In adult education, von Glasersfeld's influence extends perhaps most notably through the work of Philip Candy (1991). It is therefore fitting that von Glasersfeld is recognized as a leading forebear of constructivist thought in adult education (Candy, 1991; Merriam & Caffarella, 1999). Although Candy is credited with a constructivist view of teaching (Caffarella & Barnett, 1994; Jackson & MacIsaac, 1994; Lee & Caffarella, 1994), his views extend to learning, and they clearly incorporate von Glasersfeld's postpositivist and postmodernist views of scientific knowledge (Candy, 1991). Consequently, Candy holds to subjectivist and relativist views of knowledge. According to Candy (1991), the individual learner is able to construct scientific knowledge of the pendulum with which he or she interacts with nothing more than his or her mind. Von Glasersfeld's radical constructivist views of education, although very popular in some educational corners, have been subject to detailed philosophical criticism by Matthews (1994, 2000a, 2002), McCarthy and Sears (2000), McCarty and Schwandt (2000), and Suchting (1992).

### *Kuhn in Adult Education*

The work of postpositivist historian and philosopher Thomas Kuhn is often cited favorably by constructivists (Loving & Cobern, 2000). Kuhn is seen "as the fount of their relativist epistemology and their constructivist view of science" (Matthews, 2002, p. 128). Von Glasersfeld (1989) for example writes that Kuhn "brought to the awareness of a

wider public” the professional crisis “of faith in objective scientific knowledge” (p. 121). Kuhn’s greatest contribution is that he brought to the attention of a wider audience the social nature of scientific knowledge. At the same time, however, many philosophers and scientists believe that too much has been made out of Kuhn’s ideas regarding the social and political nature of scientific theorizing. Matthews (2002) delineates the existing divide between the main point of Kuhn’s ideas, on the one hand, and the nature of their limitation, on the other hand.

To recognize that ideas have a historical and social dimension, that concepts do not just drop out of the sky, and that people (including scientists) are products of their time—is all to the good (although the world did not have to await Kuhn to learn this). But to confuse these historical, psychological, and sociological matters with normative and logical ones is a major mistake. (Matthews, 2002, p. 128)

What Matthews is critical of here is Kuhn’s insistence that theory choice can be explained ultimately by non-cognitive, or historical, psychological, and sociological, factors—a thesis which fails to account for the logical and methodological norms that practicing scientists actually use. In other words, it is one thing to provide a historical, psychological, and sociological account of scientists’ choices for particular paradigms. However, it is an entirely different matter to claim that these social factors double as the very scientific justification scientists employ for theory choice. Some philosophers are highly critical of what they believe to be Kuhn’s unfounded arguments involving theory choice, which in turn underpin his portrayal of science as a non-rational affair, one which

promotes an illusion of, rather than real, scientific progress (Curd & Cover, 1998; Laudan, 1998a; McMullin, 1998; Shimony, 1976; Stove, 1982).

The editorial comment by Wilson and Hayes (2002a, p. 5), in reference to disciplinary inquiry, “that there is nothing objective or neutral about knowledge production,” can be seen as an allusion to Kuhnian postpositivism. Because of the importance of Kuhn’s influence in adult education, Kuhn’s work will be discussed in a subsequent section entitled “Postpositivist Constructivism.”

### *Dewey in Adult Education*

Of the three most important constructivist influences in adult education, the pragmatist influence is arguably the greatest. Indeed, the influence of pragmatism is found, for example, in the thought of adult educators Lindeman, Knowles, and Houle (Merriam & Brockett, 1997). One could add to this list Rachel and Mezirow (Wilson & Hayes, 2002b). Pragmatism has also influenced adult learning theory by stimulating thought outside the field, including, for example, the thinking of Kolb and Schön. Student-centered forms of instruction involving activity that begin with students’ own interests, rather than disciplinary knowledge as the practical starting point of instruction, have been largely credited to Dewey (Prawat, 2000). Such practices are not reserved for lower grade education. Adult educators note that “[t]he constructivist discourse, along with andragogy, has represented another movement away from content and teacher-centered education, to learner and learner-centered education” (Pratt & Nesbit, 2000, p. 121). However, recent scholarship has begun to question Dewey’s commitment to the

idea of student-centered learning as the basis of his educational philosophy as has often been attributed to him (Prawat, 2000, 2002a, 2003a, 2003b; Ryan, 1998).

Perhaps Dewey's most enduring idea captured by adult education was his commitment to the idea of experience being at the heart of learning. According to Wilson and Hayes (2002b), "Nothing is perhaps more sacred to adult educators than the ideas of learning and experience. . . . learning and experience are central ideas in the thinking and practice of adult education" (p. 173). "Ever since Lindeman echoed Dewey's injunction to learn from experience, experiential learning has held adult educators in thrall. . ." (p. 173). So potent and resilient is the idea of learning from experience in adult education that it has been successfully incorporated into postpositivist and postmodernist discourses (Usher & Edwards, 1994; Miller, 2000).

In adult education, experience seems to mean much of the time subjective experience, whether in pragmatist, postpositivist, or postmodernist thought. Lindeman (1926/1961) notes that "the approach to adult education will be via the route of *situations*, not subjects" (p. 6, original italics). Lindeman hereby subordinates abstract, or subject matter, knowledge in favor of personal experience. Lindeman notes that "the resource of highest value in adult education is the *learner's experience*" (p. 6, original italics). Finally, Lindeman leaves no doubt that he is referring to subjective knowledge, when he notes that the learner's own experiences and knowledge are of greater importance and not "some one [*sic*] else's experiences and knowledge" (p. 6). That is, "Intelligence performs its functions in relation to actualities, not abstractions" (p. 6). Actualities born of experience are personally meaningful, while abstractions represent the distillation of other

people's understanding. The former are preferred, while the latter are devalued. The subjectivism inherent in pragmatist-inspired adult education is preserved in its postpositivist and postmodernist versions.

### *The Nature of Constructivism in Adult Education*

#### *Constructivism*

Within the last decade, adult educators have increasingly noted the importance of constructivism in their field (Candy, 1991; Fenwick, 2000a; Hayes & Wilson, 2000; Merriam & Brockett, 1997; Merriam & Caffarella, 1999). In spite of its presence and importance, characterizing constructivism proves difficult (Bentley, 1998; Bickhard, 1995; Ernest, 1995). Yet, if one is to be able to talk about constructivism in some meaningful way, particularly as it might relate to issues of teaching and learning, then some sort of characterization is necessary. Constructivism is extremely malleable in that it is able to incorporate many different positions. It adopts many postpositivist and postmodernist tenets. Moreover, many constructivist positions are positivist. In this, "It is ironic that many constructivists, who are the staunchest critics of positivism in education, nevertheless, base their position on distinctly positivist premises" (Matthews, 2004c, p. 11).

Phillips (1995) notes that "because there are so many versions of constructivism with important overlaps, but also with major differences, it is difficult to see the forest for the trees" (p. 7). Consequently, constructivism is an extremely heterogenous movement,

one that is capable of subsuming any number of positions, even those that are conflictive. Phillips states that “If we were to turn to mainstream educational writing, the list [of constructivist writers] would become intolerably long” (p. 6). Ernest (1995) adds that “there are almost as many varieties of constructivism as there are researchers” (p. 459). Thus, learning that someone is a constructivist is “to acquire no useful information whatsoever” (Phillips, 1998, p. 139). For some, the term “constructivism” provides only negative information (about what an author opposes); while, in the positive sense, it indicates a “wild multiplicity” of approaches (Bickhard, 1998, p. 99). When attention turns to science education, one finds the same type of diversity. Bentley (1998) states that, “While constructivism has become a major philosophical referent for the reform of science education, it is an umbrella term covering diverse interpretations. . .” (p. 237). The malleability of constructivism in adult education is evident in the work of Stephen Brookfield (2000), who incorporates into his own version of pragmatist constructivism noticeable postpositivist and postmodernist commitments.

In spite of its diversity, there do seem to be some basic commitments that are characteristic of constructivism. As it pertains to science, Matthews (1994) notes that constructivism “emphasizes that science is a creative human endeavor which is historically and culturally conditioned, and that its knowledge claims are not absolute” (p. 138). Matthews notes, however, that these are generally non-contentious philosophical truisms. Beyond this, “constructivism is committed to certain epistemological positions that are very contentious. . . At its core constructivism has a subjectivist, empiricist, and personalist understanding of human knowledge, and consequently of scientific

knowledge” (p. 138). Speaking to the more controversial commitments of constructivism, Bredo notes that

The controversial claim or suggestion of constructivism, then, is not only that knowledge is made but, more fundamentally, that *the objects and properties we experience and know are themselves in some manner products of human (mental or physical) activity*. This is the more radical claim that we live in an “invented reality.” (Bredo, 2000, p. 131, original italics)

Bredo is referring to the idealist ontology present in much of constructivism. Idealist ontology concerns the existential status of scientific and everyday objects. As Matthews (1994) puts it, “Idealist ontology maintains that the world is created by and dependent upon human thought” (p. 141). Idealism opposes realism, since the latter maintains that the objects of the world are independent of human theorizing about them. In essence, Bredo is claiming that if there were no humans, then there would be no objects in the world. It is one thing to claim that scientific knowledge arises from human thought and activity. But it is an altogether different matter to claim that the objects of the world themselves are the products of human mental or physical activity. The first claim is noncontroversial, while the second is extremely controversial.

In addition to ontological commitments, Matthews (1994) notes that constructivists adopt many epistemological theses of postpositivist philosophy of science. It is useful to note some of these commitments.

- 1) Observational statements are always dependent upon particular theoretical systems for their expression.

- 2) The distinction between observational and theoretical terms in a theory can only be made on pragmatic grounds, not on epistemic grounds.
- 3) Observations themselves are theoretically dependent or determined; what people look for and what they notice is influenced by what they want to see or what they regard as relevant to an investigation.
- 4) Theories are always underdetermined by empirical evidence.
- 5) Theories are immune from empirical disproof or falsification because adjustments can always be made to their auxiliary assumptions to accommodate the discordant evidence. (adapted from Matthews, 1994, pp. 140-141)

These different theses are sometimes referred to as theory-ladenness of observation, instrumentalism, meaning variance, and underdetermination. These postpositivist commitments call into question traditional notions of theory choice and scientific progress. In other words, postpositivist philosophy questions both the rationality of science and whether scientific theorizing gets closer to the truth. Because these are important questions, these same postpositivist theses will be dealt with in a subsequent section, entitled “Postpositivist Constructivism.” For the time being, however, many philosophers have offered arguments against the main suggestions of these theses (a) that science is nonrational, and (b) that there is no such thing as scientific progress.

Another philosophical characterization of constructivism is provided by philosopher Michael Devitt (1997). Devitt holds that constructivism is a twentieth-century philosophy that is based on two Kantian commitments to which has been added a third commitment, one that is totally foreign to Kant, namely relativism.

The post-Kantian guiding influence on constructivism, according to Devitt, are the postpositivist philosophers, notably Kuhn and Feyerabend. On the one hand, Devitt claims that there is much in the rhetoric of these two postpositivist philosophers that is realist. In other words, “They talk of an implicitly non-mental, theory-independent ‘world,’ ‘nature,’ or ‘reality,’ made up of ‘real objects,’ which constrains theories and which ‘theoretical objects’ must in some sense fit” (p. 156). Nonetheless, Devitt believes Kuhn’s and Feyerabend’s position “to be profoundly anti-realist” (p. 157). Devitt maintains that “Their position is a relativistic Kantianism sometimes called ‘Constructivism’” (p. 157).

Kant’s philosophy, according to Devitt (1997), espouses two elements. The first maintains that “[t]he only independent reality is beyond the reach of our knowledge and language; it is the noumenal world of things-in-themselves” (p. 157). Due to this, Devitt holds that Kant is a “Weak Realist” (p. 157). The second element is that “[t]he known world is partly our construction; it is the phenomenal world of appearances, created by the imposition of our concepts on things-in-themselves” (p. 157). Because of this second element, Devitt claims that Kant “is an anti-Realist (for the known world is the world of physical entities like stones, trees, and cats)” (p. 157). But this does not make Kant a relativist, according to Devitt, since Kant believes that the concepts that we impose on the world are shared by everyone. However, constructivism is both anti-realist and relativist, according to Devitt. This is because constructivists believe that

The only independent reality is beyond the reach of our knowledge and language.

A known world is partly constructed by the imposition of concepts. These

concepts differ from (linguistic, social, scientific, etc.) group to group, and hence the worlds of groups differ. Each such world exists only relative to an imposition of concepts. (Devitt, 1997, p. 157)

It is important to understand how constructivism relates to scientific understanding, since it is held out as a referent for science education (Bentley, 1998; Bredo, 2000; Tobin, 1993). Devitt relates what constructivism implies for science.

In the scientific form . . . electrons, muons, and curved space-time are said to exist relative to contemporary theories, but not to past theories; and phlogiston, witches, and the four bodily humours exist relative to various past theories, but not to contemporary ones. None of these things exists or does not exist “absolutely.” Neither does the familiar observable world of stones, trees, and cats. Only things-in-themselves, which are for ever beyond our ken, exist absolutely. (Devitt, 1997, p. 157)

One consequence of constructivism is that the objects of the world change concomitantly with scientific theorizing. On this view, as scientific theories change, so too does the world. In other words, while realists maintain that theory refinement, or changes in our understanding of the atom’s nucleus, for example, represent advancements in atomic understanding of the same atom, some constructivists, on the other hand, disagree. Instead, theory modification for many constructivists implies new ontic references, that is, completely new objects. On this view, the world constantly changes concomitantly with human theorizing (Mead, 1938). The suggestion of idealism is apparent. These same postpositivist ideas are noted by Devitt, when he writes that “if worlds really change

when theories change, it is not surprising that the meanings, references, and ontological commitments of theories differ; and theories that talk about different things are likely to be incommensurable” (p. 158). If scientific theories are incommensurable, then they cannot be compared with one another. And if they cannot be compared with one another, then scientific progress is illusory. These postpositivist themes, which are crucial to many forms of constructivism, will be revisited under “Postpositivist Constructivism.”

There is an uncanny resemblance between many forms of constructivism and what Matthews (2004c) refers to as immature or nascent positivism. After listing eleven commitments of constructivism, Matthews then states that these same “eleven epistemological and ontological commitments are also, more or less, found in the early positivism of Carnaps’s *Aufbau* and of Wittgenstein’s *Tractatus*” (p. 12). Among other things, these include: (a) the dismissal of the possibility of objective knowledge of reality, (b) a commitment to the idea that the world has no preexistent structure; rather, structure is derived from the world being perceived, (c) a commitment to an instrumentalist rather than a correspondence theory of truth, (d) a commitment to the idea that the object of knowledge is experience rather than reality, (e) a commitment to the idea that the senses are both the fount and test of knowledge claims, and (f) a commitment to the idea that the experiencing or cognizing individual is the bearer of knowledge. These same positivist commitments often surface in adult learning theory, although they are not identified as positivist. For example, they are captured nicely by Pratt’s (1993) explication of Knowlesian andragogy, the rudiments of which are found in Lindeman.

First, the world may exist, but it is the individual's experience of that world that is most important to learning. Learning is not, therefore, the discovery of an independent, preexisting world outside as much as it is the construction of meaning through experience. Second, learning is more subjective than objective, with an emphasis on individual interpretation and integration, and even transformation of knowledge. Therefore, andragogy appears to rest on two implicit principles of learning. First, knowledge is assumed to be actively constructed by the learner, not passively received from the environment; and, second, learning is an interactive process of interpretation, integration, and transformation of one's experiential world. (Pratt, 1993, pp. 16-17)

### *Pragmatist Constructivism*

Pragmatism is perhaps the greatest guiding influence on adult education. The pragmatists Dewey, James, and Peirce probably inspired much of Lindeman's philosophy (Stewart, 1987). "By the time Lindeman graduated from college Progressivism was at a fever pitch. Education, science and efficiency were joined with organic views of society as popularized by Dewey. . ." (Long, 1989, pp. xviii-xix). Mead is generally recognized, along with Dewey, James, and Peirce, as one of the most prominent of American pragmatists (Scheffler, 1974). Indeed, "Mead and Dewey maintained a lifelong friendship and were colleagues for many years during which they visited each other nearly every day. So intermeshed were their ideas that it is often impossible to determine who originated what" (Garrison, 1998, p. 43).

Like Dewey (Merriam & Brockett, 1997; Phillips, 1995), Mead is often portrayed in the educational literature either as a constructivist (Bredo, 2000; Garrison, 1998) or as a constructivist forbear (Bentley, 1998). Under the broad umbrella of constructivism, pragmatist constructivism has been stretched to include both postpositivist and postmodernist philosophy (Brookfield, 2000). The point here is that pragmatism and its relationship with education may have evolved into something radically different from what both Mead and Dewey ever intended. For example, pragmatist ideals were incorporated into the progressivist movement in education which created dualisms that Dewey opposed (Prawat, 2000; Ryan, 1998). Dewey was no more student-centered than he was teacher-centered (Ryan, 1998). Nor did Dewey believe that instruction must always begin with subjective experience, as opposed to disciplinary understanding as many believe (Prawat, 2000). In fact, not only was it necessary to begin instruction with disciplinary knowledge, according to Dewey, but if true education were to occur, then students' ideas would ultimately need to be addressed in light of disciplinary knowledge (Prawat, 2000). Part of the difficulty with pragmatism, as it relates to education, is that Dewey's basic ideas of science continued to evolve throughout his relatively long career. For example, the later—as opposed to the early—Dewey was not inductivist (Prawat, 2000). This is not to say that pragmatism, as it evolved in the thinking of Dewey or Mead, began to mirror scientific realism. Dewey's conception of causation, for example, did not accord with that of scientific realism (Garrison, 1994). Moreover, although Dewey maintained his autonomy, in later life he “associated with logical empiricism” (Reck, 1998, p. 48).

Pragmatists recognized, even before the postpositivists, that each of us is historically and culturally conditioned. Although the problems we assume and entertain may ultimately be our own, they nonetheless arise from the cultural milieu into which we are born. It follows, then, that although pragmatism is a uniquely American philosophy (Aune, 1970), it also was influenced by the particular socio-historical context in which it arose, responding according to the individual interests, backgrounds, and abilities of the pragmatists, themselves, to the pertinent questions of the day. Consequently, it is highly likely that pragmatism should hold some of the same commitments of the major philosophies of its day. Given the fact that pragmatist philosophy blossomed during the heyday of logical positivism, it should not come as a surprise perhaps that the two philosophies held much in common.

Although pragmatism certainly differs from positivism, nonetheless, pragmatists and positivists share several commitments all of which are antithetical to realist understanding. “The pragmatist Charles Morris<sup>4</sup> was quick to note the similarity between logical positivism and pragmatism, and his view became widely shared” (Phillips, 2004, p. 72). The opinion that American pragmatism and European logical positivism were compatible, was not something that pragmatists, alone, imagined. The feeling was mutual. The preface of the 1929 manifesto of the logical positivists—a group of philosophers and scientists at the University of Vienna who were known at the time as the Vienna Circle—states that one of its objectives was to promote “a scientific world conception . . . described as the continuation of . . . the English empiricists and their

---

<sup>4</sup> Charles Morris received his Ph.D. under George Herbert Mead.

successors, American pragmatism . . .” (Stadler, 2001, p. 337). That pragmatism and logical positivism share several fundamental commitments is not something that readers are likely to find in the adult education literature.

What philosophical commitments did American pragmatists share with their European logical positivist counterparts? Among other things, they include (a) an overt hostility toward metaphysics, (b) verificationism, (c) instrumentalism, and (d) empiricism.

The “logical positivists were marked by a great hostility toward metaphysics” (Phillips, 2004, p. 72). An anti-metaphysical stance is also evident in Mead’s work. For example, as it relates to malarial science, Mead’s doctrine dissolves the metaphysical object, the mosquito-borne parasite, *Plasmodium*—responsible for malaria in both humans and birds—discovered by science a quarter century before Mead’s doctrine. In his description of Mead’s work, Bredo (2000) notes that neither objects nor their meanings exist prior to activity. Consequently, abstract entities, such as a mosquito-borne parasite, which come into play as a result of active inquiry, are to be thought of as nothing more than “tools of instrumental thought, not as metaphysical givens” (Bredo, 2000, p. 148).

The positivists sought to ground knowledge in experience. Phillips (2004) notes that “the logical positivists adopted the verifiability principle of meaning, which stated that something is meaningful if and only if it is verifiable empirically. . .” (p. 72). The verifiability principle of meaning of the logical positivists was translated by the American pragmatists into the “pragmatic criterion of meaning” (p. 72). A crude statement of the

verifiability principle is that, if something could not be measured, then it was not meaningful. This gave rise to the “use of operational definitions” in science by both the logical positivists and the pragmatists.

The defining of scientific concepts by operational definitions was championed by Percy Bridgman (1927) and the early Rudolph Carnap (1928) and came to be known as operationalism (Psillos, 1999). Carnap proposed that all scientific concepts could be defined operationally. For example, according to operationalism, the concept of temperature could be reduced to a set of statements of the instruments and procedures involved in taking temperature measurements. There are two types of problems with this approach, however. First, because there are different types of thermometers and conditions under which temperatures are taken, operationalism promotes a proliferation of operational definitions all of which relate to the concept of temperature. Second, in spite of the proliferation of operational definitions pertaining to temperature, none of them captures the scientific meaning of temperature (Psillos, 1999). The scientific concept of temperature does not reduce to a set of specific instruments and procedures, even if the same measurements can be replicated, that is, verified by a number of different scientists. Mead (1938) was not opposed to operationalism. Bredo (2000) alludes to the operationalism of Mead’s doctrine, when he states that “The scientific community then introduces both new constraints and wider generality by approaching objects in a purely instrumental fashion and insisting that anyone who performs the appropriate experiment . . . should get the same results” (p. 152).

Many logical positivists and pragmatists adopted instrumentalist views toward unobservable entities. Neither the logical positivists nor the pragmatists were realists with regard to unobservable entities. Phillips notes that

Least understood by researchers is the fact that, by-and-large, the logical positivists were not realists with respect to the status of theoretical entities. Consider the entities postulated in subatomic theory; these are not directly observable and thus are not reducible in any straightforward way to “sense experience” . . . (Phillips, 2004, p. 73)

Mead (1938) maintained, for example, that there was no ontic entity in back of the concept of cellulose. Instead, cellulose was to be thought of as an organizing principle—a hypothesis or theory—which could be reduced to the tactile stimulation of woody things. The position of some of the logical positivists was quite similar. “Thus scientific theories could not be true or false, but as tools they could be economical, useful, or instrumentally helpful; theories were hypotheses designed to predict facts (facts being sense experiences, or rather reports of sense experiences in terms of propositions)” (Phillips, 2004, p. 73).

A deeper understanding of constructivism can be found in its motivating influences. Proponents of pragmatist constructivism (Bredo, 2000; Garrison, 1994, 1998) are correct in pointing out that both Dewey and Mead were under the spell of Hegelian organicism. In Hegel, Dewey and Mead developed an aversion to all sorts of dualisms. Consequently, pragmatist constructivism balks at the mind-body dualism, in particular the idea that reality consists of real objects, separate from our minds, which we recognize by means of our internal mental state. Instead, Dewey and Mead recognized the object and

its meaning by the use to which the object is put. However, this tends to reduce objects to human interests (Murphy, 1939). In his criticism of pragmatism, House (1994) notes that “For Dewey the ‘essence’ of things emerges from our interests in them based on our purposes and preferences” (p. 15). House maintains,

However, if things depend on the mind, then Dewey is not a realist in the sense that things can be mind-independent. It is one thing to say that we investigate objects because we have an interest in them and in pragmatic excitement put them to use. It is quite another to say that things are the way they are because of human preferences. . . . [Dewey] has tried to connect knowledge and reality through a naturalized epistemology, but has produce an anthropomorphic ontology in which things are shaped too much by the mind. (House, 1994, p. 15)

Pragmatism is marked by an instrumentalist conception of knowledge.

Instrumentalism is widespread in adult education. For example, Peter Jarvis (1999) describes the instrumentalist aspect of problem-centered and experiential approaches to learning. One of the reasons for adopting experiential approaches to learning is that they place an “emphasis on the provisional and changing nature of knowledge. In this light, learning is not the acquisition of knowledge (for later use) but the creation of new knowledge in specific and concrete situations” (Holford & Jarvis, 2000, p. 651). Rather than disciplinary (theoretical) knowledge and professionally derived knowledge complementing one another, Holford and Jarvis (2000) describe the tension between the two different forms of knowledge. On this view, they write that “Disciplinary or theoretical knowledge has no necessary superiority to knowledge in or derived from

practice. Any knowledge achieved is always provisional, and its ‘truth’ or ‘validity’ established only as long as it continues to work” (p. 653). This last sentence reveals the instrumentalism of the position which Holford and Jarvis describe. There are several aspects of this position deserving of comment.

Setting aside for a moment the question of whether or not theoretical knowledge is superior to knowledge derived from practice, one can question two aspects of the instrumentalist learning model Holford and Jarvis describe. First, that adult “learning is not the acquisition of knowledge (for later use) but the creation of new knowledge in specific and concrete situations” seems too strong. It is too strong in that it seems to dismiss the necessity of prerequisite theoretical knowledge required in many professions but which is learned pre-professionally. When attention turns to professional knowledge, the position seems too strong as well. One could argue that professional knowledge is an amalgam of both theoretical knowledge and practical knowledge. The prophylactic practice of hand washing and the observance of universal precautions by health-care providers are practices that stem directly from the germ theory of disease, not from professional practice. Based on the history of the germ theory of disease, it not likely that health-care workers will abstract this important theoretical knowledge from the “specific and concrete situations” of professional practice. Nor is it likely that professional practice will allow for the confirmation of the germ theory of disease. Second, the assertion that “Any knowledge achieved is always provisional, and its ‘truth’ or ‘validity’ established only as long as it continues to work” (p. 653), can be seen as a subordination if not a denial of theoretical knowledge. Instrumental, or non-theoretical, truth becomes

privileged in this case. However, not all knowledge that is crucial to health-care professionals can be derived from professional practice. Thus, the instrumentalist position that Holford and Jarvis describe, that “learning is not the acquisition of knowledge (for later use) but the creation of new knowledge in specific and concrete situations” would seem to condemn learners to the “local and temporary incidents of experience” against which Dewey (1916, p. 270) warned, as well as the closing down of “intellectual vistas” which become obscured “by accidents of personal habit and predilection.” Unless students are exposed to the germ theory of disease and apprized as to how it relates to the transmission of infection and disease in their pre-professional education, they will not be knowledgeable of this bit of theoretical knowledge which is crucial for good practice. Scientific theories which pertain to unobservable entities and processes do not arise from induction (Charlesworth, 1983). The practices of hand washing and the observance of universal precautions by health-care professionals derive from the germ theory of disease and not from the exigencies of professional practice in an instrumentalist fashion.

The instrumentalist position that Holford and Jarvis describe can be compared to a list of empiricist commitments provided by Matthews.

1. There is a distinction between basic, observational or intuited knowledge and theoretical knowledge.
2. Basic, observational or intuited knowledge does not involve theory.
3. Basic, observational or intuited knowledge is available or given to individual observers or thinkers (or knowers, or subjects).

4. Theoretical knowledge is derived from, or ultimately justified by reference to, basic, untheoretical knowledge. (Matthews, 2000c, p. 257)

The statement that “Disciplinary or theoretical knowledge has no necessary superiority to knowledge in or derived from practice” draws a distinction between theoretical and non-theoretical knowledge. Thus, the position Holford and Jarvis describe adheres to the first empiricist commitment. Additionally, the statement that “Any knowledge achieved is always provisional, and its ‘truth’ or ‘validity’ established only as long as it continues to work” (p. 653) subscribes to the fourth empiricist commitment. Therefore, the position which Holford and Jarvis describe implies that theoretical knowledge is reducible to practically derived knowledge and that its truth is determined by instrumental usage. This move is similar to Mead’s dissolution of the scientific object (such as cellulose and malarial parasites) by reducing it to observable objects that can be manipulated.

### *Postpositivist Constructivism*

Postpositivist philosophy has found its way into adult education, blending with pragmatist views of experience under the mediating influence of constructivism.

Postpositivist philosophy has had enormous influence on education, particularly with regard to constructivism. Matthews (1994) notes that “constructivists adopt most of the epistemological theses of postpositivist philosophy of science” (p. 140). Much of the postpositivist inspiration for constructivism in education stems from the work of historian and philosopher, Thomas Kuhn (Loving & Cobern, 2000).

Although there are several different postpositivist theses, postpositivism does not mean “post-empiricism.” Nor does postpositivism represent a twentieth-century realist turn in the philosophy of science.

Postpositivist critics (Kuhn, Feyerabend, Rorty, etc.) took aim at this empiricist account of observation, but only to say that, contra positivist hopes, observation was infected with theory. Most postpositivists did not dispute the Aristotelian-derived primacy accorded to observation by the positivists and empiricists that they were railing against. (Matthews, 2000c, p. 265)

Several arguments—or theses—in Kuhn’s (1962) landmark text *The Structure of Scientific Revolutions* call into question closely held twentieth-century beliefs by scientists and philosophers about the nature of science. Specifically, Kuhn calls into question both the rational and progressive natures of science. Philosophers Curd and Cover (1998) divide Kuhn’s arguments for the lack of rationality and objective progress of science into two groups. In the first group they include two Kuhnian arguments, theory-ladenness of observation and meaning variance. The second group of arguments, also denying the rational nature of science and scientific progress, maintains that cognitive values alone are insufficient for enabling scientists to choose between two rival theories or paradigms. Instead of cognitive values, Kuhn argues for the primacy of subjective considerations governing theory choice. Introducing his concept of “paradigm,” Kuhn held that objective scientific progress was illusory, that theories do not get any closer to truth. According to Kuhn, reason and evidence play little role in determining the outcome of scientific revolutions (Curd & Cover, 1998). In place of

reason and evidence, Curd and Cover (1998) write that Kuhn “turned to psychology, sociology, and history in order to draw a picture of science that, he claimed, was more faithful to the original than anything that philosophers of science had yet proposed” (p. 83). Thus, Kuhn maintained that science was largely a nonrational affair.

Many philosophers of science have been highly critical of Kuhnian postpositivism (Curd & Cover, 1998; Devitt, 1997; Feyerabend, 1970; Lakatos, 1970; Laudan, 1998a, 1998b; McMullin, 1998; Popper, 1970; Scheffler, 1966; Stegmuller, 1976; Stove, 1982; Toulmin, 1970; Watkins, 1970). As the result of the onslaught of criticism aimed at *The Structure of Scientific Revolutions*, Kuhn began to ameliorate his rhetoric. This was particularly true for his theses of the theory-ladenness of observation and meaning variance.

Theory-ladenness of observation “means that what scientists observe depends on the theories they accept” (Curd & Cover, 1998, p. 220). This is true in so far as it calls into question the inductive derivation of theories. According to philosophers Curd and Cover (1998), to support Kuhn’s various theses regarding theory choice, theory-ladenness of observation must mean two things. First, according to Curd and Cover, it would have to mean that all proponents of one theory can never observe anything contrary to that theory. Second, it would also have to mean that “scientists who accept rival theories can never observe the same thing” (p. 220). Further, they argue that, though theory-ladenness is key to Kuhn’s arguments concerning both the progress and rationality of science, it is inconsistent with another of his key claims, which is that scientific revolutions are brought about by an accumulation of observed anomalies that contradict the theoretical

expectations of the reigning paradigm. In other words, for Kuhn to be consistent, perception must not be so theory-laden that it prevents scientists from observing inconsistent results.

On the other hand, Kuhn's thesis of meaning variance states that the meaning of the terms of rival paradigms are so theory-dependent that scientists have no basis for comparing theoretical terms. In other words, there is no common language that can link the two groups. On this view, scientists of rival theories cannot help but talk past one another, which is to say that rival paradigms are incommensurable. Theories cannot be meaningfully compared, because there is no common ground for comparison. According to Kuhn's thesis of meaning variance, because theories cannot be compared in any rational way, the eventual acceptance or rejection of rival paradigms is nonrational. Again, what is at stake is the apparent rationality, or lack thereof, of science and of scientific progress. Kuhn's thesis of meaning variance seems flawed, however, to Curd and Cover.

Many of Kuhn's critics have pointed out an apparent contradiction between Kuhn saying, on the one hand, that rival paradigms are incommensurable with respect to meanings and, on the other hand, that it is impossible to believe both paradigms at the same time. For, without commensurability of meaning, there cannot be logical incompatibility. (Curd & Cover, 1998, p. 223)

Curd and Cover conclude that neither of Kuhn's two theses, "neither the one based on the theory-ladenness of observation nor the one based on the paradigm-dependence of

meaning—is strong enough to support his radical conclusions about the lack of rationality and progress in scientific revolutions” ( p. 224).

The criticisms engendered by the first edition of *The Structure of Scientific Revolutions* and Kuhn’s subsequent tempering of those views are important considerations, given that “so much educational writing has relied, explicitly or implicitly on Kuhn’s original 1962 depiction of the structure of scientific revolutions” (Matthews, 2000b, p. 5). Indeed, according to Matthews (2000b), “Kuhn spent a good deal of the rest of his life back-tracking from the original analysis” (p. 6).

. . . Kuhn began to back away from the more extreme of his early claims regarding the canons of rationality being entirely intra-paradigmatic, the essential irrationality of theory choice, the theoretical dependence and subjectivity of observation, and the incommensurability of theories. Paradigms were not such all-developing and defining constraints on observation, methodology and theory choice as they first appeared to be in 1962. (Matthews, 2000b, pp. 3-4)

Philosopher Larry Laudan (1998b) notes that once Kuhn began addressing his critics, the provocativeness of his original assertions was tempered.

Since 1962 most of Kuhn’s philosophical writings have been devoted to clearing up some of the ambiguities and confusions generated by the language of the first edition of *The Structure of Scientific Revolutions*. By and large, Kuhn’s message has been an ameliorative and conciliatory one, to such an extent that some passages in his later writing make him sound like a closet positivist. More than

one commentator has accused the later Kuhn of taking back much of what made his message interesting and provocative in the first place. (Laudan, 1998b, p. 139)

In spite of ameliorating much of his original message, this does not mean that there were no remaining problems with what Kuhn had not retracted (Laudan, 1998b; Matthews, 2000b). In an initial wave of criticism, “Many philosophers deplored Kuhn’s rejection of objective progress and realism in favor of relativism about truth and instrumentalism about theories” (Curd & Cover, 1998, p. 84). In spite of these criticisms, “Kuhn continued to reject scientific realism, persisting in his view that scientific theories should be regarded as instruments for solving puzzles rather than as literal descriptions (or would-be descriptions) about reality” (Curd & Cover, 1998, p. 84).

One of Kuhn’s (1962) greatest contributions to philosophy of science was his notion of the concept of “paradigm.” Kuhn’s notion of paradigm was a crucial element in his arguments against the rational and progressive natures of science during scientific revolutions. However, critics noted that the concept of paradigm was ambiguous (Masterman, 1970), something that Kuhn both acknowledged and attempted to clear up in the “Postscript” of the second edition of *The Structure of Scientific Revolutions* (1970). Even after clarification, some philosophers argued that Kuhn’s conception of paradigm failed to capture the true nature of scientific revolutions (Laudan, 1998b; McMullin, 1998).

Philosopher Ernan McMullin (1998) questions several aspects of Kuhn’s concept of paradigm. McMullin believes that Kuhn has greatly exaggerated the significance of inter-paradigmatic change. McMullin contends that the true number of large-scale

scientific revolutions is much smaller than Kuhn claims. Therefore, the number of potential disagreements between scientists arising between paradigms is greatly overstated by Kuhn. Second, the difference between large- and small-scale revolutions is more a matter of degree than kind. Third, McMullin claims that Kuhn has misinterpreted real-life theory choice even with respect to large-scale, or inter-paradigmatic change. In short, McMullin claims that scientists do not act as instrumentalists when it comes to theory choice. That is, scientists do not simply value theories because of their predictive value. Instead, scientists hold other epistemic values, for example, coherency. That is, scientists value theories which are internally coherent rather than ad hoc. For these reasons, McMullin claims that Kuhn has misunderstood the rational nature of theory choice in true, large-scale scientific revolutions. McMullin discusses one large-scale scientific revolution about which Kuhn is very familiar, having written *The Copernican Revolution* (Kuhn, 1957).

On what grounds does McMullin make his claim that Kuhn has misunderstood the Copernican revolution? McMullin believes that Kuhn's instrumentalism will not allow him to appreciate the fact that the appeal of the heliocentric Copernican model was due to more than just its predictive accuracy, that there were other epistemic reasons as well. For Kuhn claims that

The real appeal of sun-centered astronomy was aesthetic . . . And to astronomers the initial choice between Copernicus' system and Ptolemy's could only be a matter of taste, and matters of taste are the most difficult of all to define or debate. (Kuhn, 1957, p. 172)

In other words, Kuhn held that both models were primarily instrumental calculating devices. This relates to the fact that Kuhn maintained that science was best conceived as a puzzle-solving enterprise (Curd & Cover, 1998). On this view, Kuhn held that science was committed to finding algorithms, or instrumental ways of solving problems. Following this line of reasoning, Kuhn held that there is no way to differentiate between puzzle-solving algorithms other than on the basis of which one makes better predictions. When two such rival algorithms appear to be equally capable of predicting events, then there are no other remaining rational ways of deciding which of the two is better. Since scientists ultimately adopt one theory over another, the basis of their choice must be other than rational. One must conclude therefore that theory choice is a nonrational affair.

McMullin (1998) disagrees with Kuhn's instrumentalist interpretation of the appeal of Copernicus's heliocentric model. McMullin maintains that Copernicus's heliocentric model "had stronger arguments. The heliocentric model could *explain*, that is, provide the *cause* of, a whole series of features of the planetary motions that Ptolemy simply had to postulate as given, as inexplicable in their own right" (p. 132, original italics). In other words, "Copernicus and others who followed him believed that they had good arguments for the reality of the earth's motion around the sun" (p. 134). Here McMullin invokes realism when he states that realists not only value predictive success, as do their instrumentalist counterparts, but that they also value other "superempirical values" as well. McMullin cites coherence and then notes that "Besides coherence, one could make similar cases for fertility and unifying power" (p. 135). McMullin adds that "It is hard to make sense of the role played by these values if one adopts the instrumentalist standpoint

that Kuhn feels compelled to advocate” (p. 135). Thus, while Kuhn valued predictive success as the single most important epistemic factor, astronomers, on the other hand, utilized additional epistemic factors as reasons for preferring the heliocentric model. These additional epistemic values—coherence, fertility, and unifying power—are rational ways of allowing scientists to choose between theories in real life, which are ignored by instrumentalism. Thus, from the vantage point of realists, Kuhn faced the same problems of accounting for theory choice faced by his instrumentalist predecessors, the logical positivists and pragmatists. McMullin notes that,

As we look back on these debates, we are ready to allow that the coherence arguments of Copernicus and Galileo did carry force, that they did give a motive for accepting the new heliocentric model as true. And their force came from something other than predictive advantage. Kuhn’s point in regard to theory assessment . . . was that the different theory values were not reducible to one another, and hence that no simple algorithm, no logic of confirmation such as the logical positivists had sought, underlay real-life theory decision. (McMullin, 1998, p. 135)

McMullin’s criticisms of Kuhn’s interpretation of theory choice in the Copernican-Ptolemaic debates are also criticisms of Kuhn’s denial “that any objective notion of progress (such as getting closer to the truth) can be applied to science across revolutionary divides” (Curd & Cover, 1998, p. 230). After all, the heliocentric model is more correct than the geocentric model.

Kuhn's concepts of paradigms and paradigm change are also questioned by philosopher Larry Laudan (1998b). Like McMullin, Laudan denies Kuhn's thesis that inter-paradigmatic debates cannot be rationally resolved. Kuhn's writing implies "that interparadigmatic debate is necessarily inconclusive and thus can never be brought to rational closure" (Laudan, 1998b, p. 144). Laudan references an example from the history of science that Kuhn uses to make his claims against the rationality of science and scientific progress, the phlogiston theory of Priestly and the oxygen theory of Lavoisier. According to Laudan, Kuhn

asserted that it was perfectly reasonable for Priestly to hold onto phlogiston theory, just as it was fully rational for most of his contemporaries to be converting to the oxygen theory of Lavoisier. . . . Priestly lost the battle with Lavoisier, not because Priestly's paradigm was objectively inferior to its rivals, but rather because most of the chemists of the day came to share Lavoisier's and Dalton's views about what was important and how it should be investigated. (Laudan, 1998b, p. 144)

Like the previous example concerning the debates of the heliocentric and geocentric models in which Kuhn claimed that the matter was beyond rational resolution, Kuhn claims the same thing here, that nonrational factors were ultimately responsible for the demise of the phlogiston theory. Laudan claims that it is assertions like these—the denial that scientific arguments can be both clarified and resolved rationally—that Kuhn has been "charged with relativism, subjectivism, irrationalism. . ." (p. 144). Kuhn is asserting that scientists do not believe in the phlogiston theory, not because they have good reasons

to believe that phlogiston simply does not exist but because they simply lost interest in the phlogiston theory. Laudan ultimately concludes that there is something to the Kuhnian thesis

that the pursuit of (and doubtless the recruitment of scientists into) rival paradigms is influenced by pragmatic as well as by epistemic considerations. That is an interesting thesis and probably a sound one, but it does nothing to undermine the core premise of scientific epistemology: that there are principles of empirical or evidential support which are neither paradigm specific, hopelessly vague, nor individually idiosyncratic. More important, these principles are sometimes sufficient to guide our preferences unambiguously. (Laudan, 1998b, p. 167)

In other words, scientists do not believe in phlogiston because, for evidentiary reasons, they believe that it simply does not exist. Both McMullin (1998) and Laudan conclude that none of Kuhn's various theses are sufficient for making his claims either that science is essentially nonrational or that science is not objectively progressive.

There is yet another important postpositivist thesis that deals with the question of the objective truth of scientific theories, the thesis of underdetermination. By itself, the underdetermination thesis is innocuous, and it poses no problem for science (Laudan, 1998a). Underdetermination simply means that theories are underdetermined by evidence. Said differently, any number of theories can be consistent with a single data set. Further, available data will never be sufficient to verify a theory over all possible rivals. Different theories will always be compatible with available evidence. Scientists do not deny this fact. On the other hand, several postpositivist philosophers use various formulations of

underdetermination to argue that there are limits to scientific knowledge claims that are based on empirical evidence and scientific methods. The strong and devastating claim for science is that its theories are inexorably underdetermined by evidence, and that scientific methodology is insufficient for bridging the gap between theory and evidence. On this strong view, “we should never accept any theory as objectively true no matter how well it agrees with the available evidence (thus abandoning scientific realism in favor of some version of skeptical relativism)” (Curd & Cover, 1998, p. 255).

According to Laudan (1998a), many postpositivist philosophers, sociologists, and others have embraced underdetermination in order to make all sorts of claims. Some “have claimed that underdetermination shows the *necessity* for bringing noncognitive, social factors into play in explaining the theory choices of scientists (on the grounds that evidential and methodological considerations alone are demonstrably insufficient to account for such choices)” (p. 321, original italics). Lakatos and Feyerabend have used underdetermination to justify the claim that “the only difference between empirically successful and empirically unsuccessful theories lay in the talents and resources of their respective advocates (i.e., with sufficient ingenuity, more or less any theory can be made to look methodologically respectable)” (p. 321). Some radical sociologists of scientific knowledge “have asserted that underdetermination lends credence to the view that the world does little if anything to shape or constrain our beliefs about it” (p. 321). They conclude from this, that sociology is sufficient for explaining scientists’ beliefs concerning theory choice. Lastly, Laudan notes that some literary theorists, such as Derrida, have used underdetermination as the rationale for “‘deconstructionism’ (in brief,

the thesis that, since every text lends itself to a variety of interpretations, texts have no determinate meaning)” (p. 321).

Laudan argues that many formulations of underdetermination are variations of the Duhem-Quine thesis. A claim made by Quine was that theories are so underdetermined by the data “that a scientist can, if he wishes, hold on to *any* theory he likes, ‘come what may’” (Laudan, 1998a, p. 321, original italics). It should be noted, however, that although a scientist might hold on to any theory, the Duhem-Quine thesis does not imply either that he or she will do so or even that he or she must. There are many reasons why scientists prefer one theory over another, aside from just empirical support. This leads to the contentious nature of the various interpretations of the Duhem-Quine thesis—whether these non-empirical considerations regarding theory choice are rational or social. Those clinging to the idea that social factors primarily, if not exclusively, govern theory choice claim that science is irrational, even relativist.

In his article, “Demystifying Underdetermination,” Laudan (1998a) characterizes each of the different underdetermination theses and then analyzes their claims relating to theory choice and scientific methodology. Laudan offers a summation of the various underdetermination theses and possible motivations for their formulation.

As my title suggests, I think that this issue has been overplayed. Sloppy formulations of the thesis of underdetermination have encouraged authors to use it—sometimes inadvertently, sometimes willfully—to support whatever relativist conclusions they fancy. . . . [O]ne important line of argument beloved of

relativists, the argument from underdetermination, will not sustain the global conclusions that they claim to derive from it. (Laudan, 1998a, pp. 321-322)

Kuhn adopts the Quinean version of underdetermination. That is, Kuhn believes that “the methods of science are inadequate ever to indicate that any theory is better than any rival, regardless of the available evidence” (Laudan, 1998a, p. 338).<sup>5</sup> If this is the case, then subjective elements are required for theory choice, and science is therefore non-rational. Kuhn (1970) maintains that subjective elements always inform objective decisions in theory choice. This is necessary, according to Kuhn, because the objective or shared criteria of scientists “are not by themselves sufficient to determine the decisions of individual scientists” (p. 106). Kuhn maintains that even shared standards used by scientists such as “Simplicity, scope, fruitfulness and even accuracy can be judged differently . . . by different people” (p. 322). And “individuals may legitimately differ about their applications to concrete cases” (p. 322). In other words, subjective elements are a part of every aspect of theory choice. Laudan concedes that the application of shared standards may be done differently by different people. However, Laudan maintains that the shared standards suggested by Kuhn are not commonly used by scientists. Laudan offers what he believes to be a better set of shared standards, including a preference for theories which are coherent, a preference for theories that are novel predictors, and a

---

5

Laudan interprets Kuhn and Quine in strongly relativist ways, and this could be disputed. It could be thought that Quine and Kuhn are closer to realism than is suggested here. However, what is important for our purposes here is that constructivists who have been influenced by Kuhn have been attracted to him because *they* understand him in just such a relativist way.

preference for theories that have proved useful over a wide range of different types of phenomena. Having provided these standards, Laudan asks rhetorically,

Even standards such as these have some fuzziness around the edges, but can anyone believe that, confronted with *any* pair of theories and *any* body of evidence, these standards are so rough-hewn that they could be used indifferently to justify choosing either element of the pair? (Laudan, 1998a, pp. 339-340, original italics)

Laudan agrees with Kuhn that concrete cases are better than hypothetical ones for determining how scientists actually conduct science. Therefore, Laudan provides an episode from the history of science in order to test Kuhn's assertion that any theory or paradigm can be preserved in the face of any evidence, which also entails Kuhn's claims that science is nonrational and nonprogressive. Laudan asserts that to show that Kuhn's thesis of underdetermination "is ill conceived . . . we need to exhibit a methodological rule, or a set of rules, a body of evidence, and a local theory choice context in which the rules and the evidence would *unambiguously* determine the theory preference" (Laudan, 1998a, p. 341, original italics).

To support his case, Laudan refers to the early 18<sup>th</sup>-century debates concerning the shape of the earth. Two rival paradigms existed. One camp, extending as far back as Aristotle and finding a modern proponent in Descartes, held that the earth was round, or, if at all deformed, it was slightly elongated along its polar axis. The opposite paradigm, based on Newton's work, held that the earth bulged along the equator. Sponsored by the Paris Académie des Sciences, measurements were taken by teams both in Peru and in

Lapland by well agreed-upon geodesic techniques of the time (Laudan, 1998a). Measurements were taken and the data were assembled by those generally sympathetic to the Cartesian hypothesis. “Nonetheless, it was *their* interpretation, as well as everyone else’s, that the evidence indicated that the diameter of the earth at its equator was significantly larger than along its polar axis” (p. 341, original italics). Everyone agreed that Newtonian celestial mechanics was better supported in this case than Cartesian. Along the way, everyone agreed to the experimental design, methods used for measuring, data collection, and interpretation. Moreover, both sides agreed to the methodological rule which requires the adoption of the better supported hypothesis. Ultimately both sides were in agreement as to which hypothesis was better supported. Laudan concludes from this that Kuhn’s underdetermination thesis which argues that rival paradigms are inexorably underdetermined by data, methods, and scientific values is unsupported. Laudan insists that for both Quine and Kuhn, “the idea that the choice between changing or retaining a theory/paradigm is ultimately and always a matter of personal preference turns out to be an unargued dogma” (p. 340). Laudan claims more universally that

no one has yet shown that established forms of underdetermination do anything to undermine scientific methodology as a venture, in either its normative or its descriptive aspect. The relativist critique of epistemology and methodology, insofar as it is based on arguments from underdetermination, has produced much heat but no light whatever. (Laudan, 1998a, p. 346)

In sum, McMullin (1998) and Laudan both conclude, contra Kuhn and others promoting

various underdetermination theses, that scientific revolutions can be both objectively rational and objectively progressive.

As it relates generally to education, the postpositivist influence is evident. Kuhn's ideas have been adopted by many constructivists in support of their positions (Loving & Cobern, 2000). Hawkins (1994) notes that Kuhn's 1962 *The Structure of Scientific Revolutions* provided "'constructivist' justification" for "philosophies of subjectivism and relativism" (p. 10). Loving and Cobern (2000) claim that the Kuhnian assertion that science progresses by a series of revolutions "provides fodder for those needing justification for the general shift from modernist or empirical to postmodern or relativist approaches in the application of theoretical frameworks" (p. 189).

The postpositivist influence is also present in adult education. Merriam and Brockett (1997), for example, note that all strains of constructivism share a subjective view of reality. Wilson and Hayes (2002a) express a postpositivist view, when they write that "Many practitioners of disciplinary inquiry are keenly aware (even as many others remain clueless) that there is nothing objective or neutral about knowledge production" (p. 5). Deshler and Grudens-Schuck (2000) write that Thomas Kuhn "convinced many people that development of disciplines and new paradigms were historically and socially constructed" (p. 594). Candy (1991) relates postpositivist philosophy of science with relativism. Invoking the name of a number of postpositivist philosophers—Kuhn, Feyerabend, and Lakatos—Candy (1991), who writes from a constructivist perspective, notes that "It seems ironic that at the time that research in education has been striving to

render itself more 'scientific' . . . research in science has become more concerned with the relativity of knowledge" (p. 253).

Adult educators are correct to remind us of the social nature of disciplinary knowledge. The sum of such considerations, however, does not mean that disciplinary knowledge can only be justified by historical and social considerations. Thus, although, Kuhn's postpositivist notions of paradigm, incommensurability, theory-ladenness of observation, and theory dependence of meaning are important to discussions of philosophy of science, they do not sound the death knell for scientific rationality and objective scientific progress.

#### *Postmodernist Constructivism*

Constructivism has the ability of uniting diverse schools of thought, even those that oppose one another (Phillips, 1995). Pragmatism and postmodernism, for example, differ widely on the goals of science and the question of their attainability. Nonetheless, constructivism is able to reconcile elements of both pragmatist and postmodernist philosophy as they center around experience as the basis of learning.

Postmodernist philosophy, like many philosophies, is diverse. Many postmodernists adhere to several commitments. These include (a) the rejection of universality, (b) the rejection of final meaning, (c) rejection of the idea of progress, (d) disillusionment with science, (e) rejection of logic and reason, and (f) the abandonment of objectivity (Rosenau, 1992). Postmodernism is generally viewed by its advocates, even in

adult education, as anti-science (Miller, 2000; Usher & Edwards, 1994). Two critics of postmodernist philosophy note that

[P]ostmodern skepticism rejects the possibility of enduring universal knowledge in any area. It holds that all knowledge is local or “situated,” the product of interaction of a social class, rigidly circumscribed by its interests and prejudices, with the historical conditions of its existence. There is no knowledge, then; there are merely stories, “narratives,” devised to satisfy the human need to make some sense of the world. In so doing, they track in unacknowledged ways the interests, prejudices, and conceits of their devisers. On this view, all knowledge projects are, like war, politics by other means. (Gross & Levitt, 1994, p. 72)

Although postmodernist philosophy is considered extreme by many, its influence is palpable in education due to the mediating influence of constructivism. Commenting on the connection between constructivism and postmodernism, philosopher and educator Phillips avers that many associated with education have been beguiled by constructivism, a term that often “is used without rhyme or reason” (1997, p. 85).

“Constructivism” is a currently fashionable magic world in the Western intellectual firmament, one which has beguiled a great many educational researchers, curriculum developers, trainers of teachers and teachers themselves, school administrators, sociologists, philosophers, and anti-philosophers who regard themselves as being of postmodern disposition. (Phillips, 2000a, p. 1)

Adult educator Stephen Brookfield describes experiential learning in a way that combines pragmatist constructivism with elements of postmodernist philosophy. In

language that is clearly imbued with postmodernist philosophy, Brookfield (2000) writes that pragmatist constructivism “emphasizes the role people play in constructing, and deconstructing, their own experiences and meanings. Constructivism rejects universals and generalizable truths, and focuses instead on the variability of how people make interpretations of their experience” (p. 37). Brookfield notes that this view is consistent with the “field’s preference for experiential methods” (p. 37) and that “the epistemology of constructivist pragmatism is subjectivist” (p. 39).

The statement by Brookfield (2000, p. 37) that “[c]onstructivism rejects universals and generalizable truths,” is a clear reference to the postmodernist dismissal of both the goals of science and its knowledge claims. Although postmodernist pragmatist constructivism rejects universals and generalizable truths, Einstein (1934/1954) believed that such knowledge is possible. Einstein held that science represents the search for universal laws that could be universally applied. Einstein stated that it was “[t]he supreme task of the physicist to arrive at those universal elementary laws . . .” and that “the general laws on which the structure of theoretical physics is based claim to be valid for any natural phenomenon whatsoever” (p. 226). Because postmodernism rejects both objective and universal knowledge claims (Rosenau, 1992), it is clearly at variance with Einstein’s science.

In cordoning off adult learning from one of the most powerful types of knowledge known, namely scientific knowledge, postmodernist constructivist positions would seem more limiting than emancipative. An emphasis, by constructivism, on adult learners “constructing, and deconstructing, their own experiences and meanings,” as it “rejects

universals and generalizable truths,” provides adults little, if any, opportunity for learning scientific knowledge. Scientific knowledge does not arise as the result of constructing and deconstructing one’s own experience.

The germ theory of disease illustrates the universal nature of scientific knowledge. The germ theory has been used for generations, and it has been applied to a broad number of contexts. The germ theory and its application seem to argue against postmodernist epistemological relativism, the idea that all knowledge is local, or situated, rather than universal.

The attribution of postmodernist commitments to pragmatism seems overreaching in some ways. One example is the clear anti-science sentiment of postmodernist philosophy not generally shared by the pragmatists. Adult educators have noted the anti-science sentiment of postmodernist philosophy (Miller, 2000; Usher & Edwards, 1994). Miller notes that,

the focus on experience as the basis for learning fits with elements of postmodernity such as uncertainty, rapid social change and technological change, dissatisfaction with totalizing explanations and grand narratives, a loss of faith in science and the rational, and the fragmentation of identity. (Miller, 2000, p. 72)

This raises the question as to whether postmodernist philosophy is reconcilable with the aims of pragmatism. Clearly, neither Dewey nor Mead were anti-science. In fact, they both held great hope for the role of science in human affairs. Dewey (1916), in fact, noted that science education in particular was the one vehicle by which students might be

emancipated “from local and temporary incidents of experience” (p. 270). Dewey claims that

The function which science has to perform in the curriculum is that which it has performed for the race: emancipation from local and temporary incidents of experience, and the opening of intellectual vistas unobscured by the accidents of personal habits and predilections. (Dewey, 1916, p. 270)

Moreover, Dewey held that science was a unique form of knowledge, one that was not easily acquired. Speaking of science and its place in education, Dewey writes that “It is artificial (an acquired art), not spontaneous; learned, not native. To this fact is due the unique, the invaluable place of science in education” (p. 189). Mead also held a high regard for both science and science education. Mead (1906b) writes, “The science courses in high school are not at the present time popular, nor is the money spent on them, either in equipment or in teaching force, comparable with their educational importance” (p. 391). It is at this point, while citing what he believes to be the important ramifications of this unfortunate situation, that Mead proclaims his high regard for science.

The result of this is that the majority of our students leave our colleges and universities, without being able to grasp the most important achievements of modern thought, without being able to take the point of view of those thinkers who are reconstructing our views of the physical universe and its constituent parts, and without being able to interpret what they see and hear and feel by means of the profoundest and most magnificent generalizations which the world has ever known. (Mead, 1906b, p. 391)

Moreover, Mead held that science teachers had certain responsibilities in terms of their subject matter and their students. In his article “Science in the High School,” Mead (1906a) writes that “What must be insisted upon is that the instructor be competent to direct the child’s work in the scientific spirit and method, giving him the doctrine pure and undefiled” (p. 246). In other words, Mead insists that students deserve to be taught by competent teachers who provide them with “spirit and method” of science responsible for the “profoundest and most magnificent generalizations which the world has ever known.”

Setting aside the difficulties of Mead’s constructivist doctrine which have been addressed by this study, it can be said that Mead’s views of science and teaching are consonant with the goals and activities of the wider scientific and educational communities. Mead’s philosophy of science can best be seen as an in-house dispute with some philosophers of his day. The same cannot be said for versions of constructivism emanating from postmodernism. Postmodernist constructivism is antithetical toward science and scientific understanding. Thus, some postmodernist attributions by adult learning theorists to the pragmatists might be for uses of pragmatism that pragmatists would not have shared. The pragmatists respected science and its aims, and they believed that science represented the “profoundest and most magnificent generalizations which the world has ever known” (Mead, 1906b, p. 391).

The postmodernist influence in adult education surfaces in the most recent *Handbook of Adult and Continuing Education* (Wilson & Hayes, 2000a) as well as *Adult Education Quarterly*. An anonymous reviewer of the Handbook noted the constructivist and postmodernist tenor of the new edition.

*Reviewer A: I think this is the finest handbook produced to date. . . . Generally the handbook is an overdose of concepts like postmodernism, constructivism, marginalization, power, social capital, human capital, context, situated cognition. I don't disagree that these are appropriate realms for examination, but after a few chapters, I'd like some new material. (anonymous reviewer, quoted by Hayes & Wilson, 2000, p. 664, original italics)*

One postmodernist theme that arises in the context of adult education is the idea that knowledge arises from power. On this view, because it is thought that knowledge stems from power, the notion of objective knowledge is an illusion. For example, Wilson and Hayes (2002a) maintain that “Many practitioners of disciplinary inquiry are keenly aware (even as others remain clueless) that there is nothing objective or neutral about knowledge production” (p. 5). Wilson and Hayes explicate this position.

Politics, in this sense, then is a code for—or represents what Wittgenstein would call a “language game” about—the systemic and particularized workings of power and knowledge in society. As Foucault has said, the production of power enables the production of knowledge. Just so, politics, the means whereby relations of power are developed and exercised, are indeed everywhere. (Wilson & Hayes, 2002a, p. 5)

The point to this argument, then, is that disciplinary knowledge is non-objective, because knowledge results ultimately from the exercise of power.

Postmodernists have done a service by pointing out the fact that power and politics—as well as religion and culture—affect knowledge construction. The question

and highly contentious point, however, is whether politics and power (i.e., social factors) by themselves are sufficient to produce—in this case—scientific knowledge.

A radical form of the postmodernist notion just expressed, which maintains that social factors alone are sufficiently capable of causing scientific knowledge, is found in the work of the Sociology of Scientific Knowledge movement (SSK) (Phillips, 2000b). The Edinburgh school, otherwise known as the Strong Programme—whose members include Bloor, Barnes, Collins, Pinch, Latour, Schaffer, Shapin, and Woolgar, among others (Nola, 1997; Phillips, 2000b)—is part of the SSK. The Strong Programme gets its name from its “strong” (or radical) set of commitments which holds that scientific knowledge is fully explainable by sociological rather than natural factors (Bloor, 1976). Some SSK members—Latour and Woolgar (1986), for example—maintain that scientific entities do not exist mind-independently, since they are nothing more than laboratory notebook inscriptions.

Despite the fact that our scientists held the belief that the inscriptions could be representations or indicators of some entity with an independent existence “out there,” we have argued that such entities were constituted solely through the use of these inscriptions. . . . [O]bjects . . . are constituted through the artful creativity of scientists. (Latour & Woolgar, 1986, pp. 128-129)

Indeed, Woolgar (1988) has referred to scientific theories as “fictions” (p. 26). Bloor is quoted by his SSK colleague Steve Fuller (1993) who writes that “science can be explained as a form of life without importing conceptions of truth, rationality, and reality that require special philosophical grounding” (p. 12). Another member, Harry Collins

(1981), summarizes the epistemological position of the SSK when he writes that “our school, however, inspired by Wittgenstein and more lately by the phenomenologists and ethnomethodologists, embraces an implicit relativism in which the natural world has a small or non-existent role in the construction of scientific knowledge” (p. 3). A critic of the SSK, Stanford University philosopher and educator Denis Phillips (1997) explicates what the principles of the SSK would mean for education.

. . . if one or other of the more radical social constructivist accounts was to be accepted, physics would no longer be depicted in our textbooks and classrooms as an enterprise which seeks true accounts of external reality; physics instead would be depicted as a political enterprise or as a realm of Rortyeian conversation<sup>6</sup>—a conversation that, explicitly, is not shaped to any significant degree by external nature, and by warranting reasons. (Phillips, 1997, pp. 89-90)

Although Wilson and Hayes do not specifically mention the SSK, they nonetheless refer to the Wittgensteinian and Foucauldian perspectives of the SSK regarding both the nature of language and the relationship between knowledge and power.

Sociologists representing the SSK maintain that the cognitive order is fully dependent upon the social order (Bloor, 1976). According to philosopher Alberto Cordero (2001, p. 180), David Bloor of the SSK “has concentrated on a ‘Wittgensteinian’ outlook in which no aspect of knowledge transcends power relations, and language and belief are understood as reflections of power relations within society.” Foucault (1970), in turn,

---

<sup>6</sup>

Richard Rorty (1979) has stated that we should “see knowledge as a matter of conversation and of social practice rather than as an attempt to mirror nature . . . (p. 171).

ponders whether “subjects responsible for scientific discourse are not determined in their situation, their function, their perceptive capacity, and their practical possibilities by conditions that dominate and even overwhelm them” (p. xiv). According to the Foucauldian account of knowledge, “individual scientists are products of a form of discourse, pawns in a collective language game which constitutes their mentalities” (Bredo, 2000, p. 137).

Not everyone concedes to the theses that science is nothing more than a “language game” or that scientists are so overwhelmed by their situations that they are incapable of critical reflection on the social and political influences that might affect their knowledge claims. There are many critics of the Strong Programme (Laudan, 1998a; Phillips, 1998; Slezak, 1994a, 1994b, 2000). Even Thomas Kuhn (1992) disavowed some of the basic epistemological assumptions which members of the Strong Programme were attempting to attribute to him. In fact, in a very pointed statement, Kuhn (1992) asserts rather emphatically that “I am among those who have found the claims of the strong program [*sic*] absurd: an example of deconstruction gone mad” (p. 9). However, Kuhn does not seem satisfied merely to attack the strong forms of the SSK, for he immediately adds: “And the more qualified sociological and historical formulations that currently strive to replace it are, in my view, scarcely more satisfactory” (p. 9). It is worthwhile to capture Kuhn’s full remarks, since they outline both sides of the contentious issues of the debate in which he found himself embroiled, the question of whether science is at all rational, or whether it can be fully explained by politics, power, and interests.

Interest, politics, power and authority undoubtedly do play a significant role in scientific life and its development. But the form taken by studies of “negotiation” has, as I’ve indicated, made it hard to see what else may play a role as well. Indeed, the most extreme form of the movement, called by its proponents “the strong program,” [*sic*] has been widely understood as claiming that power and interest are all there are. Nature itself, whatever that may be, has seemed to have no part in the development of beliefs about it. Talk of evidence, of the rationality of claims drawn from it, and the truth or probability of those claims has been seen as simply the rhetoric behind which the victorious party cloaks its power. What passes as scientific knowledge becomes, then, simply the belief of the winners. (Kuhn, 1992, pp. 8-9)

The Foucauldian thesis raised by adult educators Wilson and Hayes (2002a) in reference to disciplinary knowledge, that “the production of power enables the production of knowledge” (p. 5), deserves comment. Although there is something to the thesis, it does not apply to all possibilities. The exercise of power, contrary to the Foucauldian thesis, is not always a sufficient guarantor of scientific knowledge. Specifically, the exercise of power does not guarantee the production of scientific knowledge. The example of Soviet genetics under Trofim Lysenko seems to oppose the thesis that politics, interests, and power are sufficient guarantors of scientific knowledge.

The Soviet experiment in agronomy during Stalin’s reign has been hailed by Sovietologist Loren Graham (1998) as the best case study of the assertions made by the Edinburgh Strong Programme. Graham notes that “At Edinburgh, in particular, Barry

Barnes, David Edge, Donald MacKenzie, Steven Shapin, and Andrew Pickering were especially articulate proponents of what came to be known as sociology of scientific knowledge, or SSK” (p. 2). Utilizing Soviet-era agronomy under Trofim Lysenko as a test cast, Graham addresses the strong claim of social constructivism, which is that sociology is fully capable of explaining science. “The revolutionary effort to build a totally new society in the Soviet Union, one different from and superior to all others in the world, was a grand effort in social constructivism, probably the most ambitious such effort in history” (p. 30). Graham notes that the Soviet Union followed a different socioeconomic path from the West and that it had different “religious, political, and cultural traditions quite unlike its Western neighbors” (p. 3). Therefore, according to Graham, “If the social constructivist thesis is correct, Russian science should be very different from Western science” (p. 3). However, Russian (or, Soviet) science was not all that different from Western science, with the exception of Soviet agronomy, which not only ignored Western genetics but was based on the unfounded principles of Lysenko’s genetics.

The Soviet Union employed the services of Trofim Lysenko, a willing participant and communist party member, to head up Soviet agriculture. Lysenko’s genetics had the full political support of the Soviet authorities, which was aimed at collectivization. Moreover, Soviet agronomy involved people without regard to class, except that academic biologists were discredited, and some were swept to their death. Lysenko referred to geneticists as “fly-lovers and people-haters” (Medvedev, 1969, pp. 81, 125). Lysenko “came from a peasant family,” and “he was a vociferous champion of the Soviet regime” (Graham, 1998, p. 20). Thus, Soviet agronomy under Lysenko can be viewed as

a prime example of social constructivism. Lysenkoism represented both the culmination and support of Soviet power, politics, economic direction, and social planning.

Lysenkoism was directed at practical problems in a collaborative effort to increase Soviet agricultural production. However, “the socially constructed doctrine of Lysenkoism was being undermined by contradictory scientific evidence, a powerful alternative cognitive scheme, and the convincing results of agricultural practices based on Western-style genetics” (Graham, 1998, pp. 22-23). Graham concludes that “the Lysenko Affair—actually provides rather convincing evidence of the weakness of the extreme form of a social constructivist understanding of science” (p. 28).

As it relates to the Foucauldian thesis that power and politics—as well as other social factors—are sufficient to produce scientific knowledge, the Lysenko affair stands out in modern history as the empirical repudiation of this thesis. It is a prime example of scientific knowledge eluding its would-be power brokers.

Unfortunately, although culturally sensitive and politically very correct, Lysenko’s doctrine was false. The world, in particular the mechanisms of heredity, was not the way he described it, not the way he wished it to be. The painful lesson for the Soviet Union, after purges of politically incorrect scientists and massive crop failures, was that ideology and science had to adjust to the way the world is.

(Matthews, 1994, p. 196)

One of the lessons of Lysenkoist social constructivism seems to be that there are objective scientific truths that cannot be changed by social, political, economic, religious, and geographical factors. No matter how many Soviet workers used Lysenko’s genetic

principles, the principles did not work. It can also be said that scientific knowledge—once created—is not bound by time or specific tool usage. In other words, scientists argue, scientific knowledge is not “situated” as postmodernists claim (Gross & Levitt, 1994, p. 72). The reason scientists do not readily accept the situated view of knowledge relates to the concept and meaning of objective knowledge.

Objective knowledge is crucial to natural science (Popper, 1972). On the other hand, not everyone agrees that there is anything objective about disciplinary knowledge. For example, in reference to disciplinary knowledge, adult educators Wilson and Hayes (2002a) assert “that there is nothing objective or neutral about knowledge production” (p. 5).

Constructivists who work from postpositivist and postmodernist positions have called into question the notion of objective knowledge. Candy (1991) states that the “objectivist or naive realist view . . . implies that there is an objective reality, to which learners should be introduced” (p. 262). In denying the possibility of objective knowledge, Candy concludes that, “central to constructivism is the perhaps radical proposition that all we can ever know for certain about the real world is what it is not” (p. 264). Candy explains that a constructivist is not concerned with how well his or her ideas match up to an external world. This is because constructivists deny all forms of correspondence theories, the idea that our statements about reality correspond in any way with reality. As an alternative to correspondence theories, some constructivists are content simply to try to determine if their experiences map with other people’s experiences. A consequence of this position is that reality is forfeited (Nola, 2003). Thus,

our knowledge is not about reality but about our experiences and whether they map other people's experiences. Candy explicates this position.

To the constructivist, knowledge does not necessarily reflect or map exactly the external reality, but consists of a set of workable hypotheses, or "templates," constantly being put to the test in interactions with other people's constructions of the "same" situation. Not only are such construct systems complex and intricate, but it seems certain that no two people would ever have exactly the same cognitive structures. (Candy, 1991, p. 265)

In other words, knowledge is tested by comparing it to other people's experiences, rather than to reality itself. The subjectivism inherent in constructivism and its consequent—that people are left no alternative but to invent reality—is summed up by two adult educators.

What all of these strains of constructivism have in common is the notion that reality can be known only subjectively (a moderate constructivist view) or that reality apart from the knower does not exist (a more radical view). Knowledge is the meaning that people make out of their experiences. (Merriam & Brockett, 1997, p. 46)

Not everyone agrees with the thesis that there is nothing objective about disciplinary knowledge or its production. Although there may be subjective elements in the production of scientific knowledge, this does not mean that the process is entirely subjective or that whatever subjective elements there may be in the process necessarily doom the product to subjectivity (Grove, 1989). Carl Bereiter (1994) maintains that disciplinary knowledge is objective. Bereiter notes that "The scholarly disciplines are

distinguished from most other occupations by their concentration on World 3. They are concerned with producing and improving World 3 objects, such as theories, explanations, historical accounts, problem formulations and solutions, proofs and disproofs” (p. 23).

“World 3” is clearly a reference to Popper’s (1972) theory of objective knowledge.

Popper explicates the meaning of his concept of the “third world” of objective knowledge.

The main point of this lecture will be what I often call, for want of a better name, “*the third world.*” To explain this expression I will point out that, without taking the words “world” or “universe” too seriously, we may distinguish the following three worlds or universes: first, the world of physical objects or of physical states; secondly, the world of states of consciousness or of mental states, or perhaps of behavioural dispositions to act; and thirdly, the world of *objective contents of thoughts*, especially of scientific and poetic thoughts and works of art. (Popper, 1972, p. 105, original italics)

Scientific knowledge, according to Popper, is objective knowledge, and it “belongs to the third world, to the world of objective theories, objective problems, and objective arguments” (p. 108).

What makes some kinds of knowledge objective? As the term suggests, objective knowledge is opposed to individual or subjective knowledge. Thus, objective knowledge is not private knowledge residing in someone’s head. Rather, it is public knowledge. It is autonomous to individuals. “In this sense, theory exists independently of individuals. Thus, scientific knowledge is, contrary to the claims of many constructivists, external to

individuals” (Matthews, 2000c, p. 259). Although an idea can be proffered by an individual or group, once it is offered, it has a life of its own.

Knowledge is an artefact; it is created by us; but once created it exists outside ourselves; it possesses a certain autonomy. . . [W]e can affect it, for example, by criticizing it, by examining its logical structure; it is real . . . . it is, in a word, *objective*. (Grove, 1989, pp. 22-23, original italics)

Not all constructivists maintain that knowledge resides in the heads of individuals. The situated view of cognition maintains that knowledge is spread across the learning context. On this view, knowledge is not autonomous, like objective knowledge, however. According to situated cognitive theory, knowledge is dependent on a specific moment in time, a specific locale, and it arises as a particular group of practitioners, utilizing the tools of their profession, interact as a social community. On this view, situated knowledge, unlike scientific knowledge, is not transportable. However valuable it may be, situated knowledge cannot be equated with scientific knowledge. Grove (1985) maintains that it is a serious mistake to conclude, as some socioculturalists, that

the knowledge claims advanced by scientists are themselves *nothing but* claims “which have been *deemed to be adequate* by particular groups of actors in specific social and cultural contexts. . . The mistake lies precisely in failing to distinguish between what scientists do and what they produce. The practice of science is a process of producing scientific knowledge, but the sociologists’ assumption that once the production process has been laid bare there is nothing more to be understood is false. . . . [Scientific knowledge] exists (particularly when it is

recorded publicly in recoverable form) independently of the minds that produced it, *or even of any minds at all*, and outside of particular time and place. (Grove, 1985, pp. 22, 24, original italics)

In other words, scientific knowledge is not only objective, it is also universal. Once produced, it is not limited to time and place as situated accounts of knowledge maintain.

*Recommendations for Adult Graduate Education, Educators, and Further Research*

The significance of this study extends well beyond the question of pragmatist constructivism's viability as a science education referent for adult learners. The general epistemological implications of this study also relate to the field of adult education, including graduate adult education, educational theory, and further educational research.

One of the positive effects of constructivism is that it has spawned wide interest in philosophical matters. At the same time, it seems that there is too much philosophizing currently in adult education. What do I mean by this? In spite of the heightened awareness of epistemological issues in adult education, there seems not to be a commensurate level of philosophical understanding. It is not that educators by-and-large are incapable of understanding philosophical matters. Rather, it seems that many in education are playing—either willfully or inadvertently—the role of philosopher, when it would seem more prudent to leave some philosophical matters to philosophers. Philosophizing is not an easy task. Many ideas which seemed good at the time have turned out later not to be so good. Aspects of both Mead's and Kuhn's philosophies provide cases in point. Speaking

of the difficulty of Mead's philosophy of the act, philosopher Arthur Murphy writes that it imposes conflicting elements.

The difficulty appears rather to arise from the essential ambiguity in the theory itself, which invites and at times even requires us to interpret it in a way consistent neither with its primary intent nor with the facts to which it appeals for confirmation. (Murphy, 1939, p. 86)

One of the examples cited by Murphy is Mead's claim that objects and their meanings are neither anterior nor posterior to the act but arise within the act, on the one hand, and "that these theories can retain their ordinary sense as an account of events and processes which antedate and extend beyond the situation in which theories arise and are reconstructed," on the other (p. 86). In other words, in spite of its claim, Mead's philosophy cannot get around the importance of antecedent theorizing prior to activity. Contrary to Mead's assertion, objects have meaning prior to and after the act. Murphy concludes regarding Mead's doctrine that "It will not be surprising if such a philosophy, even in the hands of an outstanding a thinker as Mead, remains frustrated, esoteric, and incomplete" (pp. 92-93).

Similar remarks have been directed by philosophers at Kuhn's work, namely the running together of ideas that should be separate. For example, Stove (1982) notes that Kuhn's irrationalism "stems from the conflation . . . of the descriptive with the prescriptive: from his steady refusal to distinguish the history or sociology of science from the logic or philosophy of science" (p. 4). The difficulty of philosophizing, which is

evident from the examples of Mead and Kuhn, should be taken to heart by adult educators.

Although constructivism has helped make philosophy vogue, in many ways it gets in the way when used inappropriately. For example, learning methods cannot be inferred from constructivist philosophy as some constructivists believe. Nor can theories of learning tell us about how the world is or how knowledge should be determined, as some constructivists think. These points are true whether one is addressing pragmatist constructivism or some other constructivist-inspired adult learning theory. Moreover, some radical constructivists seek to supplant traditional epistemologies with their own. This is true with the radical social constructivists, for example, who assert that the sociology of scientific knowledge is the rightful heir of what was once the province of philosophy (Bloor, 1983). It also holds for the radical psychological constructivism of von Glasersfeld (1993, 1995a) which asserts that constructivism is postmodernist, post-metaphysical, and post-epistemological. Even less radical forms of constructivism can be at odds with scientific understanding. These include varieties that are based on instrumentalist and subjectivist epistemologies.

In sum, constructivism has successfully resurrected a large number of discredited ideas from the wastebasket of the history of philosophy. This phenomenon has been characterized rather bluntly by two educators who write that constructivist epistemology amounts to a “garage sale of outdated philosophical falsisms” (McCarty & Schwandt, 2000, p. 42).

### *Recommendations for Adult Graduate Education*

It seems, then, that a full awareness of philosophy is not limited to an awareness of its presence in education, that is, to things philosophical, but to a fuller understanding of philosophy as it is understood by philosophers themselves. Graduate students cannot learn philosophy of science solely by what is written by educators about Kuhn, for example, which some have described as an admiration society for Kuhn (Loving & Cobern, 2000). Nor is it possible to learn philosophy of science solely by reading Kuhn, although a reading of Kuhn is important. The same things can be said for reading Dewey. Graduate students in education need exposure to critical analyses of the ideas of important figures like Piaget, Dewey, Kuhn, and von Glasersfeld, for example. The ideas of these constructivists need to be placed alongside the disciplinary accounts of knowledge to which they apply, whether philosophical, scientific, or both. If one is to pay attention to Kuhn's postpositivist critique of the philosophy of science, then surely one must entertain the reply of philosophers of science to Kuhn's ideas as well. As a case in point (addressed by this study), although pragmatism speaks to scientific understanding, pragmatism was never considered a leading philosophy of science on the world scene. This is a serious consideration, given that Mead's doctrine is held out as a referent for science education (cf. Bentley, 1998).

The need for philosophical understanding for graduate students in education can be extended to include the philosophy of science, even for those who are not directly concerned with science. House (1991) writes in *Educational Researcher* that "Disputes in educational research over the past few decades have resulted in part from an inadequate

conception of the nature of science itself” (p. 2). Thus, whether or not one is directly concerned with either science or science education, the field of education is affected nonetheless by epistemological issues relating to science. House adds that “A common confusion [in the educational literature] is that positivism and realism are the same thing, but positivism and realism are, in fact, opposed to one another in key dimensions” (p. 3). It is perhaps because of a lack of philosophical understanding that so many constructivist sects have positivist foundational commitments (cf. Matthews, 2004c). The downside to a general lack of understanding of philosophy is that all of education, not just science education, suffers.

Turning specifically to the portrayal of philosophical positivism in education, for example, Phillips (2004) maintains that some people have made careers out of mis-characterizing positivism. Specifically, Phillips maintains that

although it is difficult (or impossible) to find a knowledgeable living person who admits to being a positivist in anything like the classical sense, there are many in the social science and education research communities, and some postmodernist and feminist philosophers, who build reputations on seeing positivists (or their ghosts) at every turn. (Phillips, 2004, p. 67)

Phillips notes that the tendency has grown in recent years “for individuals to charge their opponents indiscriminately with being ‘positivists’ without being clear what actually characterizes this position” (p. 67). It seems that the term “positivist” has come to be used simply as a rhetorical device for discrediting the position of an opponent. The device is effective, since “One of the worst things that can be said about a theorist or researcher in

education” is that he or she is “positivist” (Matthews, 2004a, p. 1). Phillips notes that, ironically, “some present-day opponents of positivism do not realize that they share its important anti-realism or instrumentalism” (p. 67). Into this category one can place the pragmatists, many constructivists, Kuhnian postpositivists, and—as Phillips notes—some postmodernist and feminist philosophers.

If one were to address the needs of graduate students of education for learning what is important, then where would one begin? In my estimation, graduate students should learn some basic epistemology. Students in graduate programs of education, particularly adult education, will often encounter the following epistemological misconceptions in the educational literature, in which both terms in each of the following pairs are often wrongly considered synonyms. In other words, although the educational literature often fails to make the distinction, graduate students should learn the differences between (a) belief and knowledge, (b) fallibilism and relativism (or tentative knowledge and relativism), (c) objectivism and absolutism (or infallibilism), (d) objectivism and positivism, and (e) realism and positivism. I would also recommend that graduate students learn the similarities and differences between idealism, empiricism, and realism. Students also need to appreciate the differences between naive realism, scientific realism, and scientism. From there, students would have a basis for beginning to understand logical positivism, constructivism, postpositivism, and postmodernism. This represents a first step in being able to recognize the epistemological dimension of these important philosophies as they might occur in adult learning theory.

### *Recommendations for Adult Educators*

In addition to these recommendations for graduate education, a few things can be recommended to adult educators. Some constructivist theorists have tried to extract pedagogical prescriptions from theories of knowledge where none exist. For example, some constructivists believe that didactic pedagogy flows from realist (Candy, 1991) or positivist (Baxter Magolda, 1999; Fleury, 1998) epistemologies. This is an interesting thesis, since realism and positivism actually oppose one another on key issues (House, 1991). In other words, if epistemology faithfully drives pedagogy, then how is it possible for two opposing epistemologies to suggest one and the same pedagogy? Conversely, some constructivist learning theorists have tried to build epistemologies based on theories of learning and the learner. On this view, learning theory doubles as epistemology. However, many would object to the idea that how we learn about unicorns, winged horses, and fairy princesses doubles as the justification for their existence.

In the first instance, the constructivist-realist debate sheds little light on pedagogical matters, that is, how teachers should teach and how learners learn. Philosopher Robert Nola (1997) notes that “Constructivists in science education often wrongly assume that the debate can tell us something about the teaching and learning of science” (p. 57). In the second instance, the drawing of epistemological and ontological principles by constructivists based on conceptions of how learning occurs, often leads to discredited empiricist philosophies (Matthews, 2000c). Consequently, I recommend that educators try to resist the urge either to formulate pedagogies based on constructivist epistemology or to formulate epistemologies based on constructivist theories of learning.

As the following discussions will reveal, these admonitions do not just apply to science education.

Epistemologies are theories of knowledge. They are not pedagogical theories. Epistemologies do not lead in any straightforward sense to pedagogies. For example, realism is a doctrine concerning the nature of the world and how science arrives at its knowledge claims. Realism is not a pedagogical theory. Realism neither dictates nor forbids any teaching or learning strategy that educators might employ which they might find to be successful in practice. The only things implied by realism concerning teaching and learning might be that (a) teachers ought to portray the scientific enterprise as it is viewed and conducted by the majority of practicing scientists, and that (b) any teaching or learning strategy that achieves this end should not be prohibited. In fact, many experienced educators employ successful teaching and learning strategies as tacit knowledge. Teachers should not be discouraged from using successful teaching and learning strategies just because they are deemed by some constructivists not to be “constructivist” (Cobb, 1994).

In maintaining that didactic pedagogies stem from non-constructivist epistemologies, some constructivists also believe that epistemological constructivism suggests non-didactic pedagogies. Jackson and MacIsaac (1994), for example, tell us that “the way we conceptualize learning has changed significantly. This change reflects a shift in our view of the nature of *knowledge . . .*” (p. 18, italics added). Moreover, like many constructivists, these two adult educators believe that constructivism provides support for student-centered, non-didactic teaching and learning methods. If, as constructivists

maintain, constructivist epistemology calls for non-didactic constructivist teaching, then non-constructivist epistemologies call for didactic pedagogies. On this view, some constructivists believe that didactic methods stem either from positivism (Baxter Magolda, 1999; Fleury, 1998) or from realism (Candy, 1991). Fleury (1998), for example, maintains that positivism is responsible for the “Faculty oriented, text-book driven classroom climate of most science classes” (p. 161), while Baxter Magolda (1999) states that “Emphasis on subject matter stems from the positivist tradition of transmitting knowledge from instructors to students” (p. 103). Candy (1991) also objects to didactic pedagogies for epistemological and ontological reasons, because he maintains that the objectivism of naive realism wrongly assumes that there is an objective reality to which students should be introduced.

The constructivist claim that particular epistemologies (both constructivist and non-constructivist) lead unequivocally to particular pedagogies does not seem to stand up under scrutiny. The actual teaching practices of several notable “constructivists” would seem to cast doubt on the thesis that constructivist epistemology calls for non-didactic pedagogies. Conversely, it seems that neither realists nor positivists are beholden to didacticism. Perhaps not well known is the fact that notable constructivists, such as Thomas S. Kuhn and John Dewey, were not averse to lecture. Kuhn explicitly championed didactic methods, and Dewey regularly lectured at Teachers College. Moreover, the logical positivist, Philipp Frank, was no more beholden to lecture than was Socrates (a realist), who, through Plato, led the slave boy in the *Meno* to the objective knowledge of the solution to the Pythagorean theorem.

Although Thomas Kuhn is often portrayed in the educational literature as a champion of constructivist philosophy (Loving & Cobern, 2000), Kuhn nonetheless insisted in his writings on science education that the success of the scientific enterprise itself was dependent upon preparing graduate students through lecture- and textbook-based instruction (Andersen, 2000; Kuhn, 2000). Kuhn (1963) writes that “science education” should remain “a relatively dogmatic initiation into a pre-established problem-solving tradition that the student is neither invited nor equipped to evaluate” (p. 351). Thus, Kuhn remains a paradoxical figure for constructivists who maintain that didactic pedagogy does not stem from constructivism, since Kuhn, in fact, expressly championed didactic methods.

Dewey’s personal pedagogy also seems paradoxical in light of the constructivist prohibition against didacticism. In fact, Dewey’s students recall the regular, hour-long lectures at Teachers College in which Dewey painstakingly and methodically developed a theme such that a few important points could be made at the end (Larrabee, 1959). One of Dewey’s students writes that “One rarely left the classroom without the conviction that something intellectually and practically important had been *said*” (Larrabee, 1959, p. 54, italics added). That something which is *said* can be of practical importance, seems inconsistent with constructivism, if not pragmatism, which places an emphasis on student activity and experience, while downplaying antecedent, or disciplinary, knowledge. Dewey’s belief early on, regarding the importance of students’ ideas for getting the learning process underway, eventually gave way to his belief that the generalizations of disciplinary knowledge were important for providing the starting point for learning

(Prawat, 2000). The early Dewey, according to Prawat (2002a), “hung everything on action; it was the linchpin of his theory” (p. 18). Later, however, “Dewey explained that the kind of action he had in mind in concept formation was mental and not physical” (p. 18).

Noted above, some constructivists maintain that didacticism stems from positivism (Baxter Magolda, 1999; Fleury, 1998). Positivism is clearly a philosophy of natural science. Its relation with didacticism is less clear. For example, the teaching practice of Philipp Frank seems to refute the constructivist thesis that positivists were obligatory didacts. Frank, who received his doctorate in theoretical physics from the University of Vienna, is considered part of the inner circle of the Vienna Circle (Stadler, 2001). One of Frank’s students at Harvard, says of the positivist that “Professor Frank spoke to us—‘lecture’ would be too formal a term—for about an hour . . . followed by a second hour of discussion. Nothing pleased him more than sharp disagreement with his own points of view in these discussions” (Blackmore, Itagaki & Tanaka, 2001, p. 71). In sum, although positivists (such as Frank) were not beholden to lecture, some constructivists, on the other hand, utilized didactic methods regularly (Dewey) or actively promoted them (Kuhn). In sum, it seems that constructivist pedagogical principles are not so easily drawn from epistemologies as some constructivists contend. More strongly, Cobb (1994) asserts that “Pedagogies derived from constructivist theory frequently involve a collection of questionable claims that sanctify the student at the expense of . . . scientific ways of knowing” (p. 4). There are many engaging ways that science educators actively involve their students in learning. This may involve instructing, explaining,

questioning, discussing—all of which involve conveying information and communication of some sort. At other times, students might conduct various types of inquiry on their own or together and share their findings in light of scientific understanding. McCarty and Schwandt (2000) also oppose the constructivist thesis that epistemology dictates pedagogy. They argue that the “philosophical characterization of a kind of knowledge, whether objective or subjective, tells us nothing about how best to convey it” (p. 79). The two educators develop their argument by posing rhetorical questions and then offer a summation.

Why shouldn't a subjective impression be conveyed, and effectively, in the form of a lecture? Why can't objective knowledge be learned “constructively,” that is by encouraging each student to find his or her own favorite approach to the subject? Hence, constructivists and constructionists err in their belief that a theory of best teaching can be derived from a theory of knowing. (McCarty & Schwandt, 2000, p. 79)

Regarding the constructivist prohibition against lecturing, McCarty and Schwandt note, ironically, that

Why couldn't lecturing—or even simple telling—turn out to be more viable for the construction of a teacher's world than dialogue or Socratic questioning? Constructivists and constructionists cannot defend the idea that they refrain from imposing objective claims upon anyone, while prohibiting the teacher outright from constructing the classroom as he or she sees fit. (McCarty & Schwandt, 2000, p. 80)

In addition to their attempt at drawing prescriptive pedagogical conclusions from epistemology, constructivists often go in the opposite direction, that is, when they attempt to draw epistemological conclusions based on theories of who learners are and how they learn. This, also, is problematic. Pratt (1993), for example, assumes that theories about adult learners can be used to draw epistemological and ontological conclusions. Although Pratt's approach may seem sound, if not popular among adult educators, the philosophical conclusions he draws are reminiscent of positivism (cf. Matthews, 2004c). Pratt (1993) notes that, "working backward" from Knowles's assumptions of the adult learner, "we can draw inferences about andragogical perspectives on learning and *knowledge*" (p. 16, italics added). Pratt begins with Knowles's assumptions of "(1) self concept, (2) prior learning, (3) readiness to learn, (4) learning orientation, and (5) motivation to learn" (p. 16) from which he draws epistemological and ontological conclusions. Although Pratt has attempted to avoid what he claims are the empiricist pitfalls of behaviorism, he does not altogether escape the clutches of empiricism. Moreover, Pratt adopts a subjectivist epistemology and an ontology that borders on idealism. Specifically, Pratt writes that

. . . the world may exist, but it is the individual's experience of the world that is most important to learning. Learning is not . . . the discovery of an independent, preexisting world. . . it is the construction of meaning through experience. . . Learning is more subjective than objective, with an emphasis on individual interpretation . . . of knowledge. . . . [K]nowledge is assumed to be actively constructed by the learner, not passively received from the environment . . .

[L]earning is . . . transformation of one's experiential world. (Pratt, 1993, pp. 16-17)

Although Pratt contends that Knowlesian andragogy supports the early Deweyan idea that “it is the individual's experience of the world that is most important to learning,” the later Dewey moved away from the foundational idea expressed above by Pratt that “[l]earning is more subjective than objective.” The later Dewey believed that ideas borrowed from the disciplines are paramount to education because they transform subjective experience (Pratt, 2000). In reference to scientific knowledge, Dewey (1916) maintained that it helps emancipate one “from local and temporary incidents of experience” and that it opens “intellectual vistas unobscured by accidents of personal habit and predilection” (p. 270).

In sum, two conclusions can be drawn relative to the relationship between constructivist learning theories and constructivist epistemology. First, epistemology does not lead in any straightforward way to pedagogy (Cobb, 1994; Irzik, 2000; McCarty & Schwandt, 2000; Nola, 1997). Second, and conversely, constructivist learning theories do not necessarily lead to workable epistemologies. Epistemological constructivism must be identified and assessed independently of constructivist pedagogy. Because constructivists who oppose didactic methods generally oppose them across disciplines, the question arises as to whether didactic pedagogies should be avoided in all disciplines. Consider the following two scenarios. If constructivism forbids didactic pedagogies across disciplines, then it is at a loss to account for the art educator who might explain the similarities and differences between the artistic representations of various schools of art so that students

might have a greater appreciation of what they are viewing. Nor can constructivism account for the situation in which a literature teacher might introduce and then compare and contrast different poetical forms—for example, the various types of sonnets—which may not be readily apparent to students. Howe and Berv (2000) comment on what they believe to be a dubious link between constructivist epistemology and constructivist pedagogy. Although neither educator is directly associated with science education, they conclude that “it is surely impracticable to always rely on constructivist teaching” and that the actual role constructivist epistemology plays in education “still remains pretty much up in the air” (p. 32). In sum, there does not seem to be a direct link between epistemology and pedagogy as some constructivists maintain. Each must stand on its own according to the particular situation.

#### *Recommendations for Further Study*

The work of adult education forebears—John Dewey, Eduard Lindeman, and Malcolm Knowles—has greatly shaped current notions of adult learning. How the work of these luminaries has shaped current adult learning theory is more than just something of historical interest. In fact, current adult learning theory bears the imprint of the philosophical assumptions adopted by these important thinkers. Thus, there is a real need to rethink existing adult education research in order to rescue well-established learning theory claims from unsound philosophical assumptions. Thus, I recommend that the philosophical dimension of the learning theories of Dewey, Lindeman, and Knowles become the focus of further study.

Taking their lead from Dewey, generations of adult education theorists have included philosophical assumptions in their learning theory claims. In many cases, however, the philosophical assumptions underpinning constructivist learning theories are suspect (McCarty & Schwandt, 2000). This is why the work of Dewey, Lindeman, and Knowles deserves more attention. The questionable philosophical assumptions of adult learning theories need to be identified and assessed.

The following are some of the questionable philosophical and methodological assumptions of current adult learning theory that stem from Dewey, Lindeman, and Knowles:

- 1) “Dewey, Lewin, and Piaget in one way or another seem to take the scientific method as their model for the learning process” (Kolb, 1984, p. 32).
- 2) “After the conquest of the inductive method in all spheres of scientific inquiry, we are not called upon to defend its claim in pedagogy” (Dewey, 1898/1972, p. 545).
- 3) After having concrete experiences, adult learners “must be able to create concepts that integrate their observations into logically sound theories” (Kolb, 1984, p. 30).
- 4) According to Knowlesian andragogy, “[l]earning is not . . . the discovery of an independent, preexisting world. . . it is the construction of meaning through experience” (Pratt, 1993, p. 16).
- 5) “. . . the epistemology of pragmatist constructivism is subjectivist” (Brookfield, 2000, p. 39).

6) “Immediate personal experience is the focal point of learning,” and it enables one “to test and validate abstract concepts” (Kolb, 1984, p. 21).

7) “[T]he approach to adult education will be via the route of *situations*, not subjects. . . . [T]he resource of highest value in adult education is the *learner’s experience*” (Lindeman, 1926, p. 6, original italics).

Each of the previous assertions involve questionable methodological and epistemological claims, including induction, verification, and subjectivism. The inductive method and subjective epistemology of many constructivist positions assume that individual adult learners can extract conceptual knowledge from their environment.

Dewey unleashed the progressive movement in education when he declared early in his career that, because the natural scientific method was inductive so, too, should be learning (Prawat, 2000). Based on the idea that induction is at the heart of learning, Dewey “is viewed as a staunch advocate of what has been variously termed an activity-based, problem-centered, or hands-on approach to education” (Prawat, 2000, p. 805).

Although Dewey had, in fact, erred when he declared that the natural scientific method of his day was inductive, the point is that pragmatist-inspired learning theories often rest on a set of questionable philosophical assumptions and scientific methods, one of them being induction. In short, pragmatist-inspired adult learning theories are nothing less than the instantiations of pragmatist views of philosophy of science and its methods. Kolb (1984) notes that “Dewey, Lewin, and Piaget in one way or another seem to take the scientific method as their model for the learning process” (p. 32). There are, however, two problems with the view that pragmatist scientific methods should serve as the model for

the learning process. First, the view assumes that pragmatist philosophy and scientific methods represent the views of today's practicing scientists. Second, the view assumes that the process of learning science, on the one hand, and the process of generating scientific knowledge, on the other, are essentially one and the same processes. Both of these claims have been contested by critics of constructivism.

Inductive learning methods hold that students are able to derive knowledge by abstracting generalities from the particulars of their experiences. Kolb maintains that the experiential learning approaches of Lewin, Piaget, and Dewey all require that, after having concrete experiences, learners "must be able to create concepts that integrate their observations into logically sound theories" (p. 30). On the other hand, Ogborn (1997) asserts that students do not learn science in this inductive fashion. Rather, they learn what science considers to be valid knowledge. Ogborn contends that students actually learn "knowledge once made public and objectively existent." Ogborn (1997) maintains that to identify the process of gaining "new knowledge by a scientific community with the learning of such knowledge once made public and objectively existent" is an idea which seems "to me to be wrong or confused" (p. 131). Constructivist critic Robin Millar shares Ogborn's view. "Science education is not about developing personal theories about phenomena but about coming to share (at some level) in consensually held theories" (Millar, 1989, p. 592). Setting aside for a moment the question of whether scientific theories can be abstracted inductively, there is another issue that needs to be considered. Because Kolb claims that experiential learning theory is essentially the instantiation of

scientific method, then it matters what scientific method is being promoted. The scientific method Kolb seems to be promoting bears a striking resemblance to logical positivism.

There are, perhaps, three distinctive philosophies of science that need to be taken seriously in an educational context. The first is *logical positivism*, which holds that true facts and theories are those that can be *verified* by observation. Induction (the process of deriving valid generalizations from a collection of specific observations) is a major part of this approach. (Millar, 1989, p. 591, original italics)

In taking his lead from Dewey's natural philosophy of science, it not surprising that Kolb's experiential learning theory might share crucial elements with logical pragmatism, given that pragmatism and logical positivism share several key elements (Gruender, 1982; Phillips, 2004). In the above description of logical positivism, Millar notes its commitment to induction and the principle of verification. In his description of Lewin's experiential learning model, Kolb notes, for example, that "[i]mmediate personal experience is the focal point for learning" and that it enables one "to validate and test abstract concepts" (p. 21). This is highly reminiscent of the verifiability principle of logical positivism, "which stated that something is meaningful if and only if it is verifiable empirically. . . by observation via the senses" (Phillips, 2004, p. 72). Thus, Kolb's conception of experiential learning theory, which maintains that students actually "create concepts that integrate their observations into logically sound theories," and that they are able "to test and validate abstract concepts," sounds very similar to Millar's description of logical positivism, which is based on induction and the validation of

abstract concepts through personal experience. However, science does not proceed by induction, nor does it verify abstract concepts by reducing them to everyday experience. These pragmatist commitments, which Dewey borrowed from Ernst Mach's science—logical positivism—held sway in many quarters at the turn of the 19<sup>th</sup> century. Matthews note that

The young Dewey shared with Ernst Mach and John Stuart Mill the wide-spread 19<sup>th</sup> century view that it was by looking carefully at nature, and then proceeding with cautious inductions, that Galileo and Newton launched modern science. He thought that if children likewise “experienced” the world at first hand, they would come to know the world. (Matthews, 2004b, p. 707)

Matthews is referring here to Dewey's commitment to the inductive method which the latter confidently proclaimed in 1898 to be the method of science. Only later did Dewey strongly renounce the inductive method as the basis of science or of learning. “It would be difficult to imagine a doctrine more absurd than the theory that general ideas or meanings arise by the comparison of a number of particulars, eventuating in the recognition of something common to them all” (Dewey, 1929, p. 155). “Unfortunately, many progressive educators either did not notice or did not attend to Dewey's change of mind” on the question of induction (Matthews, 2004b, p. 709). Instead, they persisted with various forms of experiential, student-centered learning (Matthews, 2004b).

Eduard Lindeman is another eminent figure in adult education. Lindeman was influenced greatly by the pragmatists (Stewart, 1987). Lindeman represents a pivotal point in the history of adult education. Lindeman adopted many of the views of early

pragmatism. For example, Lindeman was adamant that all worthwhile adult education begins with personal experience. According to Lindeman (1926), “the resource of highest value in adult education is the *learner’s experience*” (p. 6, original italics). This is because “Intelligence performs its functions in relation to actualities, not abstractions” (p. 6). Borrowing from the early Dewey, Lindeman maintains that adults first “dig down into the reservoirs of their experiences before resorting to texts and secondary facts” (p. 7). Lindeman’s assumption, of course, is that all meaningful knowledge for adults must be concrete (as opposed to abstract) and that it must arise from personal experience. Finally, this gives rise to the oft-repeated maxim that “in adult education the curriculum is built around the student’s needs and interests” (p. 6). The point here is not to argue the merits and demerits of Lindeman’s various theses. The point is to call attention to specific, non-empirical assumptions that remain current in adult education that can rightly be questioned. In fact, there is some evidence that Dewey did not share a lot of the progressivist ideals that became the fabric of Lindeman’s adult learning theory. Some of these are worth noting.

Although Dewey would later reverse his earlier position that learning must begin with the particulars of experience rather than with the motivating ideas of disciplinary knowledge (Prawat, 2000; 2002a, 2002b), Lindeman did not adopt this later Deweyan position. Lindeman (1926) also remained committed to the kinesthetic basis of learning. For Lindeman, “Experience is, first of all, doing something” (p. 87). Learning for Lindeman was dynamic (Kidd, 1961).

You don't change until you do something. You don't change by listening. You don't change by talking. You actually change when something happens to your muscles. When you step or move in a new way, then the change becomes really significant. (Lindeman, quoted by Kidd, 1961, p. xxix)

The early Dewey, according to Prawat (2002a), "hung everything on action; it was the linchpin of his theory" (p. 18). Later, however, "Dewey explained that the kind of action he had in mind in concept formation was mental and not physical" (p. 18).

Again, the point is not to rule either in favor of either Lindeman or Dewey, both of whom are adult education forebears. However, one cannot help but draw attention to some of the important differences between them, because it indicates that current adult learning theory is in fact rife with many contested and contestable philosophical assumptions, which can rightly be questioned. Therefore, a study of the thought of Dewey, Lindeman, and Knowles, although of utmost historical and biographical interest, is also important for showing how their basic philosophical assumptions have helped shape current notions of adult learning theory. Just as I have attempted to show in this study that pragmatist constructivist philosophy dooms pragmatist constructivism as a science education referent, similar studies focusing on the work of Dewey, Lindeman, and Knowles might shed new light on the philosophical assumptions that underpin our notions of adult learning.

## References

- Andersen, H. (2000). Learning by ostension: Thomas Kuhn on science education. *Science and Education*, 9, 91-106.
- Askov, E. N. (2000). Adult literacy. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 247-262). San Francisco: Jossey-Bass.
- Aune, B. (1970). *Rationalism, empiricism, and pragmatism: An introduction*. New York: Random House.
- Baldwin, J. D. (1986). *George Herbert Mead: A unifying theory for sociology*. Beverly Hills, CA: Sage Publications.
- Baxter Magolda, M. B. (1999). *Creating contexts for learning and self-authorship*. Nashville, TN: Vanderbilt University Press.
- Bentley, M. L. (1998). Constructivism as a referent for reforming science education. In Marie Laroche, Nadine Bednarz, & James W. Garrison (Eds.), *Constructivism and education* (pp. 233-249). New York: Cambridge University Press.
- Bereiter, C. (1994). Constructivism, socioculturalism, and Popper's World 3. *Educational Researcher*, 23(7), 21-23.
- Bettencourt, A. (1993). The construction of knowledge: A radical constructivist view. In Kenneth Tobin (Ed.), *The practice of constructivism in science education* (pp. 39-50). Washington, DC: AAAS Press.

Bianchini, J. A. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. *Journal of Research in Science Teaching*, 34, 1039-1065.

Bickhard, M. C. (1995). World mirroring versus world making: There's gotta be a better way. In Leslie P. Steffe & Jerry Gale (Eds.), *Constructivism in education* (pp. 229-267). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bickhard, M. C. (1998). Constructivisms and relativisms: A shopper's guide. In Michael R. Matthews (Ed.), *Constructivism in science education: A philosophical examination* (pp. 99-112). Dordrecht: Kluwer.

Blackmore, J. T., Itagaki, R., & Tanaka, S. (Eds.) (2001). *Ernst Mach's Vienna 1895-1930*. Dordrecht: Kluwer Academic Publishers.

Bloor, D. (1976). *Knowledge and social imagery*. London: Routledge and Kegan Paul.

Bloor, D. (1983). *Wittgenstein: A social theory of knowledge*. New York: Columbia University Press.

Bouret, S. G., & Simerly, R. B. (2004). Minireview: Leptin and development of hypothalamic feeding circuits. *Endocrinology*, 145(6), 2621-2626.

Bredo, E. (2000). Reconsidering social constructivism: The relevance of George Herbert Mead's Interactionism. In D. C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 127-157). Chicago: University of Chicago Press.

Brickhouse, N., Ford, D., Kittleson, J., & Lottero-Perdue, P. (2003). Challenging the empiricist nature of elementary science instruction with text. *7<sup>th</sup> International History, Philosophy of Science and Science Teaching Conference Proceedings* (pp.180-186). Winnipeg, Canada.

Bridgman, P. W. (1927). *The logic of modern physics*. New York: The Macmillan Company.

Broglio, F., Gianotti, L., Destefanis, S., Fassino, S., Abbate Daga, G., Monelli Lanfranco, F., et al. (2004). The endocrine response to acute ghrelin administration is blunt in patients with anorexia nervosa, a ghrelin hypersecretory state. *Clinical Endocrinology*, 60(5), 592-599.

Brookfield, S. D. (1985). Self-directed learning: A conceptual and methodological exploration. *Studies in the Education of Adults*, 17 (1), 19-32.

Brookfield, S. D. (2000). The concept of critically reflective practice. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 33-49). San Francisco: Jossey-Bass.

Brown, S. (1998). Idealism. In S. Brown, D. Collinson, & R. Wilkinson (Eds.), *One hundred twentieth-century philosophers* (pp. 216-217). London: Routledge.

Burke, R. (1992). G. H. Mead and the problem of metaphysics. In Peter Hamilton (Series Ed.), *George Herbert Mead: Critical assessments: Vol. 4* (pp. 34-40). London: Routledge.

Caffarella, R. (1993). Self-directed learning. In Sharan B. Merriam (Ed.), *An update on adult learning theory. New Directions for Adult and Continuing Education*, no. 57 (pp. 25-35). San Francisco: Jossey-Bass Publishers.

Caffarella, R. S., & Barnett, B. G. (1994). Characteristics of adult learners and foundations of experiential learning. In L. Jackson & R. S. Caffarella (Eds.), *Experiential learning: A new approach. New Directions for Adult and Continuing Education*, no. 62 (pp. 29-34). San Francisco: Jossey-Bass Publishers.

Calabrese, E. J., Stanek, E. J., James, R. C., & Roberts, S. M. (1997). Soil ingestion: a concern for acute toxicity in children. *Environmental Health Perspectives*, 105(12), 1354-1358.

Campbell, N. A., Reece, J. B., & Mitchell, L. G. (1999). *Biology* (5<sup>th</sup> ed.). New York: Addison Wesley Longman.

Candy, P. C. (1989). Constructivism and the study of self-direction in adult learning. *Studies in the Education of Adults*, 21, 96-116.

Candy, P. C. (1991). *Self-direction for lifelong learning: A comprehensive guide to theory and practice*. San Francisco: Jossey-Bass.

Cape Fear Community College (2004). Psychological service bureau (PSB) study guide. (n.d.). Retrieved September 9, 2004, from <http://www.cfcc.net/learninglab/PSP/PSB.htm>

Carnap, R. (1928). *The logical structure of the world* (trans. R. George). Berkeley, CA: University of California Press.

Carson, R. & Rowlands, S. (2003). Mechanics as a logical point of entry for the enculturation of scientific thinking. *7<sup>th</sup> International History, Philosophy of Science and Science Teaching Conference Proceedings* (pp. 716-727). Winnipeg.

Charlesworth, M. (1982). *Science, non-science, and pseudo-science*. Burwood, Victoria, Australia: Deakin University Press.

Cobb, P. (1994). Constructivism in science and mathematics education. *Educational Researcher*, 23(7), 4.

Cochrane, C., Malcolm, R., & Brewerton, T. (1998). The role of weight control as a motivation for cocaine abuse. *Addictive Behaviors*, 23(2), 201-207.

Cohen, A. M., & Brawer, F. B. (1996). *The American community college* (3<sup>rd</sup> ed.). San Francisco: Jossey-Bass.

Colburn, A. (2000). Constructivism: Science education's "Grand Unifying Theory." *Clearing House*, 74(1), 9-13.

Coll, A. P., Challis, B. G., O'Rahilly, S. (2004). Peptide YY3-36 and satiety: Clarity or confusion? *Endocrinology*, 145(6), 2582-2584.

Collard, S. (1985). The self-directed andragogue is alive and well and inhabiting discourse. Unpublished manuscript, Department of Adult Education, University of British Columbia (cited in Philip Candy, 1991).

Collins, H. M. (1981). Stages in the empirical programmes of relativism. *Social Studies of Science*, 11, 3-10.

Collins, R. (1989/1992). Toward a neo-Medean sociology of mind. In Peter Hamilton (Series Ed.), *George Herbert Mead: Critical assessments: Vol. 4* (pp. 263-296). New York: Routledge.

Confrey, J. (1990). What constructivism implies for teaching. In R. B. Davis, C. A. Maher, & N. Noddings (Eds.), *Constructivist views on the teaching and learning of mathematics* (pp. 107-122). Reston, VA: National Council of Teachers of Mathematics.

Conlin, M. F. (1999). The popular and scientific reception of the Foucault pendulum in the United States. *Isis*, 90(2), 181-204.

Cordero, A. (2001). Scientific culture and public education. In Fabio Bevilacqua, Enrico Giannetto, & Michael R. Matthews (Eds.), *Science education and culture: The contribution of history and philosophy of science* (pp. 17-29). Dordrecht: Kluwer Academic Publishers.

Cuntz, U., Frühauf, E., Wawarta, R., Tschöp, M., Folwaczny, C., Riepl, R., et al. (2002). A role for the novel weight-regulating hormone ghrelin in anorexia nervosa. *American Clinical Laboratory*, May: 22-23.

Curd, M., & Cover, J. A. (Eds.) (1998). *Philosophy of science: The central issues*. New York: W. W. Norton & Company.

Deshler, D., & Grudens-Schuck, N. (2000). The politics of knowledge construction. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 592-611). San Francisco: Jossey-Bass.

Devitt, M. (1997). *Realism and truth* (2<sup>nd</sup> ed.). Princeton, NJ: Princeton University Press.

de Waal, C. (2002). *On Mead*. Belmont, WA: Wadsworth/Thomson Learning.

Dewey, J. (1897/1972). My pedagogic creed. In J. Dewey, *The early works, Vol.*

5. Carbondale: Southern Illinois University Press.

Dewey, J. (1898/1972). Report of the committee on a detailed plan for a report on elementary education. In J. Dewey, *The early works, Vol. 5*. Carbondale: Southern Illinois University Press.

Dewey, J. (1916/1986). *Democracy and education: An introduction to the philosophy of education*. New York: Macmillan.

Dewey, J. (1929). *The quest for certainty: A study of the relation of knowledge and action*. New York: Minton, Balch.

Dewey, J. (1931). George Herbert Mead. *The Journal of Philosophy*, 27, 310-311.

Dewey, J. (1933/1986). How we think: A restatement of the relation of reflective thinking to the educative process. In J. A. Boydston (Ed.), *John Dewey, the later works, 1925-1953, Vol. 8* (pp. 105-352). Carbondale, IL: Southern Illinois University Press.

Dewey, J. (1938). *Experience and education*. New York: Collier.

Dijksterhuis, E. J. (1986). *The mechanization of the world picture*. Princeton, NJ: Princeton University Press.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher*, 23 (7), 5-12.

Druce, M. R., Small, C. J., & Bloom, S. R. (2004). Minireview: Gut peptides regulating satiety. *Endocrinology*, 145(6), 2660-2665.

Dugas, R. (1988). *A history of mechanics* (J. R. Maddox, Trans.). New York: Dover. (Original published 1955)

Einstein, A. (1954). Principles of research. In Carl Seelig (Ed.), *Ideas and opinions by Albert Einstein* (Sonja Bargmann, Trans.). New York: Crown Publishers. (Original article published 1918)

Einstein, A. (1954). Johannes Kepler. In Carl Seelig (Ed.), *Ideas and opinions by Albert Einstein* (Sonja Bargmann, Trans.). New York: Crown Publishers. (Original article published 1930)

Einstein, A. (1954). On the method of theoretical physics. In Carl Seelig (Ed.), *Ideas and opinions by Albert Einstein* (Sonja Bargmann, Trans.). New York: Crown Publishers. (Original article published 1934).

Einstein, A. (1954). Principles of research. In Carl Seelig (Ed.), *Ideas and opinions by Albert Einstein* (Sonja Bargmann, Trans.). New York: Crown Publishers. (Original article published 1934).

Einstein, A., & Infeld, L. (1966). *The evolution of physics: From early concepts to relativity and quanta* (2<sup>nd</sup> ed.). New York: Simon & Schuster.

Ellsworth, J. H. (1992). Adults' learning: The voices of experience. *Mountain Plain Adult Education Association Journal of Adult Education*, 21 (1), 24-34.

Ernest, P. (1995). The one and the many. In Leslie P. Steffe & Jerry Gale (Eds.), *Constructivism in education* (pp. 229-267). Hillsdale, NJ: Lawrence Erlbaum Associates.

Fensham, P. (1992). Science and technology. In P. W. Jackson (Ed.), *Handbook of research on teaching* (p. 801). New York: Macmillan.

Fenwick, T. J. (2000a). Expanding conceptions of experiential learning: A review of the five contemporary perspectives of cognition. *Adult Education Quarterly*, 50, 243-272.

Fenwick, T. J. (2000b). Putting meaning into workplace learning. In A. L. Wilson & E. R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 294-311). San Francisco: Jossey-Bass.

Fermi, L., & Bernardini, G. (1961). *Galileo and the scientific revolution*. New York: Basic Books.

Feyerabend, P. K. (1970). Consolations for the specialist. In I. Lakatos and A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 197-230). Cambridge: Cambridge University Press.

Feynman, M. (2005). The Feynman file. *Discover*, 26 (3), 46-51.

Fleer, M. (1999). Children's alternative views: Alternative to what? *International Journal of Science Education*, 21 (2), 119-135.

Fleury, S. C. (1998). Social studies, trivial constructivism, and the politics of social knowledge. In Marie Larochelle, Nadine Bednarz, & Jim Garrison (Eds.), *Constructivism in education* (pp. 156-172). Cambridge: Cambridge University Press.

Fosnot, C. T. (1996a). Constructivism: A psychological theory of learning. In Catherine Twomey Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (pp. 8-33). New York: Teachers College Press.

- Fosnot, C. T. (1996b). Preface. In Catherine Twomey Fosnot (Ed.), *Constructivism: Theory, perspectives, and practice* (pp. ix-xi). New York: Teachers College Press.
- Foucault, M. (1970). *The order of things*. New York: Random House.
- Fuller, S. (1993). *Philosophy of science and its discontents*. New York: Guilford Press.
- Gadsby, P. (2004). The Intuit paradox. *Discover*, 25 (10), 48-55.
- Garrison, J. (1994). Realism, Deweyan pragmatism, and educational research. *Educational Researcher*, 23 (1), 5-14.
- Garrison, J. (1998). Toward a pragmatic social constructivism. In Marie Larochelle, Nadine Bednarz, & James W. Garrison (Eds.), *Constructivism and Education* (pp. 43-60). New York: Cambridge University Press.
- Geary, D. C. (1995). Reflections of evolution and culture in children and cognition: Implications for mathematical development and instruction. *American Psychologist*, 50, 24-37.
- Gibson, C. C. (2000). Distance education for lifelong learning. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 423-437). San Francisco: Jossey-Bass.
- Graham, L. R. (1998). *What have we learned about science and technology from the Russian experience?* Stanford, CA: Stanford University Press.
- Grayling, A. C. (1995). Metaphysics: Introduction. In A. C. Grayling (Ed.), *Philosophy: A guide through the subject* (pp. 183-184). Oxford: Oxford University Press.

- Gross, P., & Levitt, N. (1994). *Higher superstition: The academic left and its quarrel with science*. Baltimore, MD: Johns Hopkins University Press.
- Grove, J. W. (1989). *In defence of science: Science, technology, and politics in modern society*. Toronto: University of Toronto Press.
- Gruender, D. (1982). Pragmatism, science, and metaphysics. *The Monist*, 65, 189-210.
- Hacker, R. G., & Harris, M. (1992). Adult learning of science for scientific literacy: Some theoretical and methodological perspectives. *Studies in the Education of Adults*, 24(2), 217-225.
- Hausfather, S. (2001). Where's the content? The role of content in constructivist teacher education. *Educational Horizons*, 80(1), 15-19.
- Hawkins, D. (1994). Constructivism: Some history. In P. Fensham, R. Gunstone, & R. White (Eds.), *The content of science: A constructivist approach to its teaching and learning* (pp. 9-13). London: Falmer Press.
- Hayes, E. R., & Wilson, A. L. (2000). Reflections on the field. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 660-676). San Francisco: Jossey-Bass.
- Hempel, C. (1966). *Philosophy of natural science*. Upper Saddle River, NJ: Prentice Hall.
- Heymsfield, S. B., Greenberg, A. S., Fujioka, K., Dixon, R. M., Kushner, R., Hunt, H., et al. (1999). Recombinant leptin for weight loss in obese and lean adults. *Journal of the American Medical Association*, 282(16), 1568-1575.

Higgins, B. (2003, September). Predictors for program completion and passage of the NCLEX. *National Association for Associate Degree Nursing*, 6-7.

Hodson, D. (1998). *Teaching and learning science: Towards a personalized approach*. Buckingham: Open University Press.

Holford, J., & Jarvis, P. (2000). The learning society. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 643-659). San Francisco: Jossey-Bass.

House, E. R. (1991). Realism in research. *Educational Researcher*, 20 (6), 2-9.

House, E. R. (1994). Is John Dewey eternal? *Educational Researcher*, 23 (1), 15-16.

Howe, K. R., & Berv, J. (2000). Constructing constructivism, epistemological and pedagogical. In D.C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 19-40). Chicago: University of Chicago Press.

Irzik, G. (2000). Back to basics: A philosophical critique of Constructivism. *Science and Education*, 9, 621-639.

Jackson, L., & MacIsaac, D. (1994). Introduction to a new approach to experiential learning. In L. Jackson & R. S. Caffarella (Eds.), *Experiential learning: A new approach*. *New Directions for Adult and Continuing Education*, no. 62 (pp. 17-28). San Francisco: Jossey-Bass Publishers.

Jarvis, P. (1999). *The practitioner-researcher: Developing theory from practice*. San Francisco: Jossey-Bass.

Joas, H. (1985). *G. H. Mead: A contemporary re-examination of this thought* (Raymond Meyer, Trans.). Cambridge, MA: The MIT Press.

Jones, J. E. (1994). Portfolio assessment as a strategy for self-direction in learning. In Roger Hiemstra & Ralph Brockett (Eds.), *Overcoming resistance to self-direction in adult learning. New Directions for Adult and Continuing Education, 64* (pp. 23-29). San Francisco: Jossey-Bass.

Johns, T., & Duquette, M. (1991). Detoxification and mineral supplementation as a function of geophagy. *American Journal of Clinical Nutrition, 53*, 448-456.

Kidd, J. R. (1961). Editor's preface to 1961 edition. In Eduard C. Lindeman (1926), *The meaning of adult education*. New York: New Republic.

Knowles, M. S. (1968). Andragogy, not pedagogy. *Adult Leadership, 16*, 350-352, 386.

Knowles, M. S. (1970). *The modern practice of adult education: From pedagogy to andragogy*. New York: Association Press.

Knowles, M. S. (1975). *Self-directed learning*. New York: Association Press.

Knowles, M. S. (1980). *The modern practice of adult education: From pedagogy to andragogy* (2<sup>nd</sup> ed.). New York: Cambridge Books.

Knowles, M. S. (1989). *The making of an adult educator: An autobiographical journey*. San Francisco: Jossey-Bass.

Kolb, D. (1984). *Experiential learning: Experience as the source of learning and development*. Englewood Cliffs, NJ: Prentice Hall.

- Koyré, A. (1968). *Metaphysics and measurement*. Cambridge: Harvard University Press.
- Kuhn, T. S. (1957). *The Copernican revolution*. New York: Random House.
- Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.
- Kuhn, T. S. (1963). The function of dogma in scientific research. In A. Crombie (Ed.), *Scientific change* (pp. 347-369). London: Heinemann.
- Kuhn, T. S. (1970). *The structure of scientific revolutions* (2<sup>nd</sup> ed.). Chicago: University of Chicago Press.
- Kuhn, T. S. (1992). *The trouble with historical philosophy of science*. The Robert and Maurine Rothschild Lecture, Harvard University, Department of History of Science.
- Kuhn, T. S. (2000). On learning physics. *Science and Education*, 9, 11-19.
- Kumar, A., & Jazieh, A. R. (2001). Case report of sideroblastic anemia caused by ingestion of coins. *American Journal of Hematology*, 66(22), 126-129.
- Lakatos, I. (1970). Falsification and the methodology of scientific research programmes. In I. Lakatos and A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 91-196). Cambridge: Cambridge University Press.
- Larrabee, H. A. (1959). John Dewey as a teacher. In W. W. Brickman & S. Leher (Eds.), *John Dewey: Master educator* (pp. 50-57). New York: Society for the Advancement of Education.

Larochelle, M., & Bednarz, N. (1998). Constructivism and education: beyond epistemological correctness. In M. Larochelle, N. Bednarz, & J. W. Garrison, (Eds.), *Constructivism and Education* (pp. 3-20). New York: Cambridge University Press.

Latour, B., & Woolgar, S. (1986). *Laboratory life: The construction of scientific facts* (2<sup>nd</sup> ed). Princeton: Princeton University Press.

Laudan, L. (1998a). Demystifying underdetermination. In Martin Curd & J. A. Cover (Eds.), *Philosophy of science: The central issues* (pp. 320-353). New York: Norton.

Laudan, L. (1998b). Dissecting the holist picture of scientific change. In Martin Curd & J. A. Cover (Eds.), *Philosophy of science: The central issues* (pp. 139-169). New York: Norton.

Lawson, A. E. (2000). How do humans acquire knowledge? And what does that imply about the nature of knowledge? *Science and Education*, 9, 577-598.

Lawson, A. E. (2002). What does Galileo's discovery of Jupiter's moons tell us about the process of scientific discovery? *Science and Education*, 11, 1-24.

Lawson, A. E., Alkhoury, S., Benford, R., Clark, B. R., & Falconer, K.A. (2000). What kind of scientific concepts exist? Concept construction and intellectual development in college biology. *Journal of Research in Science Teaching*, 37(9), 996-1018.

Lee, P., & Caffarella, R. S. (1994). Methods and techniques for engaging learners in experiential learning activities. In Lewis Jackson and Rosemary S. Caffarella (Eds.), *Experiential learning: A new approach. New Directions for Adult and Continuing Education, no. 62* (pp. 43-54). San Francisco: Jossey-Bass.

Lewis, L. H., & Williams, C. J. (1994). Experiential learning: Past and present. In L. Jackson & R. S. Caffarella (Eds.), *Experiential learning: A new approach. New Directions for Adult and Continuing Education, no. 62* (pp. 5-16). San Francisco: Jossey-Bass Publishers.

Lindeman, E. (1926/1989). *The meaning of adult education*. New York: New Republic.

Lombardi, O. (1999). Aristotelian physics in the context of teaching science: A historical-philosophical approach. *Science and Education, 8*, 217-239.

Long, H. B. (1989). Editor's preface to 1989 edition. In Eduard Lindeman, *The meaning of adult education*. Norman, OK: University of Oklahoma.

Loving, C. C., & Cobern, W. C. (2000). Invoking Thomas Kuhn: What citation analysis reveals about science education. *Science and Education, 9*, 187-206.

Masterman, M. (1970). The nature of a paradigm. In I. Lakatos and A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 59-89). Cambridge: Cambridge University Press.

Matthews, M. R. (1992a). Constructivism and the empiricist legacy. In M. K. Pearsall (Ed.), *Scope, sequence and coordination of secondary school science: Relevant research* (pp. 183-196). Washington, D. C.: National Science Teachers Association.

Matthews, M. R. (1992b). Constructivism and Empiricism: An incomplete divorce. *Research in Science Education*, 22, 299-307.

Matthews, M. R. (1993). Constructivism and science education: Some epistemological problems. *Journal of Science Education and Technology*, 2, 359-370.

Matthews, M. R. (1994). *Science teaching: The role of history and philosophy of science*. New York: Routledge.

Matthews, M. R. (2000a). Appraising constructivism in mathematics and science education. In D.C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 161-192). Chicago: University of Chicago Press.

Matthews, M. R. (2000b). Editorial. *Science and Education*, 9, 1-10.

Matthews, M. R. (2000c). *Time for science education: How teaching the history and philosophy of pendulum motion can contribute to science literacy*. New York: Kluwer.

Matthews, M. R. (2002). Constructivism and science education: A further appraisal. *Journal of Science Education and Technology*, 11 (2), 121-134.

Matthews, M. R. (2004a). Editorial. *Science and Education*, 13, 1-5.

Matthews, M. R. (2004b). Idealisation and Galileo's pendulum discoveries: Historical, philosophical and pedagogical considerations. *Science and Education*, 13, 689-715.

Matthews, M. R. (2004c). Reappraising positivism and education: The arguments of Philipp Frank and Herbert Feigl. *Science and Education*, 13, 7-39.

McCarthy, C., & Sears, E. (2000). Science education: Constructing a true view of the real world? In L. Stone (Ed.), *Philosophy of Education 2000* (pp. 369-377). Urbana, IL: Philosophy of Education Society.

McCarty, L. P., & Schwandt, T. A. (2000). Seductive illusions: Von Glasersfeld and Gergen on epistemology and education. In D.C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 41-85). Chicago: University of Chicago Press.

McMullin, E. (1998). Rationality and paradigm change in science. In Martin Curd & J. A. Cover (eds.), *Philosophy of science: The central issues* (pp. 119-138). New York: Norton.

Mead, G. H. (1906a). Science in the high school. *School Review*, 14, 237-249.

Mead, G. H. (1906b). The teaching of science in college. *Science*, 24, 390-397.

Mead, G. H. (1932). *The philosophy of the present*. Arthur Murphy (Ed.). Chicago, IL: The Open Court.

Mead, G. H. (1934). *Mind, self, and society from the standpoint of a social behaviorist*. Charles W. Morris (Ed.). Chicago: University of Chicago Press.

Mead, G. H. (1936). *Movement of thought in the nineteenth century*. M. H. Moore (Ed.). Chicago: University of Chicago Press.

Mead, G. H. (1938). *The philosophy of the act*. Charles W. Morris (Ed.). Chicago: University of Chicago Press.

Mead, G. H. (1964). *Selected writings*. Andrew W. Reck (Ed.). Indianapolis, IN: Bobbs-Merrill Company.

Mead, G. H. (1982). *The individual and the social self: Unpublished work of George Herbert Mead*. David Miller (Ed.). Chicago: University of Chicago Press.

Medvedev, Z. (1969). *The rise and fall of T. D. Lysenko*. New York: Columbia University Press.

Merriam, S. B. (2001). Andragogy and self-directed learning: Pillars of adult learning theory. In Sharan B. Merriam (Ed.), *The new update on adult learning theory. New Directions for Adult and Continuing Education, no. 89* (pp. 3-13). San Francisco: Jossey-Bass Publishers.

Merriam, S. B., & Brockett, R. G. (1997). *The profession and practice of adult education: an introduction*. San Francisco: Jossey-Bass Publishers.

Merriam, S. B., & Caffarella, R. S. (1991). *Learning in adulthood: A comprehensive guide*. San Francisco: Jossey-Bass.

Merriam, S. B., & Caffarella, R. S. (1999). *Learning in adulthood: A comprehensive guide* (2<sup>nd</sup> ed.). San Francisco: Jossey-Bass.

Millar, R. (1989). Constructive criticisms. *International Journal of Science Education, 11*, 587-596.

Miller, D. L. (1973). *George Herbert Mead: Self, language, and the world*. Austin, TX: University of Texas Press.

Miller, N. (2000). Learning from experience in adult education. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 71-86). San Francisco: Jossey-Bass.

Morris, C. W. (1934). Introduction. In G. H. Mead, *Mind, self, and society from the standpoint of a social behaviorist* (pp. ix-xxxv). Chicago: University of Chicago Press.

Murphy, A. E. (1939). Concerning Mead's The philosophy of the act. *The Journal of Philosophy*, 36, 85-103.

Musgrave, A. (1998). Realism versus constructive empiricism. In Martin Curd & J. A. Cover (Eds.), *Philosophy of science: The central issues* (pp. 1088-1113). New York: W. W. Norton.

Nagel, E. (1961). *The structure of science*. London: Routledge and Kegan Paul.

National Center for Education Statistics (1995). *Profile of older undergraduates: 1989-90*. (NCES 95-167). U. S. Department of Education, Office of Educational Research and Improvement. Washington, DC: Susan Choy and Mark Premo.

National Science Foundation (1993). *Knowledge dissemination and use in science and mathematics education: A literature review* (NSF 93-75). Directorate of Education and Human Resources, Division of Research, Evaluation and Dissemination. Washington, DC: Janet Hutchinson and Michael Huberman.

Niaz, M., Abd-el-Khalick, F., Benarroch, A., Cardellini, L., Laburú, C. E., Marín, N., et al. (2003). Constructivism: Defense or a continual critical appraisal—A response to Gil-Pérez et al. *Science and Education*, 12, 787-797.

Nola, R. (1997). Constructivism in science and science education: a philosophical critique. *Science and Education*, 6(1), 55-83.

Nola, R. (2003). "Naked before reality; skinless before the absolute": A critique of the inaccessibility of reality argument in constructivism. *Science and Education*, 12(2), 131-166.

Norris, C., & Papastephanou, M. (2002). Deconstruction, anti-realism and philosophy of science—an interview with Christopher Norris. *Journal of Philosophy of Education*, 36, 265-289.

Nowak, L. (1994). Remarks on the nature of Galileo's methodological revolution. In M. Kuokkanen (Ed.), *Idealization VII: Structuralism, idealization and approximation*. *Poznań Studies in the Philosophy of Science and the Humanities* 42, Amsterdam: Rodopi, pp. 111-126.

Nystedt, L., & Magnusson, D. (1982). Construction of experience. In J. Mancuso & J. Adams-Webber (Eds.), *The construing person* (pp. 33-44). New York: Praeger.

Ogborn, J. (1997). Constructivist metaphors of learning science. *Science and Education*, 6, 121-133.

Osborne, J. F. (1996). Beyond constructivism. *Science Education*, 80(1), 53-82.

Pépin, Y. (1998). Practical knowledge and school knowledge: A constructivist representation of education. In Marie Larochelle, Nadine Bednarz, & James W. Garrison (Eds.), *Constructivism and Education* (pp. 173-192). New York: Cambridge University Press.

Phillips, D. C. (1995). The good, the bad, and the ugly: The many faces of constructivism. *Educational Researcher*, 24 (7), 5-12.

Phillips, D. C. (1998). Coming to grips with radical social constructivisms. In Michael R. Matthews (Ed.), *Constructivism in education: A philosophical examination* (pp. 139-158). Dordrecht: Kluwer Academic Publishers.

Phillips, D. C. (2000a). An opinionated account of the constructivist landscape. In D.C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 1-16). Chicago: University of Chicago Press.

Phillips, D. C. (2000b). Social constructivism: Editor's introduction. In D.C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 87-89). Chicago: University of Chicago Press.

Phillips, D. C. (Ed.) (2000c). *Constructivism in education: Opinions and second opinions on controversial issues*. Chicago: University of Chicago Press.

Phillips, D. C. (2004). Two decades after: "After the wake: Postpositivistic educational thought." *Science and Education*, 13, 67-84.

Phillips, D. Z. (1973). Democratization: Some themes in unexamined talk. *British Journal of Educational Studies*, 21 (2), 133-148).

Pommerville, J. C. (2004). *Alcamo's fundamentals of microbiology* (7<sup>th</sup> ed.). Boston: Jones and Bartlett Publishers.

Popper, K. (1934/1959). *The logic of scientific discovery*. London: Hutchinson.

Popper, K. (1970). Normal science and its dangers. In I. Lakatos and A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 51-58). Cambridge: Cambridge University Press.

Popper, K. (1972). *Objective knowledge*. Oxford: Clarendon Press.

- Poser, C. M., & Bruyn, G. W. (1999). *An illustrated history of malaria*. New York: Parthenon Publishing.
- Pratt, D. D. (1988). Andragogy as a relational construct. *Adult Education Quarterly*, 38 (3), 160-172.
- Pratt, D. D. (1993). Andragogy after twenty-five years. In Sharan B. Merriam (Ed.), *An update on adult learning theory. New Directions for Adult and Continuing Education*, no. 57 (pp. 25-35). San Francisco: Jossey-Bass.
- Pratt, D. D., & Nesbit, T. (2000). Discourses and cultures of teaching. In A. L. Wilson & E. R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 117-131). San Francisco: Jossey-Bass.
- Prawat, R.S. (2000). The two faces of Deweyan pragmatism: Inductionism versus social constructivism. *Teachers College Record*, 102 (4), 805-840.
- Prawat, R. S. (2002a). Dewey and Vygotsky viewed through the rearview mirror—And dimly at that. *Educational Researcher*, 31 (5), 16-20.
- Prawat, R. S. (2002b). Evidence for the Dewey discontinuity hypothesis: A rejoinder to Garrison. *Teachers College Record*, 104 (4), 867-877.
- Prawat, R. S. (2003a). The debate continues: Further evidence of discontinuity in Dewey's philosophy. *Teachers College Record*, 105 (5), 893-912.
- Prawat, R. S. (2003b). The nominalism versus realism debate: Toward a philosophical rather than a political resolution. *Educational Theory*, 53(3), 275-311.
- Psillos, S. (1999). *Scientific realism: How science tracks truth*. London: Routledge.

- Rathbone, C. H. (Ed.) (1971). *Open education. The informal classroom*. New York: Citation Press.
- Reck, A. J. (1964). Introduction. In A. J. Reck (Ed.), *Selected Writings: George Herbert Mead* (pp. xiii-lxii). Indianapolis, IN: Bobbs-Merrill.
- Reck, A. J. (1998). John Dewey. In S. Brown, D. Collinson, & R. Wilkinson (Eds.), *One hundred twentieth-century philosophers* (pp. 45-48). London: Routledge.
- Reilly, C., & Henry, J. (2000). Geophagia: why do humans consume soil? *Nutrition Bulletin*, 25, 141-144.
- Renger, P. (1980/1992). George Herbert Mead's contribution to the philosophy of American education. In Peter Hamilton (Series Ed.), *George Herbert Mead: Critical assessments: Vol. 4* (pp. 146-169). London: Routledge.
- Rorty, R. (1979). *Philosophy and the mirror of nature*. Princeton, NJ: Princeton University Press.
- Rose, E. A., Porcerelli, J. H., & Neale, A. V. (2000). Pica: Common but commonly missed. *Journal of the American Board of Family Practice*, 13(5), 353-358.
- Rosenau, P. (1992). *Postmodernism and the social sciences*. Princeton, NJ: Princeton University Press.
- Ryan, A. (1998). Deweyan pragmatism and American education. In Amélie Oksenberg Rorty (Ed.), *Philosophers on education: New historical perspectives* (pp. 394-410). London: Routledge.
- Sahu, A. (2004). Minireview: A hypothalamic role in energy balance with special emphasis on leptin. *Endocrinology*, 145(6), 2613-2620.

- Scheffler, I. (1966/1982). *Science and subjectivity*. Indianapolis, IN: Hackett.
- Scheffler, I. (1974). *Four pragmatists: A critical introduction to Peirce, James, Mead, and Dewey*. New York: Humanities Press.
- Schick, T. S., & Vaughn, L. (1995). *How to think about weird things: Critical thinking for a new age*. Mountain View, CA: Mayfield.
- Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.
- Schön, D. A. (1987). *Educating the reflective practitioner: Toward a new design for teaching and learning in the professions*. San Francisco: Jossey-Bass.
- Shimony, A. (1976). Comments on two epistemological theses of Thomas Kuhn. In R. S. Cohen, P. K. Feyerabend, & M. W. Wartofsky (Eds.), *Essays in memory of Imre Lakatos* (pp. 569-588). Dordrecht: Reidel.
- Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15 (2), 4-14.
- Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-22.
- Simpson, E., Mull, J. D., Longely, E., & East, J. (2000). Pica during pregnancy in low-income women born in Mexico. *Western Journal of Medicine*, 173, 20-24.
- Slezak, P. (1994a). Sociology of science and science education: Part I. *Science and Education*, 3 (3), 265-294.
- Slezak, P. (1994b). Sociology of science and science education: Part II: Laboratory life under the microscope. *Science and Education*, 3 (3), 329-355.

Slezak, P. (2000). A critique of radical social Constructivism. In D. C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 91-126). Chicago: University of Chicago Press.

Slusarski, S. B. (1994). Enhancing self-direction in the adult learner: Instructional techniques for teachers and trainers. In Roger Hiemstra & Ralph Brockett (Eds.), *Overcoming resistance to self-direction in adult learning. New Directions for Adult and Continuing Education, vol. 64* (pp. 71-79). San Francisco: Jossey-Bass.

Solomon, J. (1987). Social influence on the construction of pupil's understanding of science. *Studies in Science Education, 14*, 63-82.

Solomon, J. (1994). The rise and fall of constructivism. *Studies in Science Education, 23*, 1-19.

Solomon, J. (2000). The changing perspectives of constructivism: Science wars and children's creativity. In D.C. Phillips (Ed.), *Constructivism in education: Opinions and second opinions on controversial issues* (pp. 283-307). Chicago: University of Chicago Press.

Stadler, F. (2001). *The Vienna Circle: Studies in the origins, development, and influence of logical empiricism* (trans. Camilla Nielson, Joel Golb, Sabine Schmidt, Thomas Ernst). New York: Springer Wien.

Steffe, L. P., & Gale, J. (Eds.) (1995). *Constructivism in education*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Steffe, L. P., & Thompson, P. W. (Eds.) (2000). *Radical constructivism in action: building on the pioneering work of Ernst von Glasersfeld*. New York: Falmer.

- Stegmuller, W. (1976). *The structure and dynamics of theories*. New York: Springer.
- Stewart, D. (1987). *Adult learning in America: Eduard Lindeman and his agenda for lifelong education*. Melbourne, FL: Kreiger Publishing Co.
- Stove, D. C. (1982). *Popper and after: Four modern irrationalists*. Oxford: Pergamon Press.
- Suchting, W. A. (1992). Constructivism deconstructed. *Science and Education*, 1 (3), 223-254.
- Tobin, K. (Ed.) (1993). *The practice of constructivism in science education*. Washington, D.C.: AAAS Press.
- Tobin, W. (2003). *The life and science of Léon Foucault: The man who proved the earth rotates*. Cambridge: Cambridge University Press.
- Todhunter, I. (1962). *History of the theories of attraction and the figure of the earth*. New York: Dover.
- Tough, A. (1971/1979). *The adult's learning projects: A fresh approach to theory and practice in adult education*. (2<sup>nd</sup> ed.). Toronto, Ontario, Canada: Ontario Institute for Studies in Education.
- Toulmin, S. E. (1970). Does the distinction between normal and revolutionary science hold water? In I. Lakatos and A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 39-47). Cambridge: Cambridge University Press.
- Tschoè, M., Smiley, D. L., & Heiman, M. L. (2000). Ghrelin induces adiposity in rodents. *Nature*, 407, 908-913.

United States Department of Education, NCES (2002a). *Nontraditional undergraduates* (NCES 2002-012). National Center for Education Statistics. Washington, DC: US Government Printing Office.

United States Department of Education, NCES (2002b). *Digest of education statistics 2001* (NCES 2002-130). Washington, DC: U. S. Government Printing Office.

Usher, R., & Edwards, R. (1994). *Adult education and the postmodern challenge*. London: Routledge.

Vico, G.-B. (1710). *De antiquissima Italorum sapientia* (Latin original and Italian trans. by Pomodoro, 1858), Naples: Stamperia de'Classici Latini. [passages trans. von Glasersfeld (1995a)].

von Glasersfeld, E. (1987). *Construction of knowledge*. Salinas, CA: Intersystems Publications.

von Glasersfeld, E. (1989). Cognition, construction of knowledge and teaching. *Synthese* 80, 121-140.

von Glasersfeld, E. (1990). Environment and communication. In L. P. Steffe & T. Wood (Eds.), *Transforming children's mathematics education: International perspectives* (pp. 30-38). Hillsdale, NJ: Lawrence Erlbaum.

von Glasersfeld, E. (1993). Questions and answers about radical constructivism. In K. Tobin (Ed.). *The practice of constructivism in science education* (pp. 23-38). Washington, D.C.: AAAS Press.

von Glasersfeld, E. (1995a). *Radical constructivism: A way of knowing and learning*. London: Falmer.

von Glasersfeld, E. (1995b). A constructivist approach to teaching. In L. P. Steffe & J. E. Gale (Eds.), *Constructivism in education* (pp. 3-15). Hillsdale, NJ: Lawrence Erlbaum Associates.

von Glasersfeld, E., & Smock, C. D. (1974). Introduction. In C. D. Smock & E. von Glasersfeld (Eds.), *Epistemology and education: The implications of radical constructivism for knowledge acquisition*. Mathemagenic Activities Program—Follow Through, Research report No. 14. Athens, GA: University of Georgia.

Vygotsky, L. S. (1987). *The collected works of L.S. Vygotsky: Volume 1, problems of general psychology* (N. Minick, Trans.). In R. Rieber & A. Carton (Series Eds.). New York: Plenum Press.

Watkins, J. W. N. (1970). Against “normal science.” In I. Lakatos and A. Musgrave (Eds.), *Criticism and the growth of knowledge* (pp. 25-38). Cambridge: Cambridge University Press.

Wilson, A. L. (1993). The promise of situated cognition. In Sharon B. Merriam (Ed.), *An update on adult learning theory* (pp. 71-79). New Directions for Adult and Continuing Education, no. 57, San Francisco: Jossey-Bass.

Wilson, A. L., & Hayes, E. R. (Eds.) (2000a). *Handbook of adult and continuing education*. San Francisco: Jossey-Bass.

Wilson, A. L., & Hayes, E. R. (2000b). A selective history of the adult education handbooks. In Arthur L. Wilson & Elisabeth R. Hayes (Eds.), *Handbook of adult and continuing education* (pp. 3-14). San Francisco: Jossey-Bass.

Wilson, A. L., & Hayes, E. R. (2002a). From the editors: The politics of knowledge construction. *Adult Education Quarterly*, 53, 5-8.

Wilson, A. L., & Hayes, E. R. (2002b). From the editors: The problem of (learning in-from-to) experience. *Adult Education Quarterly*, 53, 173-175.

Woolgar, S. (1988). *Science: The very idea*. London: Tavistock Publications.

Wren, A. M., Small, C. J., Ward, H. L., Murphy, K. G., Dakin, C. L., Taheri, S., et al. (2000). The novel hypothalamic peptide ghrelin stimulates food intake and growth hormone secretion. *Endocrinology*, 141, 4325-4328.