Chapter 75
John Dewey and Science Education

James Scott Johnston

75.1 Introduction

John Dewey is perhaps the most well-known philosopher of education of the twentieth century. His output was prodigious and he is distinctive for placing education at the centre of important philosophical discussions. Dewey has in addition a series of attentive accounts on traditionally philosophical topics, such as theory of knowledge, meaning, experience, reality, ethics, political and social theory and aesthetics—all of which count education as important. Dewey’s most important educational treatises include The School and Society (1899), How We Think (1910), Democracy and Education (1916) and Experience and Education (1938), and the former three were in use as textbooks for hundreds of thousands of teachers in teacher-training programmes in America over several decades in the first half of the twentieth century. Dewey continues to have an influence on teacher training and, important for our purposes here, science education.

In this chapter, I will concentrate on three themes: Dewey’s theory of experience and the role of reflection or thought, Dewey’s theory of inquiry (scientific method) and Dewey’s claims for science education. The three are interrelated and discussing Dewey’s claims for science education presupposes discussing his theories of experience, reflection and inquiry. I will follow with a brief discussion of recent developments in science education that have invoked and used Dewey: constructivism and science education, science education and models of inquiry in the curriculum, and the teaching of science. I will finish the chapter with my assessment of the scholarship on Dewey and science education.

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75.2 Brief Biographical Sketch

John Dewey was born in Burlington, Vermont, on April 22, 1859. He grew up in Burlington and attended the University of Vermont. Dewey taught high school for 2 years in Oil City, Pennsylvania, and a further half-year in Charlotte, Vermont, prior to attending graduate study in philosophy at newly minted Johns Hopkins University under advisor, George Sylvester Morris. Having graduated in 1884, Dewey began his university career at the University of Michigan (1884–1888; 1890–1893) and the University of Minnesota (1888–1889), followed by the University of Chicago (1894–1903) (where he ran the famed laboratory school) and, finally, Columbia University in New York (1904–1927) where, in addition to an appointment as professor of philosophy, he was also professor of pedagogy at Teachers College. Dewey married Alice Chipman in 1886, and together, they raised seven children, though two died at very young ages. Dewey would also adopt two children. Dewey travelled and lectured extensively, especially in later life, most famously in Russia, China, Turkey and Mexico. After retirement from active teaching in 1930, his already prodigious output increased; when he died in 1952 in New York City at the age of 92, he had published some 47 books and 1,500 articles.

75.3 Dewey’s Philosophical Project

Dewey’s philosophical project was to aid in the bringing of the attitudes, criticisms, methods and results of philosophers to bear on practical concerns (Middle Works (MW) 10, 47). As well, it was to make philosophy and philosophers a valued enterprise for the task of democratically associated living (MW 9, 91). Dewey famously claimed that philosophy was the ‘criticism of criticisms’ and that this ought to be put to work in social and cultural transformation (Later Works (LW) 1, 309). Central to his philosophical project was the ‘method of intelligence’ (MW 10, 45), variously understood as ‘inquiry’, ‘problem-solving’, ‘how we think’ and ‘scientific method’. Though Dewey sometimes distinguished between these (largely on the basis of context), they were coterminous in the project of getting philosophy (and other disciplines) to bear on what Dewey considered ‘the problems of men’ (MW 10, 48).

75.4 Dewey’s Educational Project

Formal education has many important aims and functions, but in terms of science and science education, this one stands out: education was for Dewey the chief means with which to inculcate in the species the problem-solving method of intelligence needed to overcome extant social problems. Having said this, other aims and functions of education are coterminous with the development of the method of intelligence. Social and cultural transmission of past matters of fact and the techniques
to solve what Dewey refers to as 'problematic situations' (LW 12, 112) is one example. Growth, which is the natural end of individuals and the human species (and is sometimes said by Dewey to be the end of education (e.g. MW 9, 47–49; LW 13, 19)), is another. To utilize the method of intelligence is to draw on past matters of fact and techniques, and to grow is to transform oneself and one's environment in accordance with a set of problem-solving methods, as I will discuss further in the section on inquiry.

75.5 Deweyan Inquiry

Dewey discusses inquiry variously, and in several key texts and articles. What I will do here is provide a summary exegesis of his various claims, beginning with the relation between experience and inquiry, followed by a discussion of Dewey's claims for the stages of thought, the role of specifically scientific thinking in inquiry and the role of scientific inquiry in the social sciences.

75.5.1 The Foundation of Inquiry: Experience

Dewey rejects the empiricist notion that we assemble bits of information through our sense-perceptive faculties and reorder them as ideas in the mind. He also rejects the rationalist notion that ideas are innate or otherwise necessary and pure principles that bear down on our sense-perceptive apparatus to fashion objects of the mind. What Dewey offers is an account of experience in which we exist in a world of what he would call 'brute facts' and 'thats' (MW 3, 164), a world that is first felt rather than cognized (LW 5, 249). What we experience as felt is a whole, not an object. Nor is a felt whole a mere feeling. It is rather that the felt whole is what we experience—as an immediate quality. The human organism exists in a qualitative state, and when she experiences, she does so qualitatively, through feeling. Feeling, in turn, is dependent on generic 'traits of existence', which arise out of every encounter of the human organism with the world (LW 1, 308). These traits are 'qualitative individuality and constant relations, contingency and need, movement and arrest...' (LW 1, 308). Dewey adds to this list 'rhythm and regularity' and 'our constant sense of things as belonging or not belonging, of relevancy...' (LW 10, 198). Not every experience will have these traits as rich and defined as others. Most experiences are 'mundane'; they evince some traits of existence but not of sufficient quality to be notable. Those experiences that do, Dewey considers to be consummatory. A consummatory experience is one in which the experience is felt and taken as a qualitative whole, a unity and a totality.

Inquiry begins and ends in experience. Experience in turn supplies inquiry with the situations or events from which inquiry forms what Dewey calls 'thought' or 'reflection'. In the attempt to reproduce the event or situation that led to the
consummatory experience, the human organism will be poised to attempt reflection. Dewey in one place calls this a ‘judgment of appreciation’ (LW 12, 177–178). Successful reflection will eventually lead to the isolation of the factors involved in the event, together with their control and prediction for further events. However, Dewey cautions we must not confuse the resultant appreciation which is felt, with the operations that bring the material into harmony. To do so is to hypostatize feeling into generalizations (LW 12, 179). Such, historically, is the case with the good, the true, the beautiful and other ‘absolutes’.

Dewey discusses the way in which we are induced to reflect upon our experiences. This occurs when we have and undergo an unsatisfying experience when we expect a satisfying or otherwise unproblematic one; an experience that has a paucity or (as Dewey sometimes says) imbalance of the traits of existence and that does not lead to a qualitative whole. In the context of inquiry, Dewey calls the event or situation that concludes in an unsatisfying experience a ‘felt difficulty’ or ‘indeterminate situation’ (MW 6, 237; LW 12, 108). We then undertake inquiry to ‘determine’ the situation. When we are able to order and control the qualities or traits of the experience of an indeterminate situation, we form an experience that is complete, satisfying and qualitatively whole. Indeed, this is the basis of Dewey’s most famous definition of inquiry: ‘Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituting distinctions and relations as to convert the elements of the original situation into a unified whole’ (LW 12, 108).

75.5.2 The Rise of Science and Scientific Thinking

The self-awareness of the role of reflection and its various techniques and stages obviously did not arise at once: it was the result of thousands of years of investigation (much of it haphazard or misleading) into the forces of nature, the constitution of material objects of use (technologies) and the increasing role of methods in ascertaining instrumental results. For much of this history, the establishment of methods and principles of science fell to philosophy, and Dewey characteristically concentrates his examination of the history of the rise of science and scientific thinking to developments within philosophy. Dewey’s thesis is that a previously stable set of affairs (both individually and species wide) is upset, unsettled or otherwise rendered dubious. The tension leading to instability is the impetus for further questioning, investigation and inquiry, and this leads (if successful) to a readjustment, a resettlement. We understand this through recourse to a historical/ developmental and evolutionary account of the rise of science—what Dewey calls ‘the genetic method’ (MW 1, 150; MW 2, 300–301). We have here the pattern Dewey would use in his discussion of inquiry generally—a pattern made famous in his discussion of the stages of thought in the two editions of How We Think (1910: 1932) and in his definition of inquiry as the settlement of an unsettled or indeterminate situation in Logic: the Theory of Inquiry (1938a).
Dewey's concentrated attention on the rise of scientific thinking through history is best exemplified in the early, extended essay, 'Some Stages in Logical Thought' (1903) together with his book, *Reconstruction in Philosophy* (1920). In his essay, Dewey notes four stages in the development of logical thinking: the magical thinking of the earliest societies, the dawning awareness of the need for method in ancient civilizations, the isolation and abstraction of principles and standards in ancient Greek (Hellenistic) societies and, finally, the rise of a scientific method in the seventeenth century and beyond (MW 1, 172–173). In *Reconstruction in Philosophy*, Dewey alters his stage account of the rise of scientific thinking, noting specifically religious, metaphysical and scientific eras. In the religious era, Dewey claims, 'Savage man recalled yesterday's struggle with an animal not in order to study in a scientific way the qualities of an animal or for the sake of calculating how better to fight to-morrow, but to escape from the tedium of to-day by regaining the thrill of yesterday' (MW 12, 80). In the metaphysical era, 'The growth of positive knowledge and of the critical, inquiring spirit undermined those in their old form...' (MW 12, 89). What was left, according to Dewey, was to 'Develop a method of rational investigation and proof which should place the essential elements of traditional belief upon an unshakeable basis; develop a method of thought and knowledge which while purifying tradition should preserve its moral and social values unimpaired' (MW 12, 89–90). Finally, in the scientific era proper, the recognition of the genetic method—a method at once empirical, experiential, and scientific, historical and developmental—is the best assurance of producing practically valuable investigative results (MW 12, 93).

### 75.5.3 The Stages of Thought

In *How We Think* Dewey outlined and then expanded upon the stages of thought. Thought for Dewey is synonymous with reflection and inquiry: to think is to pass through the stages or phases of inquiry, from a problematic situation first felt, to the articulation of a problem, to the imagination of various anticipated outcomes, to the actual testing of the results using the various techniques and operations of isolation, ordering and control and prediction of phenomena, and finally, to the objective settlement and felt resolution or satisfaction of the original problematic situation. Thinking or inquiry is in other words, loosely circular. Here, I will spell out the various stages of thought. Dewey first gives a summary estimation of the five stages of the '...complete act of thought' (MW 6, 236). 'Upon examination, each instance of genuine thought reveals, more or less clearly, five logically distinct steps: (i) a felt difficulty; (ii) its location and definition; (iii) suggestion of positive solution; (iv) development by reasoning of the bearings of the suggestion; (v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief' (MW 6, 236–237).

All genuine thought begins with a problematic situation, which for Dewey manifests as 'a felt difficulty' (MW 6, 237). This is the experiential basis of all
thinking: a genuine inquiry can only take place if a genuine problem is found and established. Genuine problems are those that are felt, rather than abstracted or given ready-made to students, and Dewey hammers this point home in all of his educational writings. Felt difficulty may take various shapes. It may exist as 'emotional disturbance, as a more or less vague feeling of the unexpected, of something queer, strange, funny, or disconcerting' (MW 6, 238). Again however, what is important is that 'observations deliberately calculated to bring to light just what is the trouble, or to make clear the specific character of the problem' are undertaken (MW 6, 238).

In the second stage of thought, a clearly articulated problem is set forth. It is imperative that the problem be set forth consciously, because the techniques and operations of further stages of inquiry cannot be properly marshalled unless 'the trouble—the nature of the problem—has been thoroughly explored' (MW 6, 238). Failure to fully articulate the problem prior to engaging in experimentation with ideas and techniques of order and control of variables leads to frustration and failure—a sort of 'mission creep' that very often nets results for no particular problem, leading to failure for inquiry. As Dewey puts it, 'The essence of critical thinking is suspended judgment; and the essence of this suspense is inquiry to determine the nature of the problem before proceeding to attempts at its solution. This, more than any other thing, transforms mere inference into tested inference, suggested conclusions into proof' (MW 6, 238–239, emphasis mine).

The third stage Dewey calls 'suggestion'. Suggestion is that idea in which 'the perplexity...calls up something not present to the senses...Suggestion is at the very heart of inference; it involves going from what is present to something absent. Hence, it is more or less speculative, adventurous...The suggested perception so far as it is not accepted but only tentatively entertained constitutes an idea' (MW 6, 239). In this stage, what Dewey elsewhere calls a 'dramatic rehearsal', wherein we reconstruct the situation in thought and attempt to control for the various conditions, takes place (LW 10, 81–82). We are literally putting forth scenarios of possible outcomes, through varying the conditions of experimentation in thought. Here, tentative hypotheses are formed, thought through and passed or rejected according to the results of the thought experiment.

In the fourth stage of thought, more extensive inferential operation is carried out on those hypotheses that bear fruit in the earlier stage. In the earlier stage, we produce ideas—anticipated consequences of possible measures of control. 'As an idea is inferred from given fact [isolated from the situation], so reasoning sets out from an idea...' (MW 6, 239). Dewey continues

...intimate and extensive observation has [its way] upon the original problem. Acceptance of the suggestion in its first form is prevented by looking into it more thoroughly. Conjectures that seem plausible at first sight are often found unfit or even absurd when their full consequences are traced out. Even when reasoning out the bearings of a supposition does not lead to rejection, it develops the idea into a form in which it is more apposite to the problem...The development of an idea through reasoning helps at least to supply the intervening or intermediate terms that link together into a consistent whole apparently discrepant extremes. (MW 6, 240)

Finally, the fifth stage or the conclusion of the 'complete act of thought' is 'some kind of experimental corroboration, or verification, of the conjectural idea...If we
look and find present all the conditions demanded by the theory, and if we find
the characteristic traits called for by rival alternatives to be lacking, the tendency to
believe, to accept, is almost irresistible’ (MW 6, 240). This is the conclusion to the
problematic situation that initially led to the complete act of thought. That is, it is
the existential and qualitative termination of the original problematic situation.
Such terminations are existentially satisfying; they are the terminations of complete
experiences—the sort that lead us to further investigation of the traits of existence
of which they are constituted.

Dewey’s stages of thought have sometimes been taken to be fixed steps that all
thinkers must ascend in linear fashion. This is a mistaken interpretation of Dewey’s
complete act of thought. Dewey’s stages are recursive: whenever one of the steps is
engaged, the entire procedure is engaged. The recursive nature of the stages
allow for the possibility that a complete act of thought occur even if the stages
are not engaged in a linear manner. This allows for inquirers to enter the procedure
without beginning at the first stage. Likewise, inquirers may exit the procedure prior
to closure.

75.5.4 The Logic of Inquiry and Scientific Thinking

As discussed with reference to Dewey’s How We Think, inquiry begins with a
‘felt difficulty’ (MW 6, 237); in Logic: the Theory of Inquiry, Dewey calls this an
‘indeterminate situation’ (LW 12, 108). It is an existential and felt difficulty that
initiates an inquiry. However, a doubt does not carry us far: ‘Organic interaction
becomes inquiry when existential consequences are anticipated; when environing
conditions are examined with reference to their potentialities; and when responsive
activities are selected and ordered with reference to actualization of some of the
potentialities, rather than others, in a “final existential situation,” is inquiry properly
speaking, begun’ (LW 12, 111). A felt difficulty and indeterminate situation must be
followed by a judgment for inquiry proper to be undertaken, a judgment that this
situation is problematic (LW 12, 111–112).

Once a problem has been identified and a judgment rendered, the investigator
searches out ‘the constituents of a given situation which, as constituents, are settled’
(LW 12, 112). We begin with these because they are settled (Dewey uses the
example of the location of aisles and exists in a hypothetical fire at an assembly
hall). The first step in the determination of a problem is to assemble these settled
constituents in observation. Dewey says ‘A possible relevant solution is then sug-
gested by the determination of actual conditions which are secured by observation’
(LW 12, 113). This solution, in turn, becomes an idea: anticipated consequence that
is then carried out in practice (LW 12, 113). Observed facts are existential, in
that they directly bear on the phenomena to be examined and/or tested; ‘ideational
subject matters’ are of conceptual import. They concern other ideas and, specifically,
the way these relate to one another (LW 12, 115). ‘Ideas are operational in that they
instigate and direct further operations of observation; they are proposals and plans
for acting upon existing conditions to bring new facts to light and to organize all the selected facts into a coherent whole' (LW 12, 116). Existential facts and ideational subject matters are to be operationalized—tested out in an existential situation. Once the investigator has established a set of anticipated consequences, she tests these. This involves submitting ideas, as hypotheses, to evaluation on the basis of documented, existential results. Those hypotheses that 'pass the test' are confirmed; those that do not are jettisoned or reconstructed. The determination of a previously indeterminate situation—a situation that is felt, rather than abstracted—is the determination proper of inquiry.

This logic of inquiry applies equally to both common-sense and scientific inquiries. What distinguishes these is not the general method or pattern of inquiry. In both we experiment; we feel an indeterminate situation; we articulate a problem; we develop anticipated consequences that are then formed into hypotheses; and we test these hypotheses in existential settings. Successful hypotheses are those that satisfy or otherwise determine an indeterminate situation. However, scientific inquiries differ from common-sense inquiries in a number of ways, some of more and some of less import; the greatest difference, aside from the contexts in which scientific inquiries operate (often under laboratory or otherwise rigorously controlled environmental conditions), is the level of abstraction common to them (LW 12, 119). Common-sense inquiry and the conclusions it develops very often end in habit formation. A stock of habits is built up that we then use in solving our day-to-day or otherwise mundane problems. These habits are used as well in scientific inquiry; they provide the basis for further psychomotor (in the case of experimental manipulation of phenomena) and conceptual (in the case of objects under investigation) developments. However, scientific inquiry must also avoid as much as possible becoming routine, as it then promotes the tendency to complacency, with the result that it overlooks crucial steps in experimentation or changes in phenomena. Even time- and experience-tested habits, including psychomotor skills and habits of thought, must be amenable to reconstruction in scientific inquiry.

It will do to examine some of the differing features of scientific inquiry. Here I will look at four critical features of scientific inquiry that are self-consciously articulated in Dewey's Logic: the Theory of Inquiry: induction and deduction; the nature of propositions; theories, laws, and causality; and the role of mathematics and symbols. In terms of induction and deduction, Dewey tells us:

Whatever else the scientific method is or is not, it is concerned with ascertaining the conjunctions of characteristic traits which descriptively determine kinds of relation to one another and the interrelations of characters which constitute abstract conceptions of wide applicability... The methods by which generalizations are arrived at have received the name 'induction:' the methods by which already existing generalizations are employed... have received the name "deduction...." Any account of scientific method must be capable of offering a coherent doctrine of the nature of induction and deduction and of their relations to one another, and the doctrine must accord with what takes place in actual scientific practice. (LW 12, 414)

With induction, we generalize a set of common characteristics, features or attributes. We take the conclusions from those generalizations and we infer what must
be the case on the basis of these. Dewey calls the typical understanding of induction 'a psychological process' in which we are 'induced to apprehend universals which have been necessarily involved all the time in sense qualities and objects of empirical perception' (LW 12, 419). In calling the typical understanding of induction a 'psychological process', Dewey means to distinguish his understanding of it from this. Whereas induction is typically understood as the movement of particular to universal, this is heavily qualified by Dewey. 'Induction I take to be a movement from facts to meaning; deduction a development of meanings, an exhibition of implications, while I hold that the connection between fact and meaning is made only by an act in the ordinary physical sense of the word act, that is, by experiment involving movement of the body and change in surrounding conditions' (MW 13: 63).

Elsewhere, Dewey says induction is an 'existential determination' (LW 12, 478); he also calls it a determination of meaning(s) (MW 13, 63). 'They make possible the operation of mathematical functions in deductive discourse' (LW 12, 478). In induction, we grasp what is general in the existential situation through examination of the sense qualities of that situation. Dewey calls the generalizations we develop in induction 'generic propositions' (LW 12, 253). These are propositions of kinds or classes. For example, the generalization of the class, 'liquid', consists in all of the like phenomenal attributes or characteristics that are grouped together under this rubric.

In induction, we have 'the complex of experimental operations by which antecedently existing conditions are so modified that data are obtained which indicate and test proposed modes of solution...' (LW 12, 423). Induction draws generalizations from the existing phenomena culled from the existential situation, which are then transformed into hypotheses that are actively brought to bear on the existing phenomena. This generalization, or generic proposition, then takes the form of an 'If-then' statement—what Dewey calls a 'universal conception' (LW 12, 253). In deduction, on the other hand, we make inferences on the basis of the conclusions of hypotheses we generate (LW 12, 422). There is thus 'a functional correspondence' between induction and deduction. 'The propositions which formulate data must, to satisfy the conditions of inquiry, be such as to determine a problem in the form that indicates a possible solution, which the hypothesis in which the latter is formulated must be such as operationally to provide the new data that fill out and order those previously obtained' (LW 12, 423).

As we have noted, if-then conceptions are claims about what will happen to phenomena under certain circumstances. Though they make claims on behalf of phenomena, they are symbolic, rather than referring to phenomena through existential operations. There is yet another class of propositions, a class that operates at a level of abstraction from these; Dewey calls these 'abstract conceptions' (LW 12, 258). Abstract conceptions help to regulate our universal conceptions. As such, these operate deductively, rather than inductively. An example will be helpful here. Consider the following if-then claim:

I hypothesize that all liquids of the kind (an existential proposition) H₂O will evaporate (an abstract concept) over time T when the temperature (an abstract concept) rises above 100 C.
This hypothesis relies on abstract concepts: evaporation and temperature. Abstract concepts do rely on propositions for their content (e.g. we need to know what physical characteristics water consists of at a given temperature); however, the concept is itself an abstraction that relates only to other concepts (such as evaporation). As such, we can assess abstract concepts in one of two ways: the first is how well they hang together with other abstract concepts (such as the case with evaporation and temperature); the second is how well they help to generate working generic propositions (such as the hypothesis above). When we assess abstract concepts in terms of their ability to relate with one another, we are testing deductively.

Some conceptions are simple and concrete. These Dewey calls conventions. Take a convention, for example, not to place your open hand over a flame. Other conventions consist in particular propositions we use for carrying out experiments; for example, ‘when attempting to ascertain the degree of evaporation of water in your experiment, be sure to fill the beaker half way for each attempt to maintain consistency across experiments’. However, though they are obviously important, conventions serve scientific inquiry only in the most mundane matters. Far more important for scientific inquiry are ‘hypotheses and their meanings’, which are ‘developed in ordered discourse, observation and assemblage of data...’. Otherwise, ‘observation and assemblage of data are carried on at random’ (LW 12, 428). Dewey calls these clusters of hypotheses ‘theories’ (LW 12, 428). Theories rely on both abstract and generic conceptions and are formed when sets of these are banded together into a general claim about a range of phenomena. So, for example, the theory of natural selection encompasses both abstract concepts (various concepts relating to organelles, tissues and organs; various concepts of change across species; various environments), together with universal conceptions (hypotheses that must have been provable for a theory of natural selection to arise) and existential propositions (classes of fauna used in formulating universal conceptions). Laws concern interactions and interrelations that allow a ‘comprehensive system of characters’. This in turn allows for ‘ordered discourse’ to be possible (LW 12, 439). So, for example, Boyle’s Law, Charles’s Law, Henry’s Law and other gas laws are laws precisely because they concern the interactions of the content of the qualitative traits that determine the relations (say, increases or decreases in volume or pressure of gases, gases coming out of solution, etc.) under investigation.

Causation is a particular type of regularity. It is a means of instituting a single, unique, continuous history of events under investigation, rather than a claim for a fixed and final sequence of occurrences (LW 12, 440). For example, consider the law

All liquids of the kind (an existential proposition) $H_2O$ will evaporate (an abstract conception) over time $T$ at temperature (abstract conception) $X$, if certain circumstances hold (result of universal conception).

The law denotes the events that take place when qualitative traits are so ordered through propositions and conceptions to render them amenable to a continuous historical series.

Dewey is keen, however, to insist on the absence of fixity or finality with respect to laws or causality. ‘The fallacy vitiating the view that scientific laws are formulations of uniform conditioned sequences of change arises from taking the function of
the universal [if-then] proposition as if it were part of the structural content of the existential [classes] propositions' (LW 12, 439). If we mistake the universal conception (the proposition that tells us what we can expect under existential conditions) with the propositions of classes actually used in carrying out the particular experiment, we will mistake regularity under strict scientific conditions for a fixed and final regularity.

Finally, scientific inquiry uses symbols and mathematics to a far greater degree than other forms of inquiry. These are tools and have arisen out of the various attempts at solving existential problems (LW 12, 392). Symbols and mathematics operate at a realm distinct from the existential and the generic; indeed, they are wholly abstract. 'When, however, discourse is conducted exclusively with reference to satisfaction of its own logical conditions, or, as we say, for its own sake, the subject-matter is not only nonexistent in immediate reference but is itself formed on the ground of freedom from existential reference of even the most indirect, delayed, and ulterior kind. It is then mathematical' (LW 12, 393). However, symbols and mathematics are not fixed and final things in themselves, nor are they pure forms in some Platonic universe. They are abstract, and they do not generally participate in existential contexts; however, they have both their genesis and their purpose(s) in existential inquiries. Not only this, but they must operate to generate workable universal conceptions that can then order existential phenomenon, as Dewey says, 'The necessity of transformation of meanings in discourse in order to determine warranted existential propositions provides, nevertheless, the connecting link with the general pattern of inquiry' (LW 12, 393).

75.5.5 **Scientific Inquiry and Social Science**

Of central import to scientific inquiry is that it be of use in solving human problems. All inquiry takes place in social contexts, the contexts of human relations (LW 12, 481). What Dewey thinks is wrong with certain scientific research programmes is the failure to reinsert the results of scientific experimentation back into the existential conditions out of which all inquiry arises. Certain fields and programmes have become so esoteric as to have fractured the connection between findings and the existential situations out of which these findings emerged. (Logical positivism is one example of this.) This is to be deplored for Dewey; scientific research has an obligation to help aid in the solution to social problems, nowhere more so than with respect to the social sciences. Classes in particular are often treated as if they were universal conceptions, with the result that they are rendered fixed and final. In these situations, 'At best, inquiry is confined to determining whether or not objects have the traits that bring them under the scope of a given standardized conception—as still happens to a large extent in popular “judgments” in morals and politics' (LW 12, 264). Some of this state of affairs is due to the faulty methods which the social sciences pursue. Dewey admits the social sciences do not as yet possess the sophistication of methods and techniques common to the physical and natural sciences.
Dewey puts the matter this way: "The question is not whether the subject-matter of human relations is or can ever become a science in the sense in which physics is now a science, but whether it is such as to permit of the development of methods which, as far as they go, satisfy the logical conditions that have to be satisfied in other branches of inquiry" (LW 12, 481). The existing methods of the social sciences have yet to allow for the logical conditions of the particular inquiries therein to be as rigorously developed and articulated as those in the physical and natural sciences.

However, it should not be concluded that the logical conditions themselves are different between the two kinds of inquiry. It is rather that it is much more difficult to convert the indeterminate situation in a social scientific inquiry into a determinate one than it is in a physical scientific inquiry, because of the complexity of social subject matters and the limitations of workable techniques and tools available to social scientists (LW 12, 485). Problems articulated in social scientific inquiry are 'gross' and 'macroscopic' in distinction to those in physical scientific inquiries (LW 12, 414). And though Dewey reminds that it is important to recognize and deal with 'the physical conditions and laws of their interactions', this is obviously not enough to go on for social scientific inquiry (LW 12, 486). New methods and techniques have to be developed to cope with the unique nature of social scientific subject matters. This cannot be a reductive social science, in which the techniques of the physical and natural sciences are transposed onto social scientific subject matters. The assumption that social inquiry is scientific if proper techniques of observation and record (preferably statistical) are employed...fails to observe the logical conditions which in physical science give the techniques of observing and measuring their standing and force' (LW 12, 492). Dewey continues, 'Any problem of scientific inquiry that does not grow out of actual...social conditions is factitious; it is arbitrarily set by the inquirer instead of being objectively produced and controlled. All the techniques of observation employed in the advanced sciences may be conformed to, including the use of the best statistical methods to calculate probable errors...and yet the material ascertained be scientifically 'dead', i.e., irrelevant to a genuine issue, so that concern with it is hardly more than a form of intellectual busy work' (LW 12, 492–493).

### 75.6 Inquiry and Science Education

In addition to Dewey's claims for the importance of science and scientific inquiry in his philosophical and logical works, Dewey had a good deal to say about the role of scientific inquiry in education (see Chap. 42). As well, an increasing number of science educators have turned to Dewey to formulate better pedagogies and curricula for science education. Here, I will discuss Dewey's claims for the role of scientific inquiry in science education; I will then turn to some of the more recent developments in science education conducted along Deweyan lines.
75.6.1 Science and Science Education

Science (and mathematics) education poses a unique and complex predicament for educators: the heightened and abstract nature of scientific findings (including the theories and laws of natural and physical science) are an impediment to learning. What makes scientific education a daunting task is not the lack of innate capabilities of children to master increasingly abstract conceptions, or various propositions; it is the haphazard way in which much science education is taught, together with the differences in background knowledge and techniques of students. A child’s genuine inquiry cannot begin with such reified conclusions; rather, it must begin with simple observations and manipulation of the environment present-to-hand. ‘What the pupil learns he at least understands. Moreover, by following, in connection with problems selected from the material of ordinary acquaintance, the methods by which scientific men have reached their perfected knowledge, he gains independent power to deal with material within his range, and avoids the mental confusion and intellectual distaste attendant upon studying matter whose meaning is only symbolic’ (MW 9, 228). Rather than producing experts in scientific methods, the point of science education is to familiarize students with ‘some insight into what scientific method means than that they should copy at long range and second hand the results which scientific men have reached’ (MW 9, 229).

Dewey recommends what he calls the ‘chronological method’ in educating children to scientific inquiry. This is the method ‘...which begins with the experience of the learner and [that] develops from the proper modes of scientific treatment...’ (MW 9, 228). Children are led up from simple observations and conclusions about the workings of their environment, through more sophisticated analyses and syntheses of isolated natural and physical phenomena. In these analyses and syntheses, children are encouraged to develop and apply the various forms of propositions and conceptions involved in actively ordering and controlling specific traits of phenomena under experimental circumstances. So, for example, what begins as a simple experiment to identify the conditions under which water evaporates in a puddle adjacent to the school (conditions such as a sunny day, increased temperature) becomes, as the student ages and is introduced to increasingly sophisticated techniques, an examination of the evaporation of water under strict laboratory conditions, with the use of such techniques as classes (liquids), universal conceptions (experimental hypotheses) and abstract conceptions (temperature, evaporation) and laws for liquids and gases, as well as tools for the examination of tendencies amongst large groups of phenomena, such as mathematics and statistics. Dewey surmises that if children were taught to use the ‘chronological method’ from the beginning of their formal education and consistently thereafter, much of the confusion that occurs in increasing the level of abstraction in science education would gradually diminish.

In order for students to engage experimentally with phenomena, they must actively engage the world around them. They must experiment with materials in various way and order and control traits of existential phenomena, beginning in a
trial-and-error manner. This requires that the material to be tested have some connection to the child's life beyond the classroom. Otherwise, genuine problems—problems that are felt rather than deduced or prescribed—will not materialize. One of the best ways for this to occur is to begin scientific inquiry with available technologies and with existing social problems (MW 9, 232). Dewey says, 'The wonderful transformation of production and distribution known as the industrial revolution is the fruit of experimental science. Railways, steamboats, electric motors, telephone and telegraph, automobiles, aeroplanes and dirigibles are conspicuous evidences of the application of science in life. But none of them would be of much importance without the thousands of less sensational inventions by means of which natural science has been rendered tributary to our modern life (MW 9, 232). Of social problems, Dewey has in mind the problems common to children at their particular developmental age and stage, as well as the particular problems of circumstance and context—including the barriers children face, such as those of race, class, gender and geography (MW 9, 91).

Properly conducted, inquiry in science education will begin with a 'felt difficulty': an 'indeterminate situation' that then stimulates genuine interest. This is the crucial stage for inquiry in science education and, indeed, inquiry in all contexts. If genuine interest is not captured, any inquiry that results will be an externally motivated one certain to result in poor focus and haphazard conclusions. This problem is the child’s, not the teacher’s. It is a waste of time and energy for the teacher to simply pronounce on what problem the student will begin with, if the student hasn’t come to see this problem on, and as, his or her own. Only with genuine interest can a problem be properly articulated so that it can satisfy the rigours of inference and testing that follow.

Once an articulated problem is produced, anticipatory consequences of acting on phenomena are put forth. This is an imaginative stage or phase of scientific inquiry, in which the student thinks through various possible courses of action. Upon deciding a course of action, the student will make use of tools of inference (as in formulating hypotheses of the 'If-then' sort, to test out specific anticipated outcomes; deduction, especially in terms of abstract concepts; induction and existential propositions of classes (all of this class or only some or none of this class). These are tools in the experimental phase of the inquiry that are put to work in order to achieve the desired outcome. Depending on the nature of the experiment and the tools and techniques available to the students, more or less attention will be spent on making this phase of the experiment and the tools of inference that belong to its self-conscious. Some of these tools and techniques can be taught and discussed; however, to be of value to the student in her experimentation, they must be developed and worked through in the experimentation.

Finally, if the experiment is successful, resolution or closure of the indeterminate situation takes place. Again, this is a felt, as opposed to abstract, resolution. Successful termination of scientific inquiry does not merely end in the 'right' result, or to the satisfaction of the teacher. On the objective side, it ends with the successful settlement of the indeterminate situation; on the subjective side, it ends when the student experiences a qualitative closure of the situation or event. Unless and until
this qualitative closure or termination takes place, inquiry is not complete. And if inquiry is not complete, the impetus for further investigation that arises as a result of the satisfaction of having closure of an indeterminate situation is denied. Closure is the ‘aha’ moment when an experience is at its most satisfying. And this is the moment of genuine growth. To deny or otherwise not conclude with this moment is to blunt the motive force for future scientific inquiries.

However, Dewey recognizes that these changes to the structure and content of science education are not, by themselves, enough; differences in background knowledge are another matter entirely. These cannot be so easily remedied and require changes in existing social and political realities—realities that have resulted in the barriers of race, class and gender and lack of education that keep some disenfranchised (MW 9, 91). Unfortunately, individual schools are hampered in their ability to mitigate circumstances such as poverty, racial and gender bigotry and socioeconomic divides. Inquiry, though inestimably important to students’ intellectual development and their capacity to solve problems, needs to be heavily supplemented with cooperative social institutions and programmes if it is going to overcome the paucity of genuine intellectual growth that results from social barriers and divides.

75.6.2 Deweyan Inquiry and Constructivism in Science Education

Dewey has been a central figure in the great mass of scholarship written on behalf of constructivism in science and science education (Von Glasersfeld 1984, 1998; Phillips 1995; Garrison 1995, 1997a; Vanderstraeten 2002; Kruckeberg 2006; Gordon 2009). While some are content to note Dewey’s historical influence on later philosophers (such as Richard Rorty) is squarely in line with constructivist beliefs and others are content to point out that Dewey’s anti-metaphysical insistence in matters of knowledge is of a piece with their constructivist values, still others have gone further and developed Deweyan accounts of constructivism. Here, I will examine briefly constructivism in science education, noting how and where Dewey is invoked. I will then turn to a very brief exposition of three accounts of Dewey in the name of constructivism and science education: Ernst Von Glasersfeld’s ‘radical constructivism’, Jim Garrison’s ‘social pragmatic constructivism’ and Raf Vanderstraeten’s ‘transactional constructivism’.

It will do to outline briefly the thinking behind the constructivist movement in education. Constructivism is a label for a variety of various, like-minded models of cognition and knowledge that share a history, as well as a central tenet: the rejection of metaphysical realist and empiricist theories of knowledge, often in favour of developmental and transactional accounts that stress the organism of person’s own role in knowledge acquisition (LaRochelle and Bednarz 1998, p. 7). In education there are ‘radical constructivisms’, ‘pragmatic social constructivisms’, ‘didactic constructivisms’ and ‘poststructualist constructivisms’, amongst others. Dewey’s
involvement in constructivism comes largely as a result of his own rejection of
metaphysical accounts of knowledge creation and production. Inquiry in con-
structivist accounts of science education invoking Dewey generally stresses the
anti-metaphysical and anti-dualist dimensions of his thinking in their respective
projects for science education. However, some thinkers have been compelled to go
further and investigate the particular areas where Dewey’s account of knowledge
creation and production reaches beyond complementarity with existing under-
standings of constructivism in science education to form a distinctive constructivism
in its own right.

Both Garrison and Ernst Von Glasersfeld draw on Dewey in their respective
understandings of constructivism, and it will do to discuss their differences. Von
Glasersfeld considers himself a ‘radical’ constructivist, a position Von Glasersfeld
says he owes to Kant, Piaget and the notion of ‘variability’—the idea that all concep-
tual schemes are premised on their utility or purpose (Von Glasersfeld 1984, p. 12). Von
Glasersfeld appropriates certain of Kant’s understandings to elaborate his own
articulations of conceptual schemes. For example, Von Glasersfeld appropriates
Kant through saying his understanding of reciprocity (as discussed by Kant at the
Third Analogy of Experience) is beneficial to understanding how shared conceptual
schemes develop. In the Third Analogy, ‘All substances, insofar as they can be
perceived in space as simultaneous, are in thoroughgoing interaction’ (Kant 1998,
p. A 211). This has obvious utility to Newton’s third law of motion. And it has utility
as well to Von Glasersfeld, who quotes Kant approvingly; ‘It is manifest that, if one
wants to imagine a thinking being, one would have to put oneself in its place and to
impute one’s own subject to the object one intended to consider...’ (Von Glasersfeld
1998, p. 124). This ‘reciprocity’, analogized further from Kant’s Third Analogy, is
said by Von Glasersfeld to be akin to how we develop our shared, conceptual
schemes. Von Glasersfeld does not intend to claim Kant’s understanding and use of
reciprocity as completely his own; he is rather content to accept the analogy and
turn to empirical factors such as adaptation to understand constructivism. His is a
“cognitive constructivism,” which also has its locus in the seminal works of Piaget.
Yet, this ‘cognitive constructivism’, as a theory invoking the transcendental substrates
of Kant, sharply distinguishes Von Glasersfeld’s project from empirically inclined
projects such as Garrison’s (Grandy 1998, p. 115).

Garrison’s account of Dewey’s ‘pragmatic social constructivism’ presents Dewey
as a social behaviourist who is inimical to mental representations (Garrison 1993,
p. 717). While Garrison clearly endorses a Dewey that evinces a strong role for
natural (non-mentalistic) conceptions, his endorsement does not extend to wholly
subjective or mentalistic representations, which he sees operating in Von Glasersfeld’s
account of ‘radical constructivism’. Garrison’s Dewey stresses language as a social
construction, together with ‘dialogicality and multiple authorship’ (Garrison 1995,
p. 727). Unlike Von Glasersfeld’s understanding of constructivism, Dewey’s account
is anti-dualist and anti-subjective (Garrison 1997a, p. 305). Indeed, Dewey’s theories
of mind and meaning were entirely behaviourist (Garrison 1995, p. 725; 1997a,
p. 308), and mind for Dewey was entirely a social construction. Social behaviour—the
behaviour existing between and within social units—transforms organic behaviour as a result of (shared) language into meaningful behaviour (Garrison 1997a, p. 308). Garrison claims that rather than focusing on traditional epistemic tasks, education and science education in particular should be attempting to construct stronger models of dialogicality and promote active listening.

Vanderstraeten's account of Dewey's 'transactional constructivism' begins with an analysis of Dewey's organic account of coordination and perception (Vanderstraeten 2002, p. 236). This leads to an analysis of habit, to thinking and to knowledge formulation and the ways these form an integral whole. Communication (as with Garrison) is key in all of this. Education is a means of communication and education is 'a participatory, co-constructive process' (Vanderstraeten 2002, p. 241). Objects and practices acquire shared meaning because they are part of larger and shared sets of experiences (Vanderstraeten 2002, p. 241). Knowing is an active construction that takes place in the organism-environment transaction. This Vanderstraeten contrasts to Von Glasersfeld's 'radical constructivism', which he seems to see as insufficiently 'deep' to thwart the accusations that it is one more example of an account of correspondence to reality (Vanderstraeten 2002, p. 243). Garrison and Vanderstraeten thus both share an antipathy towards mentalistic representations and a regard for a 'transactional' accounting of constructivism in education.

It is difficult to evaluate the various constructivisms developed in Dewey's name. They clearly concentrate on central themes and concerns of Dewey and to do so is correct. The focus on transaction of the child and environment and the social dimension(s) of experience are vitally important to any further pedagogy of science, as is the stress on communication and dialogue. Beyond this, it is unclear how helpful it is to include Dewey in the pantheon of constructivists, let alone develop a constructivism from his various educational and philosophical writings. While Dewey shares many of the intellectual proclivities of other constructivists (including constructivist science educators), it remains to be seen what tangible benefits to science education come from including Dewey in this pantheon. Much if not most of the work in constructivism is content to present accounts of Dewey that do little to advance our understanding of him beyond what has elsewhere been articulated.

I attribute much of this lack of advance to the superficial nature of the readings of Dewey. In my opinion, seldom do constructivists dig deep enough to reveal the connections between Dewey's theories of knowledge and logic and his theory of aesthetic experience, to say nothing of his social and political writings (Garrison is the exception, here). More problematically, running Dewey together with Kant and Piaget as Von Glasersfeld does serves to mask tremendous underlying differences in their respective epistemologies: if Kant, as a transcendentalist, was a constructivist and Dewey, as a naturalistic empiricist, was a constructivist, it becomes a huge task to explain what foundation constructivism rests upon. Sadly, most constructivists (Garrison is again the exception) do not probe the foundations, and the resultant constructivisms they champion are but castles made of sand (see Chap. 31).
75.6.3 Dewey and the Science Curriculum

Dewey's written output while serving as the head of the University of Chicago Laboratory School (1896–1903) is well known to most educators. It includes School and Society (1899) as well as numerous monographs on various aspects of pedagogy and curriculum. Additionally, historical, biographical and philosophical work on the Laboratory School (Camp Mayhew and Camp Edwards 1936; Wirth 1979; Tanner 1997; Johnston 2006) has invoked inquiry directly. Recently, curriculum leaders and scholars have developed novel understandings of science education with a strong role, if not a focus, for inquiry to play. I will discuss some of these further.

Inquiry has become a dominant theme in science education (Rudolph 2005, p. 43). Aside from its logical features, this generally extends to 'hands-on' manipulation of objects, the emphasis on 'real world' activities and the use of associated technologies. As well, projects, where a number of related exercises are undertaken as part of a larger curricular whole, are often stressed. The continuity between a child's past experiences and those the teacher wishes the child to undergo is also maintained (Howes 2008, p. 538). Models of science education for early childhood education that propose drawing on a child's basic impulses to create further situations for the development of intelligent dispositions and skills have also been developed (Howes 2008, p. 538). Beyond this, more specific accounts of Dewey's holism and particularly how science and science education merge with art and aesthetic experience in an organic accounting have been offered. These latter accounts have been developed simultaneously by philosophers of education (Garrison 1997) and curriculum scholars such as those working at the Dewey Ideas Group at Michigan State (Wong and Pugh 2001; Girod and Wong 2002; Pugh and Girod 2007). All stress the importance of inquiry in regards to science education.

Garrison stresses the importance of aesthetic experience and particularly the precognitive background we draw upon when we inquire (1997b, p. 101–102). The logics that we use when we solve educational problems rely on this precognitive background and inform them. Garrison's point is to underscore the situation-specific nature of logic; there is no one logical method right for all situations; the situation itself will very often dictate what logical processes are to operate (Garrison 1997b, p. 98). Attention to the background conditions of experience, as well as the particular experience a child forms, is thus vital for science educators if they are to gauge successfully the student's learning.

Wong, Girod and Pugh also stress the precognitive dimension of experience. This drives instrumental understanding and forms the context out of which instrumental understanding operates (Girod and Wong 2002, p. 200). Like Garrison, these scholars concentrate on the motivation for learning in the first place, rather than the specific logical steps or processes undertaken. This necessitates concentrating on the experiences students have, rather than the outcomes of the particular lesson. A focus on the relationship between the concepts and ideas developed in the lesson and the experience the student has, together with attention to the satisfaction and
interest inherent in genuine experiencing, is key (Pugh and Girod 2007, p. 14–16). Aesthetic experience is at once the highest and deepest of the forms of experience had and undergone. Helping to bring a child to have an aesthetic experience involving scientific experimentation is to ensure that genuine learning is taking place. Doing so releases the 'transforming' and 'unifying' elements of aesthetic understanding (Girod and Wong 2002, p. 208). The satisfaction had in having and undergoing the aesthetic experience of a scientific experiment through all of its phases is the basis for the development of real, as opposed to merely rote, knowing. Thus, in crafting science lessons, aesthetic experience must be borne in mind. This is not to say that other forms of experience are valueless; however, facilitating an aesthetic experience is the surest means to the 'teachable moment' that teachers value above all.

75.6.4 Dewey and the Teaching of Science

Problem-solving, discovery and inquiry methods are popular and well represented in theories of teaching science, in part due to Dewey's role in connecting his theory of inquiry to educational situations and events (Glassman 2001). All of these methods insist on taking the needs, desires, attitudes and developmental ages and stages of students as primary in the facilitation of science education, rather than teaching the discipline as a coherent subject matter (Eshach 1997). Concentrating on students' experiences rather than on the dissemination of the subject matter, together with a focus on the active role played by students in investigating natural phenomena, is paramount. This insists the teacher manipulate the environment to help facilitate the students' experiences such that they can actively inquire, in the manner of the stages of inquiry Dewey discusses in How We Think and elsewhere.

This facilitation of experiences also insists on conducting science in a manner similar to how scientists conduct it themselves, in their experimental investigations. Science, as Dewey insists, does not occur in isolation: nor should science education. The scientific investigation of natural phenomena is most clearly reproduced when students work in teams or groups, conducting an inquiry from beginning to end (from the first to the final stage of inquiry), rather than learning isolated facts or formulae from a textbook. Models of cooperative learning often cite Dewey as an early exponent (e.g. Brown and Palinscar 1989, p. 397–398). Furthermore, scientific investigation demands corroboration of results and not simply the findings of an isolated experiment (Eshach 1997). Writing up results and (re)testing them are as vital to science as the initial experimentation, and both must be included in a programme of science education. This might include both whole-class discussion and the writing of novel 'texts', particularly in the elementary grades (Howes 2008, p. 545).

Recently, it has been suggested that Dewey's understanding of scientific inquiry and science education be utilized to help integrate existing rival theories such as constructivism and objectivism under the rubric of scientific literacy (Willison and Taylor 2009, p. 32). It is argued that this may help resolve some of the tension that keeps at bay the practical advices nesting in the various theories. Dewey has also
been invoked in the ongoing debates about the role of science education in the overall preparation of students: while the standards-based push to increase scientific subject matter and instructional time in public schools is laudable, it is also the case that what gets pushed first is very often abstract concepts, formulae and principles, at the expense of context and experimentation (Rudolph 2005, p. 806; Chinn and Malhotra 2002, p. 199). Dewey’s understanding of the contexts of scientific inquiry is a valuable corrective in this regard.

75.6.5 Overall Assessment of Dewey’s Role in Science Education

Deweyan models of science education have been helpful, particularly in stressing the cooperative nature of learning, the experimental nature of knowledge acquisition and the aesthetic dimensions of children’s experiences. It makes good theoretical sense to concentrate our attention on issues of interest, motivation, satisfaction and other ‘traits’ of experience that bookend inquiry in science education. Furthermore, invoking Dewey, scholars and practitioners have developed comprehensive models of science education that do not resemble cookbooks or ‘how-to’ manuals (or lists of objectives and standards). As well, they have contextualized intellectual tools such as concepts, ideas, algorithms and processes. Rather than being set off from the curriculum or subject matter, inquiry is now thoroughly integrated in these models. And rather than being a procedure that is separate from the child or a set of steps or stages the child must plod her way through, inquiry is now seen as a process involving her experience throughout.

However, much of the scholarship on Dewey in science education has been content to draw on Dewey in so superficial a fashion that little of Dewey’s actual logical, epistemological or experiential philosophy has been adequately mined. What remains for science educators using Dewey’s philosophy of education is to further connect Dewey’s theories of experience and art with his theory of logic—especially the accounts of propositions and conceptions he details in *Logic: the Theory of Inquiry*. A suitably comprehensive account of Deweyan inquiry for science education (one that integrates both experience and the tools of logical inquiry) has yet to be fashioned. Beyond this, educators must do a better overall job of convincing sceptics (and there are many) that think Deweyan-inspired methods of science education will reap advantageous results. To give but one example, criticisms regarding the bracketing or ignoring of psychological research that indicates the importance of working memory have been raised against constructivist and inquiry-based teaching:

Any instructional theory that ignores the limits of working memory when dealing with novel information or ignores the disappearance of those limits when dealing with familiar information is unlikely to be effective. Recommendations advocating minimal guidance during instruction proceed as though working memory does not exist or, if it does exist, that it has no relevant limitations when dealing with novel information, the very information of interest to constructivist teaching procedures. We know that problem solving, which is
central to one instructional procedure advocating minimal guidance, called inquiry-based instruction, places a huge burden on working memory....The onus should surely be on those who support inquiry-based instruction to explain how such a procedure circumvents the well-known limits of working memory when dealing with novel information. (Kirschner et al. 2006, p. 77)

These concerns are to be taken seriously. As these are empirical concerns, they must be addressed empirically. To address these means not simply providing a re-articulation of Dewey’s texts (though this is valuable initially); rather, further articulation of Dewey’s understanding, further articulation of the application of Dewey’s understanding of science and science education to various teaching practices and further empirical verification of this reconstructed articulation through experimental design must be demonstrated. In other words, the way to address these concerns is through following the stages of inquiry from articulation of the problem, to hypothesis testing and the formation of anticipated consequences (the formation of universal conceptions), to rigorous testing (using the ‘tools’ of induction and deduction, as well as the construction and invocation of abstract concepts) and to evaluation in the empirical setting in which the problem is first felt and articulated. Following the lines of Dewey’s theory of inquiry is the only reasonable way to reveal problems with the empirical investigations undertaken in the quest to confirm or disconfirm claims on behalf of inquiry, discovery or problem-solving methods.

75.7 Conclusion: Dewey and Science Education

Dewey has and doubtless will continue to provide fertile ground for explorations into various dimensions of scientific inquiry and science education, including pedagogy and the curriculum. Dewey’s account of inquiry offers advantages other accounts very often lack: it is holistic, context-bound and self-correcting; it is rooted in experience and the generic ‘traits of existence’ that arise out of the transmutations of human beings and their environments (including the ‘social’ environment of other people). Yet, it is rigorous in its logical processes, with a strong and detailed accounting of conceptions, ideas, proposition and other logical functions. Historically, it has been vitally important for various accounts of pedagogy and curriculum.

The state of Deweyan scholarship on science education is another matter; as it stands, Dewey scholarship in science education repeats many of the same mantras as Dewey scholarship in other areas of education: the importance of inquiry, discovery and problem-based methods and pedagogies; group, cooperative and team-oriented projects; and an emphasis of experimental learning over and against disciplinary or subject matter learning (at least for the elementary grades). However, it has not progressed much beyond these, despite the invocation of Dewey in constructivism and other fashionable models of teaching and curriculum. In my opinion, what is necessary for further scholarship is to develop a cogent model of Deweyan inquiry for science education that integrates Dewey’s accounts of experience and art with his detailed account of the functions of logical inquiry, including the tools of
conception, propositions and symbols. Doing so requires us to dig deeper into Dewey’s logical, epistemological and experiential theories than is usually done. A few scholars (e.g. Garrison) have begun this scholarship, but much more work on the part of the Deweyan community of scholars remains. A systematic model of science education that is attentive to logical, epistemological, experiential and social-political as well as educational concerns will be of inestimable value for further pedagogical and curricular claims on behalf of science education. Beyond this, it remains to be seen whether any of these accounts of science education involving the name or scholarship of Dewey are able to penetrate the morass of objectives-driven ‘standard’ science education.

References


