ETHICAL AND SCIENCE UNDERSTANDINGS IN SCHOOL SCIENCE: A CONCEPTUAL FRAMEWORK OF CLASSROOM PRACTICES AND UNDERSTANDINGS

by

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ABSTRACT

The principal contribution of the study is a conceptual account of classroom activities in school science, which incorporates both ethical and conventional science understandings within a single conceptual framework. In order to illustrate and explore the strengths and limitations of the conceptual framework developed, an exploratory case study involving 7 science classes was conducted at 2 schools.

The 'classroom practices and understandings' conceptual framework presents a novel approach for understanding activities of students and teachers in the science classroom. According to this framework 'understanding' is a grasp of inferential connections as part of either practical or cognitive types of activity, whereas a 'practice' is a set of activities organized by understandings, rules and characteristic aims, emotions, and projects. On this basis the grounds for a given understanding are described in terms of a unifying structure for both ethical and science understandings. In both cases 'authority in understanding' refers to the specific sources of authority for a given understanding, which may include authoritative individuals in addition to more conventional grounds such as reasons or evidence. Finally, 'richness' of understanding refers to the quality of such connections to sources of authority in understanding, and is thus is a measure of the strength of understanding generally.

Classroom lessons developed for the exploratory case study focused on ethical questions of sustainability. These were implemented in the science classroom at two research sites, with the researcher acting as guest teacher. One site focused on study of ecology in grade 11; the other site focused on study of genetics in grade 10. At both sites student interviews were conducted to supplement the findings of the classroom-teaching component. The findings support the integrity of the conceptual framework, while highlighting significant challenges for seeking to make explicit the sources of authority in science students' ethical understandings. Building from the conceptual framework and cases studies, a number of further directions for empirical and theoretical research are suggested.

Table of Contents

Acknowledgement

I'd like to acknowledge the generous support of my thesis committee: Gaalen Erickson, James Gaskell and John Robinson. Their assistance through each stage of this process is greatly appreciated.

Dedication

This dissertation is dedicated to ....

Nanette, whose love and support is felt constantly, for which I am eternally grateful;

my parents, who have inspired and led the way by their commitments to learning;

and Polly, without whose heartfelt presence and encouragement I could not have made it this far.

Chapter 1 – Introduction

Rationale

Science classrooms are potentially very exciting and important places. Few would disagree that what happens in science classrooms holds prospects for furthering students' understandings of the natural world in deep and significant ways. But less obviously, what happens there also holds the potential to contribute to students' *ethical* understandings in highly significant ways. All told this is a vast landscape of potential meaning for students, covering not only understandings of the place and time in which students live—naturally, socially, culturally, historically—but also with respect to key areas of self-understanding.

But this potential may remain *only* at the level of promise if the great possibilities for meaning in the science classroom are cut short by neglecting key features of the social environment of science classrooms. This remains true, moreover, whether the approach in question to science learning is traditional or contemporary. For even acknowledging the diversity of approaches to school science under consideration today, we remain vitally in need of robust accounts of meaning development belonging to the social environment of science classrooms. For a key feature of the social environment is assessment of human *conduct*—or in other words one's ethical involvement. Simply to participate in a social environment implicates one in treating certain conduct as preferred relative to alternatives. So neglecting the social environment means neglecting an essential feature of what it is to belong to that environment. And depending on the interdependence between ethical and science understandings, neglect of the social environment will implicate possibilities for science learning directly.

There is of course a large literature in science education research associated with constructivism and the construction of meaning in science classrooms (Glaserfeld, 1989; Glaserfeld, 1991; Driver et al., 1994; Matthews, 1998; Staver, 1997; Irzik, 2000; Seatter, 2003). Notwithstanding a great deal of important work in this area the question of how exactly to understand meaning construction in terms of a general conceptual framework remains unclear. A framework adequate to the task must, on the one hand, be general enough to encompass a diverse range of practical understandings involved in classroom science learning, while on the other hand particular enough to respond to questions of science knowledge specifically.

In this work I address this need for a robust account of the construction of meaning in science classrooms. And I do so in a very unique way. Whereas the primary focus of this study is squarely focused on an account of *specifically* ethical understandings in classroom science, it is developed from an account of understanding and meaning construction *generally* in science classrooms. Both the specific and more general accounts, as shown below, make needed contributions to science education. The respective importance of the two areas, as well as the relationship between them, stems from the following broad rationale for the study.

I claim ethical features of school science as a topic are important for three chief reasons. The first is that ethics are a key feature of self-understanding in today's world. Exploring conceptually the options for students and teachers in the area of ethical self-understanding is thus important, if science education is to respond to this key aspect of being alive today. This suggestion shares the commitment of constructivist research in science education focusing on students' background understandings and active learning

as important contributions to learning (Driver, 1994; Meyer, 2004). But it goes further to suggest the importance of specifically ethical background understandings and active learning.

Second, assisting the social coordination of students in their present and future citizenship roles remains a key aim for education and science education specifically (SCC, 1984; AAAS, 1993; Hodson, 1999; Solomon, 2004). But judging from the range of views on the topic, how to go about achieving this aim in science classrooms is far from clear in science education research. By elaborating a general framework for the development of ethical understandings, and in the context of the authority structure of classroom science, the present account goes some distance towards addressing the aim of assisting students with social coordination in their prospective citizenship roles.

Finally, as suggested, a developed account of the specifically ethical features of the construction of understanding in science classrooms holds the potential to clarify the construction of understanding generally. Research so far on ethical understandings in science education has focused on students' ethical views and reasoning (Zeidler & Schafer, 1984; Zeidler, 1985; Zeidler, 2005; Zeidler et al., 2002; Sadler & Zeidler, 2004; Sadler & Zeidler, 2005) but not on offering a conceptual framework for how to understand 'understanding' itself in the case of ethical views. We can think of the proposed relationship in the following way. Because ethical features are seen as conspicuous in terms of the challenge they present for general accounts of understanding, when compared to other features (e.g. perceptual observation or skill performance), an account of ethical understanding holds the promise to improve accounts of understanding generally. In other words, by cracking the *harder* nut—of ethical understanding, the

easier nuts—of other features of understanding, may follow in turn. This is a key claim of the study, to be spelled out and defended over the work as a whole.

Research Questions

Having proposed the case above for the importance of better understanding of ethical features of school science, and the relationship between ethical and other understandings, we can now state without elaboration the research questions for the study. These are:

1) How do ethical features of secondary school science relate to the construction of science understanding in the classroom?
2) What, if anything, characterizes 'ethical inquiry' in these classrooms?
3) What do the specific interventions of this study, which focus on explicit ethical content of science learning and teaching, contribute to understanding ethical features of secondary science classrooms in general?

The Social World of Science Classrooms

So given its importance, yet faced with limited success so far in science education research, what makes a viable account of ethical features of classroom science so difficult to achieve? A full answer to this question must of course await the account to follow in subsequent chapters. But by way of introduction the answer is that ethical features of school science are pervasive, yet virtually invisible features of the social world of the science classroom. Without a more adequate account of this social world of the science classroom, accounts of ethical features therein will be correspondingly lacking.

Consider the following illustration. Among other activities, students in the science classroom take notes, ask and respond to questions, examine scientific specimens,

consider newly proposed ways for looking at natural events, calculate using formulae, make lab observations and measurements, and memorize new terms. Suppose we attend for the moment, to the private level of students' inner thoughts occurring as part of some of these activities above. We might imagine, for example, a student whose thoughts on a given day include the following: "I wonder what that term he wrote on the board means." "What are Ella and Irene doing for this step of the lab?" "What will Mr. P. do if we don't hand the homework in on time?" "I wonder if others are doing this problem the same way!"

The point to make with respect to these proposed thoughts or wonderings is that considerations of some kind along these lines—attributing to students socially informed thoughts—is often **necessary** for interpreting their activities. Otherwise many of students' *public* behaviours—involving what students say and do (including often with respect to their own thoughts)—no longer make sense. For example, a student looks quizzically at her neighbour's science assignment, and then proceeds to erase the response she had for a question. Without attributing understandings of specific kinds to this student, the behaviours in question simply would not have the needed meaning for interpretation of this behaviour.

Recognition of this point paints the start of a needed picture of science classroom events. As we proceed to move outward from the thought world of students to increasingly public events, such as speech acts, overt behaviours and other activities, the social contributions to classroom activity become all the more evident. It is for these reasons—as a first approximation, to be developed in detail over subsequent chapters—

that social contributions to classroom activity are considered basic and necessary to a successful account of classroom learning in school science.

Hopefully there should be little question that the school science classroom is a unique social world for students and teachers. On the one hand it is a world of students' and teachers' own making, in terms of what they as participants do and say in the classroom. On the other however, the social world of the science classroom includes contributions from many directions and sources. Let us consider briefly some of these sources.

To begin, each participant brings with them a host of background *understandings*, marking their unique history and identity as individuals. In addition there are many conventions or *rules* at play, including those of society, the school and class, science learning and teaching, scientific disciplines, diverse language communities, school and classrooms generally, and those of social behaviour generally, in diverse ways. And finally, against this already considerable array of background influences, there are also diverse *aims* for science learning and teaching, characteristic *attitudes* towards these endeavours, and specific kinds of *projects* or *undertakings*.

This brief cataloguing of contributions to the social world of the science classroom serves the purpose of highlighting some of the broad areas that are likely relevant to an account of ethical features of school science; *if* that is, such an account is to succeed at capturing the social world of the science classroom.

In light of these diverse contributions, how can such ethical features be studied? What conceptual resources are available for such an account? What empirical approaches are best suited to study of the topic? And finally, what limits are there to

empirical study of the topic, at the present stage of *conceptual* understanding of the issues? We turn now to these types of questions in discussing the relationships between the conceptual and empirical contributions to the present work.

Conceptual and Empirical Contributions to the Work

In summary, so far we've observed that accounts of ethical features of school science are important for addressing student self-understanding; student citizenship roles; and to improve what we know of student understanding generally in school science. But their description presents a challenge, because the social world of the classroom in which ethical features are based receives a host of contributing influences, which complicate the prospects of any viable account. As we've seen, the required approach must make room not only for background understandings of classroom participants, but also conventions or rules of various sorts, and characteristic aims, attitudes and types of projects or undertaking contributing to what happens in science classrooms.

So evidently a suitable account must either draw from sufficiently clear extant descriptions of 'understanding,' or include this as one of the items to be explained in the work at hand. It is the latter direction that is taken here. 'Understanding' on the account presented is one of the central items in need of description and explanation. What so far have been described as ethical *features* of classroom science become, on the proposed view, ethical *understandings* arising in science classrooms. The substitution of 'ethical understanding' might be supposed to leave out important aspects of ethical features. But this I will argue depends on the view of 'understanding' under consideration. The suggestion here, borne out in what follows, is that 'ethical understanding,' on the account

here, can indeed cover ethical features generally, so long as a sufficiently careful view of understandings (including who they belong to) is maintained.

We saw earlier how many types of behaviour depend for their intelligibility on attributing to others various 'thoughts'. A version of this idea is used in what follows, to sustain a distinction between understandings that are implicit in activity, but either not consciously a matter of reflection or not explicit in language, and those understandings that are explicit to reflection in such ways as part of language use. This makes understandings a natural part of a much wider range of classroom activity than otherwise would be the case. For this reason, a key claim to be defended in this work is that nothing is lost by shifting talk of ethical features to talk of ethical understanding.

In light of the importance of this view of understanding for making sense of the distinction between implicit and explicit understanding[1], and the centrality of a developed view of understanding for an account of classroom activity generally, it is essential to the task here to develop a conceptual framework sufficient to the task. It no doubt would be different were a suitable framework readily available already, which could then be employed to further empirical knowledge of ethics in the science classroom. But no such account in science education research is available.

In light of this fact, the relationship between the conceptual framework and the empirical contribution to the study is **not** one of generalizable empirical knowledge claims. Although the empirical research of the study, as we'll see, does further understanding of ethical features of school science, the principal contribution of the

[1] The reader will note this distinction runs closely parallel to the commonly cited contrast between theoretical or propositional knowledge, and practical knowledge or skill. It will be one of the suggestions of the present work that 'understanding' is better suited as a term than knowledge for capturing this distinction (as well as generally as one of the principal aims of science education), by avoiding the connotation surrounding knowledge that knowledge in general must be explicitly justified.

present work is conceptual rather than empirical. The reason for this, as suggested, is that in light of the centrality to the research aims of a well developed conceptual framework, and which prior to the present work was found not to exist, the focus here has been dedicated principally towards that end.

What then, is the envisioned relationship between the conceptual framework developed and the empirical component of the study? Rather than grounding empirical claims that are generalizable to events in science classrooms generally, the empirical research performed is instead *exploratory*, and *illustrative* of the conceptual framework. What this means is that the empirical research is designed to explore options for future empirical work, and to serve as an illustration of the conceptual approach (and as such a type of *test* of that framework), as opposed to making empirical claims of science classrooms generally. The distinction is a subtle but important one. It should not be supposed that since the research here is not generalizable to empirical events in classrooms, that it is therefore not generalizable at all. Rather, insofar as conceptual frameworks should be understood to supply needed interpretive and predictive frames from which empirical study can occur, they clearly play a role in generalization. But the generalization arises instead in relation to the strength of the conceptual framework in fulfilling these interpretive and predictive roles. By *illustrating* the proposed framework, the empirical (classroom) research of the study generalizes to the conceptual approach for understanding classroom events.

Moreover, once the framework of this study is in place, the possibilities of course for future empirical study grow accordingly. On the strength of the present account so will depend options for such future empirical study. As we'll see, some of these options

come to light in the course of the empirical study—which is exactly as we'd hope from an exploratory study.

Outline and Sequence of the Arguments

Because of the significant emphasis in this study on the theoretical approach presented, it will be helpful to have an outline and sequence of the arguments to follow. This is meant both to prepare the reader and set the stage for what's to come.

In chapter 2 I propose ethics are to be understood in terms of Dewey's (1932) definition of ethics as study of what's better or worse, good or bad, in the way of human conduct. This offers a very simple starting point for understanding the content of ethics. To the extent a student or teacher has views about what's better or worse in the way of human conduct, those views are ethical views. Study of such views, on Dewey's account, is ethics. The challenge then becomes to decide what counts as *holding* such a view. Is it enough simply that a person engages in behaviour that appears to imply an ethical view? Or does one need further to be able to *articulate* their views, whether in speech or self-consciously in thought? A response to this question will await the framework of practices and understanding laid out in Chapter 3.

Chapter 2 also presents Putnam's characterization of contemporary pragmatism, which supplies needed philosophical background, particularly in thinking about commonsense understandings in the classroom, but also in how to understand the conceptual nature of the study as a whole.

To the pragmatist framework so described, is added a view regarding the role of ethical *authority* in the classroom, drawing on the work of John Rawls. The main focus here is to lay out an approach for understanding teachers' role as classroom authorities

regarding permissible behaviour in the classroom, insofar as this role necessarily includes a role of authority with respect to ethical issues. On the basis of Rawls' account of "public reason"—for him a key condition of a society modeled on principles of fairness—it is argued that since teachers are representatives called to act and make decisions in the interests of the larger society, they are therefore called to give priority to public ethical views and decision-making in the classroom. This means that in order to fulfill their responsibilities as ethical authorities (in the way just specified), if the teacher's ethical position is one affecting student experiences at school, whenever possible they should have reasons available that students can reasonably be expected to understand and find persuasive.

The question arises at this point whether, or to what extent, the mere potential to describe (i.e. availability of) such public ethical reasons implies anything necessarily with respect to students' *involvement* in discussions or thinking about those reasons. Is it enough for science teachers, for example, to have at some point considered ways to explain why the theory of evolution is preferred over creationism in science instruction? Or do teachers in some cases (and if so, which?) need to raise such matters for more active thinking about by students, to avoid the charge they are proceeding unfairly with respect to a defensible view of public education in democratic society? While it will be suggested that a full response to this question is more than can be tackled in this study, it is again left to Chapter 3 to present a sufficiently fine grained theoretical account of understanding in the science classroom to better gauge at least possible inter-influences between ethical and other curricular understandings in the classroom.

Chapter 3 presents the conceptual framework of practices and understandings that comes to play such a central role in the account as a whole. A survey of approaches to practice from the field of practice theory is laid out, with the aim of both situating the study in the philosophical literature and identifying those elements from each of them that can serve the present needs of this study. Definitions for the core theoretical terms of the study, *understanding* and *practice* are presented, adopted from the works of Robert Brandom and Theodore Schatzki, respectively. Finally, the role of ethical understanding vis-à-vis other types of understanding is at last given a precise meaning in the context of the newly developed account of practices and understanding.

'Practices' on this view are ways of acting, thinking and speaking that are organized by the understandings, rules and characteristic feelings, aims and projects caught up in them. This offers a needed approach to incorporating the highly significant contextual contributions to ethical features of classroom science, such as the prior history together as a class, institutional setting and conventions of diverse sorts.

Understanding, for its part, on this account takes its lead in a specific way from what one is able to *do*. Rather than supposing understandings refer to particular instances of brain activity, understanding is rather an explanatory concept. This means that one attributes understanding to others regularly as part of making sense of (explaining) their behaviours and activities. So against a sceptical view that sees understanding as always private or inscrutable, the explanatory view described denies that behaviours of these kinds are so much as available for interpretation, without first requiring understanding to be attributed to those whose behaviour is being interpreted. (Recall that this was seen to

follow from the argument that simple recognition of these behaviours already involves such an attribution of understanding.)

Once understanding is freed in this way from an account exclusively in terms of purported brain activity, it becomes (on the practice view presented) an organizing feature of activities-in-context generally. A *grasp of inferential connections* and the *richness of inferential grasp* are put forward as working definitions of understanding, and the quality of understanding, respectively. These definitions make it possible to speak about understandings underlying more 'practical' abilities, like riding a bike, as well as more 'theoretical' abilities, like mathematical thinking, without at once suggesting that theory should always precede practice, or that practice is only applied theory. Rather, on the view recommended, understandings belong to practices generally. Along with rules and characteristic aims, hopes, feelings and projects, understandings are key organizing features of activities or behaviours.

Together Chapters 2 and 3 provide the needed theoretical account of the role of 'authority' in the science classroom. Whereas in Chapter 2, as mentioned, authority is framed in relation to the responsibilities of teachers to affirm some student behaviours and deny or discourage others, in Chapter 3 authority is described more generally as the inferential support behind a given understanding. This is the sense of authority one might mean if they were to ask "on what authority do you claim your understanding?" It may refer equally to *who* is responsible for a particular view, whereby the person referred to, for some further reason or other, is seen as authoritative, as to *other* kinds of reasons, which are thus authoritative for the understanding. The earlier sense of ethical authority, framed in terms of teacher responsibilities, on the more general view is now seen as a

specific understanding; namely one that has widespread currency in society, even to the point of becoming institutionalized in schools. So like other understandings, the understanding of a *person's* authority may be more or less rich depending on what is grasped as part of the understanding.

So for example, that a student understands the teacher as responsible for ensuring only certain behaviours are permissible in the science classroom, is a specific understanding, based in particular reasons held by the student. Depending on the specific reasons held by the student, their understanding of the teacher's authority may be limited simply to recognizing the teacher as an authority in this sense. They may not for example, understand more richly something about teacher authority generally. Authority thus generalizes on this view to the support implied by the nature of a given understanding, which is richer or poorer depending only on what is grasped by that understanding.

A major advantage of this view is the symmetry it makes possible between understandings of teacher management authority, in areas of permissible behaviour, and teacher subject-area authority, in areas of teachable content. In both cases, whether a given student understands richly depends on whether they grasp reasons going beyond the fact simply that a perceived authority (such as the teacher) affirmed the view in question. An impoverished understanding on this view is understanding that something is so simply because affirmed by someone else. Richer understanding, in turn, is understanding that something is so because of fuller reasons than just that someone affirmed the view. In both cases the issue turns on *what* is grasped inferentially in comprising the understanding in question. In cases of impoverished understanding the

inferential grasp places authority for understanding in *who* endorses the view, whereas with richer understandings reasons for *the view itself* are (also) taken into consideration.

In many cases this attribution is an implicit process, to the extent authority of teachers in deciding permissible school and classroom behaviours, and even to some extent subject area content, goes without saying for most students and teachers. But of course, teacher authority in relation to more *explicit* views put forward in the classroom, whether on ethical or science topics, is equally a possible contribution to student understandings. And understandings so formed are again richer or poorer, depending on the specific relationships to the teacher's views, taken as authoritative. At one extreme, a poor or diminished understanding of a given curricular item, for example, might be the classic example of a student who understands only what the teacher said, and very little else of the science concepts or the teacher's trustworthiness. By contrast, at the other extreme is the example of a student who knows from experience that the teacher is clearly trustworthy and informed regarding science, and thus understands more richly when endorsing a curricular science concept on the authority of his teacher. Nothing is necessarily amiss with recognizing an authority for what they know in ways we do not, and endorsing their views on the basis of such reasons and the various contributions to such trust.

In relation to ethical views, where there is less clear agreement than with scientific views, whether from a community of experts or otherwise, the role of questioning the authority represented or endorsed by the teacher takes on a more significant role. A clearer understanding of the possible implications of the often silent endorsement by science teachers of student ethical understandings, which are of varying

richness or poverty, is the primary question to be tackled. It is to this question that the research questions have directed our attention, and to which we must now look to the results of the field research for an illustrative and exploratory response.

Chapter 4 presents the methodological approach and specific methods of the classroom research component of the study. It begins by presenting the research questions of the study, followed by a general discussion of the required features of a suitable methodology to address the research questions. Case study methodology is presented as the most suitable choice of available methodologies, while at once noting some of the disagreements over what case studies entail among experts in the area. I capitalize on this disagreement by interpreting the contested issues as supplying needed room for calling the classroom research of the present work a case study, even though in the end the research is empirical only in the illustrative and exploratory senses outlined earlier. The earlier mentioned case is made that the role of the classroom research in the study is to be understood as exploratory of directions for future research, and illustrative of the conceptual framework put forward, but not as supporting empirical claims. Case study methodology is adapted in Chapter 4 to serve this need, but in a way that may be seen by some to diverge slightly from more traditional approaches to case studies.

Also appearing in Chapter 4 are a definition of the 'case' and the Propositions of the study. In keeping with the approach to case studies laid out earlier in the chapter, such propositions serve to connect the conceptual framework to the research questions of the study. The four proposed propositions presented are designed so that the classroom research will later be found either to support a given proposition or not. While this is surely the area of the study that is closest to making empirical claims, it will be seen that

the empirical scope of the propositions is sufficiently modest that their purpose is to suggest possibilities for future work and to illustrate the conceptual approach along the lines described.

Chapter 5 presents the classroom research of the study. This research occurred with classes of grade 10 and 11 science students at two separate schools, in each case focusing on ethical features of the curriculum and classroom instruction. For both schools I developed the lessons as well as acted as a guest teacher in presenting these lessons. This is in keeping with the definition of a case for the classroom research; namely "A set of sustainability lessons designed and taught by the researcher in a school science grade and subject community"[2]. In addition to the classroom teaching, I conducted student interviews to explore their views on a range of topics related to ethics, science, nature and what's "natural". Excerpts from both written work and student interviews are employed throughout the chapter to demonstrate students' ethical understandings and the interactions between such ethical views and science understandings. I also share in Chapter 5 self-reflexive observations as researcher and guest teacher for the case study, regarding the challenges to negotiate my own authority in relation to seeking to understand the sources of authority in student understandings. Finally, in keeping with the aim of *exploratory* case study research, an additional major role of Chapter 5 is to generate a series of proposed research questions for future empirical study.

The concluding chapter draws together the various contributions of the study. It begins with a section on responses to the research questions of the study, drawn from

[2] A fuller description of what this means must wait for elaboration until Chapters 4 and 5.

Chapters 2, 3, and 5. The following section then engages in detail with other related work in science education research. Given the breadth of the conceptual approach presented in the study, each of ethical features, understandings and knowledge, and practices as topics of science education research are given separate treatment. It is evident at this stage that the present work makes a much-needed contribution to work in these areas.

Finally, the study as a whole concludes with a look at possible directions for future theoretical work in science education on the basis of the study, to complement the directions for future empirical work developed in Chapter 5. In doing so, the study as a whole is put into perspective in exciting ways, through recognition of the many prospects for continuing interesting and needed science education research on the basis of the work here. Included in the list of promising directions are 'knowledge' versus 'understandings' as aims for science education; knowledge or understanding transfer; science skills and practical knowledge; metacognition; and ethical practices and teachers' self-understanding. In the light of this concluding discussion there is no remaining question that the present study holds great promise for future developments in science education research.

Chapter 2 – Ethical Frames

Introduction

In accounting for ethical features in school science[3], there are a number of possible questions to consider. Central among such considerations for the present chapter are 1) how ethical content is to be determined; 2) how ethical content is seen to relate to understandings (ethical and otherwise) of teachers and students; and 3) how ethical content is legitimized, both in terms of an account that describes features of science classrooms, as well as in terms of what classroom participants actually do and say in the classroom. In what follows in the present chapter I attempt to give a response to each of these considerations. What arises is a basis for a 'practice view of ethical understandings in classroom science'. But while the account of this chapter ends up pointing in the direction of (i.e. provides a basis for a view of) practices as the central organizing concept for understanding ethical features of classroom science, it remains for chapter 3 to give details on how the view of practices suggested is suited to this task.

The chapter is organized in the following way. I begin with an attempt to motivate the discussion that follows with an appeal to commonsense intuitions concerning explicit versus implicit ethical content. This is a first attempt to chart the breadth of ethical features in classroom science, by acknowledging not only what is evident or recognized as ethical by those involved with such content, but also what is

[3] In choosing to discuss ethical features *in* school science, the focus is slanted in a certain way towards those features that involve *participation* of teachers and students. This contrasts with approaches that focus on ethical features *of* school science, which as a more general area includes ethical aspects beyond what teachers and students actually do in the classroom. An example of the contrasting approach might be a description of school science as enculturation into oppressive, sexist or colonizing ways of understanding, specifically in ways that are non-negotiable at the level of student and teacher practices.

ethical by virtue of its role in understandings that arise without separate recognition of *what* one understands. They are rather imbedded in activity.

I then proceed to lay out a particular framework for accounting for ethical features of classroom science. I characterize the proposed framework as at once *pragmatist* and *constructivist*. In calling the framework pragmatist I draw connections to a summary of pragmatism offered by Hilary Putnam. John Dewey's ethical thinking is then presented as an example of a pragmatist view of ethics, as well as the basic view of ethics adopted for the study.

The constructivist leg of the framework in turn builds from this basis an account that can address what are seen as two needed beginning points for any workable account of ethical features of classroom science. First, ethical features of classroom science are seen as the result of what students and teachers collectively achieve in the classroom, in the sense of reciprocal interaction and experiences of participants themselves. They are said thus to be *constructed* from classroom activities because without this interaction and the respective experiences of students and teachers the ethical features simply would not arise. Second, it is suggested that any defensible view of ethics that is to be endorsed as suitable for the science classroom must acknowledge the existing pluralism in classroom communities. This restricts the range of acceptable approaches to ethics in science classrooms to those that can be *publicly* legitimized in some way, without at once unnecessarily restricting the broader terrain of ethical concerns that go beyond this public role. Such an approach is seen as *defensible* because established with public reasons—i.e. *constructed* publicly—instead of relying on private metaphysical views for its

justification[4]. The work of John Rawls in describing a public conception of justice is the model for the constructivist side of the proposed framework.

Explicit Versus Implicit Ethical Understanding

I begin with an appeal to intuitive or commonsense differences between *explicit* and *implicit* ethical features belonging to school science. Explicit ethical features of school science involve exploration of ethical issues related to school science that are identified or recognized as ethical by some or all participants in the classroom. These typically involve ethical issues that are deliberately included in curriculum or as a part of a teacher's teaching, and which then become a focus of study for science classes. Common examples include lessons or units focusing on ethical aspects of environmental issues, military uses of science, or genetic engineering. What characterizes this kind of approach is that the ethical content is explicit in what happens in the science class, and moreover what students and teachers recognize as their activity; it is either an official part of the curriculum (i.e. it is featured in the curriculum and/or teacher's lesson planning) or at least a chosen focus for teaching and/or learning occurring in the classroom (however briefly it plays this role).

By contrast, implicit ethical features of school science are features of classroom practices that are not themselves direct objects of reflection or study. They are distinguished instead by their role in how ethical features of events in the science

[4] One might ask how the two ways of talking about constructivism described here are related; that is, the one in terms of how ethical understandings in general are *formed* in the classroom, and the other in terms of how an ethical approach can be *justified.* This question is answered below in the discussion on John Rawls.

classroom are structured socially and are 'in-practice'[5]. *Socially*, as a result of the reciprocal responsiveness of participants to one another's activities in the classroom; and *in-practice*, by how participants' activities and behaviours (rather than the design of those activities, as with the case of explicit ethical content) manifest or embody the ethical content arising in the science classroom. Relationships in the science classroom, for example, manifest many ethical features implicitly: in how authority is attributed to various understandings or knowledge; in the kinds and degrees of respect and caring for one another demonstrated by students and teachers; and in how rules for learning and management structure classroom activities.

It should be clear that as described, explicit and implicit ethical features of classroom science often interact. A key question therefore for an account of ethical features of science classrooms is the nature of these interactions between explicit and implicit ethical features. The approach taken (in Chapter 3) will be to describe both explicit and implicit ethical features of classroom science as features of classroom *practices*. Practices, as we'll see, are organized sets of activities, the organization of which makes possible both explicit and implicit ethical content. But in advance of describing in detail the proposed account of practice, the present task is to illustrate the differences and connections between explicit and implicit ethical features in a typical science lesson, and then to give substance to a framework suited to addressing them. So we turn next to a brief vignette drawn from the science classroom.

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[5] I use the awkward adjective 'in-practice' rather than 'practical' to note, by way of sign-posting to the next chapters—that both 'theoretical' and 'practical' knowledge or understanding are equally features of practice on the present view. The distinction between these types of understanding, as we'll see in detail in Chapter 3, is rather one of *implicit* versus *explicit* understanding.

Illustrative Vignette

As part of a lesson on different forms of energy production, a student in the class raises her hand and asks "What about wind power? Why don't we use renewable power instead—to help the environment? Isn't it right to help the environment?" The teacher on this particular day is in a hurry to continue, and so responds quickly: "Overall, wind power isn't right for most locations. It requires a steady supply of wind and lots of uninhabited land for windmills." Instead of addressing the further issues raised by the student, regarding renewable energy, 'helping' the environment, and what should be seen as "right", the teacher hurriedly carries on with the lesson. As a result the student mistakes the teacher's response as a criticism of renewable energy, which was meant to discourage concern for the environment. And since the typical format for discussion in this class has few opportunities for students' critical engagement with questions of this sort (the teacher perceives them as 'extra-curricular' and thus outside the scope of the class), none of the students ask for clarification. The student concludes to herself that since the response came from a science teacher—whom she trusts, renewable energy "according to science" isn't worthwhile. Further, several times over the next two weeks, the student repeats this view of renewable energy in conversation with friends and family.

Though brief, this vignette serves to illustrate the essential differences between the two types of ethical features in school science of interest to this study. The student's questions raise for consideration by the class issues of renewable energy and the question of whether it's "right" to help the environment. "Right" in this context is an explicit ethical term. Moreover, the topic has familiar ethical issues associated with it, which those in the class are likely to recognize, such as protection of the environment and

decision-making regarding the environment. To the extent these are part of the exchange between the students and the teacher, or become (under different circumstances) a topic for classroom discussion or study, they are defined as explicit ethical features of classroom science. In the case at hand, the explicit ethical issues are developed only very briefly. As a result, the explicit content is limited to what is either said or reflected on consciously by students and teacher regarding questions of what's better or worse (i.e. ethically) for society and the environment.

On the other hand, there are a number of implicit ethical features belonging to the situation. There are the ethical understandings and reasoning of students and teachers as part of the situation. Reasoning refers here very broadly to concept-laden activity that develops new understandings[6]. Ethical reasoning on this view is an implicit feature of the situation by virtue of its role in the activities of classroom participants: the initial asking of the question by a student, the teacher's response, and the various unspoken responses throughout the class as students form new understandings. Implicit reasoning, then, is evidently often nonverbal, even non-conscious in terms of an activity that a given student or the teacher is conscious of carrying out. Such reasoning, moreover, is ethical reasoning just in case it serves as the basis of ethical understanding. Understanding, as is developed in detail in Chapter 3, can also be described as either explicit or implicit, according to whether the understanding in question belongs to acts of conscious reflection and language-use or not, respectively[7]. Among the many implicit ethical understandings potentially present in the situation described, are ideas concerning the

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[6] We leave aside for the moment the question of distinguishing explicit from implicit reasoning. Cf. Ch. 3, below.

[7] For the moment this key distinction between explicit and implicit understandings rests on an appeal to commonsense. A fuller account is provided in the next chapter.

possible importance for society of renewable energy, how best to think about ethical issues related to alternative energy, and the role of scientific authority[8].

Thus, the ethical significance of the explicit student or teacher responses in the vignette, or in a classroom generally, may be lesser or greater depending on the nature of the understandings, both explicit and implicit, and how the authority for understanding is attributed as understandings are formed. This in turn will be seen to depend on embedded classroom relationships and other features of classroom practices. So although implicit ethical understandings may at times seem vague—or even invisible altogether—they are nonetheless an essential area in ethical features of school science. They are implicit by belonging to a fuller characterization of what's happening in the classroom, one which goes beyond the explicit discussion or study in the classroom, to an account of the social and "in-practice" structure of classroom events. Both ethical reasoning and ethical understanding are implicit features of such activity: they are necessary to a fuller description of the events in question. By relating to what occurs often invisibly—whether as part of students' reasoning[9] or the social dynamics of the classroom generally—both implicit **and** explicit features of school science are important for research in science education to understand. It remains for the rest of this work to develop an account that serves this aim.

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[8] Including, significantly, the authority of the science teacher in deciding or recommending what's best ethically. Not surprisingly, *authority* attaching to different understandings (ethical and otherwise) arises as an important theme for the proposed framework. Cf. the discussion of authority in Ch. 2, below.

[9] On the view to be described such reasoning can include cognitive, affective and a host of other components. Cf. Ch. 3.

Ethics: Starting Points

Having explored briefly with the help of the vignette the kind of ethical content of interest here, I'm now in a position to situate in more detail the ethical approach in terms of ethical theory. Let us begin by reviewing requirements of the needed approach. We are interested in an approach to ethics that can accommodate two basic features of classroom life (which, as we'll see, relate closely to the two ways of discussing constructivism mentioned earlier). The first feature is a commitment to commonsense understandings. As the term is used here, commonsense understanding is relative to a language community, and refers to the understandings that make possible coordinated behaviour as a community (i.e. as something more than a collection of people). Commonsense understanding in a community is the set of understandings that are readily intelligible to others in the community. They are understandings that assist in coordinating respective individuals' thinking, feeling, acting and speaking in shared social situations (such as events in the classroom), such that additional understandings are not needed to make sense of the situation[10].

The second basic feature is pluralism in classroom communities. This pluralism arises from the fact that members of science classrooms have different past experiences, cultural backgrounds, family histories and even individual styles. Since such pluralism is a common feature of science classrooms, and one that, importantly, teachers and other working in education are charged to acknowledge and even respect, the chosen approach must accommodate this basic feature of science classrooms.

[10] Note that according to this definition, what is common or specialized in a given case is always relative to the understandings at play in the relevant community.

For the purposes of the present study these two features serve as starting points for the development of the approach. It is thus important before continuing to elaborate briefly on why these features should be seen either as sufficiently important or uncontroversial to warrant their role as starting points. I begin first with the issue with pluralism, and then turn to the focus on commonsense understandings.

By seeking an approach that is maximally flexible with respect to the diversity of understandings of classroom participants, the aim is to ground the approach as much as possible in existing practices, in the kinds of things classroom students and teachers actually think, believe, feel and do with respect to ethical matters. Thus, to 'ground' in this case means simply to fit the descriptive and critical approach undertaken to the practical context at hand; namely, secondary school science in contemporary societies. On the one hand this is simply an emphasis on practicality, or a fit to existing contexts in relevant ways. But more critically, it is to endorse the idea that usefulness of research in this area depends significantly on how useful it is for classroom participants, which includes the critical guidance it makes possible[11]. By seeking from the beginning to accommodate the diversity of students' and teachers' respective understandings, it is believed the prospects of the approach for contributing usefully to classroom practices are much greater[12].

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[11] This view is central to what I take as a *critical* edge to the study. The key idea as I understand it, is that critical research is both descriptive and prescriptive. So for example, the views here of teaching practice and science education research practice include implications at places for what should be done differently to acknowledge pluralism in the science classroom.

[12] The diversity in question here is primarily the existing diversity of typical science education contexts in western industrialized nations. Moreover, it is as much a factor of the diversity in background understandings of participants as it is more visible types of diversity such as ethnicity of religious affiliation. So even with contexts that are mostly or even entirely homogeneous in *some* areas, one can still argue for the diversity of participants along lines of background understandings.

As a brief example to illustrate this point, consider the broad political context of school classroom communities in liberal democratic countries such as Canada. A core feature of liberal society is some notion of the 'separation of church and state'. Today this can usefully be understood in terms of a separation between privately held metaphysical views and what plays a role in public institutions such as the school. In classrooms this typically translates to a respect for student diversity, by avoiding imposing on students as part of their educational experience a particular religious or metaphysical view (including non-religious metaphysical views such as atheism or agnosticism).

An additional core feature of liberal democratic societies is a respect for persons, enshrined in notions such as human rights, and protected through intricate legal practices. In classrooms this often means a predominant emphasis (in aim at least) on non-coercive methods of classroom management, relying instead as much as possible on the cooperative involvement of students. Further, and related to this, is the more distinctly educational insight that quality of learning depends generally on the degree of active participation by students in shaping the terms of their understanding.

Together these political and educational points shape the kinds of ethical approach suited to school classrooms in the direction of considerations for diversity in understanding of classroom participants[13]. In turn they also shape the kinds of ethical approach that suited in accounts of ethical features of school science, both practically and critically. So whether in terms of an account that is accurate in its portrayal **or** one that affords critical guidance to classroom participants, fitting the account to the pluralism in

[13] More particular shaping will of course depend on what is unique about particular classrooms.

existing understandings present in school science is important to the approach undertaken.

The commitment to commonsense ethical understandings is likewise a commitment to understandings typical of actual schools and classrooms. It reflects a priority to what students and teachers often recognize implicitly by their conduct and in the conduct of others. Commonsense understanding can be thought of in one sense as the kind of understanding one assumes—and must assume—others with whom one interacts acquire from one's conduct, in cases where those others are unlikely to share one's more specialized understandings. In this sense commonsense understanding is *socially coordinated understanding*.

On the other hand the emphasis on commonsense ethical understanding as a typical common denominator in classrooms doesn't mean specialized understandings are not a regular feature of classroom conduct. They are. Specialized understandings in general and specialized ethical understandings specifically develop constantly as conduct becomes established and shared interpretations develop[14]. Even whole classrooms may develop ethical understandings shared by the class as a whole. But the amount of specialization is always constrained by the need to make sense of others' conduct—including, importantly, what others (such as the teacher) say. And since diversity in understanding persists even as shared understandings develop (given that individuals are always forming new understandings), commonsense understanding remains a common denominator even where specialized understandings are widespread.

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[14] It is hoped that the argument here makes clear that what is 'common' in commonsense is always relative to a set of shared understandings making social coordination possible. Commonsense understandings therefore do not rule out more particular understandings—even those which are directly opposed to some *other* set of commonsense understandings.

Moreover, since specialized understandings often require for their development the help of explicit understanding (such as the possession of consciously formulated reasoning or understanding) in those situations where understanding of others is mostly implicit in conduct, commonsense understanding will play a pivotal role[15]. Ethical understanding in particular falls in this area, it is suggested, since explicitly formulated ethical understandings are not only rare in the classroom, but difficult to find agreement on between participants. This is so, it is suggested, both because ethics as an area is difficult to sort through conceptually, and because settled answers for ethical questions are often unavailable. Typically ethical understandings in the classroom result instead from the coordinated interactions of classroom members (notably teachers in their role as management authorities) and are both commonsense and implicit in conduct.

Finally, when it comes to offering a research account of ethical features of school science (as in the present study) since the relevant audience (science teachers and researchers in science education) almost surely possess diverse ethical understandings, prior agreement in understanding cannot be assumed. On the other hand, in contrast to most ethical understandings in the classroom, the understandings discussed in this study are often explicitly formulated. But even though this is true, the approach nonetheless stresses commonsense ethical understanding, since such understanding is more typical of science education contexts.

It has thus been shown that both diversity in existing ethical understanding among teachers and students, and commonsense understandings can be understood as needed

[15] The argument that implicit understandings, as part of activity and conduct, precede explicitly formulated understandings is laid out in a future chapter (cf. Chapter 3). The key point is that because in each instance understanding relies on practices of different kinds, and which include characteristic behaviours and activities, there is strictly speaking no such thing as an explicitly formulated understanding without some prior basis in implicit understandings as part of those behaviours and activities. .

starting points for an account of ethical features of school science, if such an account is to be representative of typical science education contexts and practical in terms participants' existing understandings. In each case the aim is to match the approach taken with actual classroom practices, so as to offer a clearer understanding of school science, and to offer a framework that holds the potential at least for critical guidance to those involved in such classrooms.

Ethics: A Pragmatist and Constructivist Approach

Assuming therefore the two basic features of school science above—pluralism among teachers' and students' backgrounds and understandings, and a related commitment to commonsense understandings—we can proceed to lay out the ethical approach of the study. The definition of ethics to be adopted throughout the study belongs to Dewey (1932)[16], presented below. While this definition is felt sufficiently inclusive and uncontroversial to demand much argument, at least indirect support for its choice is found in the following sections, as itself an example of the pragmatist and constructivist emphasis in this study.

On Dewey's (1932) view, ethics is defined as the study of human conduct involving considerations of right and wrong, or good and bad. It is this most basic view of ethics that will be adopted throughout the study to follow. When students and teachers act or speak or speak according to considerations of 'right' and 'wrong'[17] (or better and worse) conduct, the understanding in question involves ethical understanding. And

[16] It will be noted this source appears in the References as *co*-authored by Dewey & Tufts. But since Dewey and his co-author are known to have authored their respective sections of the book separately, I follow the custom of referencing Dewey's part of the combined authorship on its own.

[17] I.e. conceptually, and as such a separate issue from whether this particular ethical vocabulary is employed.

similar to other forms of understanding, ethical understandings are better or worse according to the richness of conceptual connections belonging to that understanding. Thus they can be appraised, criticized, challenged, reflected upon and even 'tested' like other understandings[18]. The study of such understandings and their role in what people say and do is ethics. It is from this starting point that the elaboration of pragmatist contributions to the study builds below.

The approach to be described is also constructivist in orientation, analogous to Rawls's (2005)[19] account of political constructivism. The central feature of a constructivist approach to ethics is the idea that what is ethical results from the structure or construction of practical activities, whether those of actual participants or a suitable hypothetical ideal group[20]. This contrasts with approaches that see what is ethical to exist independently of human activity (e.g. moral intuitionism), or to depend only on features of that activity which are insensitive to rational understanding (e.g. emotivism). By analogy to Rawls' account defining the political sphere in liberal democratic society, resulting in the principles of justice as fairness, I sketch an account later in the chapter

[18] Cf. the discussion of fallibilism to follow, below.

[19] Rawls's (2005) *political* constructivism is founded on four features: 1) the content of political justice results from the structure of a decision-making procedure (that selects the principles governing the basic structure of society); 2) the procedure is based in practical reason, the distinction of which (as against theoretical reason) is that practical reason produces objects based on conceptions of those objects (whereas theoretical reason is concerned with knowledge of objects); 3) the form and structure of the constructed account are based on complex views of person and society; and 4) an emphasis on reasonableness (rather than truth), which is distinguished by reasonable persons, who in turn are distinguished by "their willingness to propose and abide by fair terms of social cooperation among equals and their recognition of and willingness to accept the consequences of the burdens of judgment" (p. 94.)

[20] As noted earlier in the chapter and discussed in more detail in what follows, constructivism as so defined can be framed either descriptively or prescriptively. On the one hand, as a description of how ethical understandings *are* formed (for example in the classroom), and on the other, as an account of how such contents of understanding *should* be thought of or seen to form.

defining the ethical sphere in school science, resulting in a privileged role for public ethical views (suitably defined in what follows).

Pragmatist Contributions

As a philosophical area pragmatism is often divided between its classical heritage and more recent developments. Classical pragmatism is typically associated with the works of American philosophers C.S. Peirce, William James and John Dewey, over the latter part of the 19th century and the earlier part of the 20th century. This contrasts with more recent pragmatist approaches (sometimes called neo-pragmatist). In light of the various differences between individual authors and between classical pragmatism and later pragmatism, it will be helpful to elaborate in some detail what 'pragmatist' means as it is used in this study. In doing so I borrow Putnam's (1994) fourfold characterization of pragmatism, while elaborating each area by reference to a broadly Deweyan approach to ethics (Dewey 1930; Dewey 1932; Dewey 1938/1986). While the issues raised in the following elaboration go well beyond ethics as such—much less their role in classroom science—they are seen to provide a core foundation of the conceptual background of the present work[21].

Putnam's (1994) characterization of pragmatism includes the following features: 1) the primacy of practice; 2) fallibilism; 3) anti-scepticism; and 4) the rejection of the fact/value dichotomy (p. 152). Each of these characteristics helps to give flesh to the overall account of ethical features in terms of practices and understandings, as well as

[21] Note that nothing of significance for this study hinges on the question of whether Putnam (1994) succeeds at characterizing 'pragmatism' generally. All I claim is the characterization he does offer picks out important features shared by the framework being proposed in the present study, and which I follow him in calling 'pragmatist'.

specifically the suggestion earlier that a suitable ethical approach must accommodate both the pluralism and commonsense understandings as they feature in science classrooms. And as we'll see, in addition to giving substance to the claimed pragmatist background for the present work, Dewey's definition of "inquiry" is described along the way, which will be important in the subsequent chapters.

A central element running throughout Dewey's work is the insistence that problems arise from life experiences in a broad sense: "Consequences arise from every experience, and they are the source of our interest in what is present" (Dewey, 1930, p.242). It is this suggestion that for Dewey places problems and problematic situations as the substance from which inquiry begins. Problematic situations are life experiences that are troublesome, obscure, uncertain or ill-defined in some way, thus prompting their resolution through inquiry. "Inquiry, in settling the disturbed relation of organism-environment (which defines doubt) does not merely remove doubt by recurrence to a prior adaptive integration. It institutes new environing conditions that occasion new problems" (Dewey, 1938/1986, pp.41-42). 'Inquiry,' understood in this way, is the controlled process of transformation of an indeterminate situation to one that is determinate, such that relations between the initial problem and its resolution form a unified whole (cf. Dewey, 1938/1986, p. 108).

It is this broad idea, that our basic immersion in life experiences provides the substance of all possible inquiry, which underlies in the most basic way practice may be seen as primary in pragmatism[22]. Insofar as every person in the course of experience is faced with the ongoing task of acting, speaking and thinking in some ways and not

[22] This connects closely the view of pragmatism so described to how constructivism has been presented so far in this chapter.

others, they are prompted by situations calling for inquiry in the Deweyan sense. The immersion in experience is defined therefore by ongoing practical activity. What distinguishes theory from practice is not that one involves practical activity whereas the other does not, but rather the specific problematic situations one faces and how they are addressed within equally specific inquiry practices. For a person to claim therefore that some activity is too theoretical or impractical may be understood to mean that the theoretical practice in question is inadequate to the needs of some other practical area. On a pragmatist reading it does not suggest (though this is of course also possible) that within its own practical area the theoretical practice is found lacking.

Furthermore, as the earlier quote suggests, inquiry for Dewey begets further inquiry. This relates to the reasons why knowledge and understanding are in general fallible. To the extent life experiences broadly lead to further life experiences, a steady stream of new problems (in Dewey's sense) results. This implies that life conditions continually prompt specific resolutions to problems, since problems are unique combinations of a potentially vast number of contributing factors in experience. In terms of knowledge and understanding, this means resolutions of problematic situations are never final or absolute, in such a way that would allow those resolutions to be applied to further contexts without adjustment.

The result is a view of fallibilism in knowledge and understanding. All knowledge and understanding are conditional and subject to revision in that they derive from specific practical problems, and apply to further problems only on condition of relevant similarity in the nature of the problems. Whatever permanence or certainty attaches to knowledge and understanding results from ongoing successful resolution of

problematic situations. And since the problems that face human beings evolve—whether as individuals or groups, and today or historically—all knowledge and understanding is subject to revision.

Fallibilism can in this way be seen as a corollary to the primacy of practice or practical understanding. Insofar as new understandings generally are the result of practical situations calling for a resolution of some kind, the permanence of any given resolution is always a question of how well it resolves the problematic situations in question. Some resolutions of course are much more enduring than others, but this points not to absolute knowledge of a kind that separates itself somehow from the process of knowledge formation, but rather to persistent problems. Conversely, knowledge or understanding in the lights of a particular group of humans today is seen as outmoded or incorrect, may reflect either improved ways of resolving the problem in question or a new variation of the problem altogether.

There are many features of the view of fallibilism suggested that are important to the conceptual approach overall undertaken here to the ethical features of school science. Fallibilism of course is a central feature of the experimentalism typical of science broadly. But within the philosophy of science fallibilism has usually stopped short of the view that knowledge and understandings generally are subject to possible revision. Rather, whether a given knowledge claim or understanding is subject to possible revision has often been a question of its relation to truth. So called analytic truths, on Kant's (1781/1998) version are those the denial of which is impossible on logical grounds alone. They are seen as unrevisable, since outside the contingency of empirical discovery or

experience. Synthetic truths on the other hand depend on experience and are therefore generally subject to revision.

Fallibilism in science has usually been seen as restricted to synthetic truths as opposed to analytic truth. So called truths of logic or mathematics have often been singled out as necessarily true (apriorism), true by convention (conventionalism) or inductively true (inductivism). Pragmatist fallibilism by contrast holds that all knowledge is subject to revision, because knowledge is related to inquiry involving particular problems, and problems depend on changing circumstances. Knowledge therefore is revisable in principle. The commitment to inquiry as the basis of knowledge contrasts with views of knowledge that are based in some prior account of truth. In part because of this commitment to inquiry, pragmatist views have been criticized for holding an untenable account of truth. The popular caricature of the pragmatist view of truth is the idea that truth is simply what 'works' as a solution to problems at hand, and thus may be no more than the consensus achieved by a given historical group.

On closer inspection however it is clear that pragmatist views of truth are far more nuanced than this caricature suggests (cf. Putnam, 1995). In particular, the pragmatist insistence to frame both knowledge and truth in terms of inquiry (rather than, say, framing both knowledge and inquiry in terms of truth) does not by itself commit one to a crude, 'whatever works' form of pragmatism. The details however of a pragmatist view of truth in contemporary philosophy are highly involved. So for the purposes of the view of fallibilism recommended here, it suffices to point out simply that truth as a research area in philosophy is far from settled (cf. Shantz, 2002), and that among the views actively discussed as part of this research are sophisticated contemporary versions of

pragmatist theories of truth (cf. op cit, with particular emphasis on the chapter by Robert Brandom).

Whether knowledge and understanding *in principle* are subject to possible revision, or whether instead some knowledge and understanding are beyond revision[23], these are technical questions the resolution of which is best approached within a fallibilist framework. For this holds the advantage of acknowledging these remain difficult questions, complete answers to which are so far lacking. Thus, significantly, in terms of a largely *conceptual* work such as the present study, the account offered can be understood as defeasible in all the same ways as more empirically based accounts, according that is to the strength of evidence and reasons. This point is important for an appropriate understanding of the relationships between conceptual and empirical contributions to the present work.

Anti-scepticism, as we'll see, is again a related idea on the pragmatist account put forward. It can be summarised as the idea that both conviction and doubt are in need of justificatory support if they are to be seen as defensible. Both what a person believes and what a person doubts equally need support from some direction. Absent this balance between justification for doubt and justification for belief, there is the possibility that sceptics swing from a sound questioning of credulity regarding knowledge (the proper target of scepticism), to the opposite extreme of rejecting all claims to knowledge as unjustified. By contrast, anti-scepticism describes a middle position between these

[23] Many people might claim for example that the axiom of identity, or perhaps non-contradiction or the excluded middle, are to understood as truths that are unrevisable *in principle*. In the wake of Quine's (1953) famous attack on the synthetic/analytic dichotomy however, on a pragmatist reading such as Putnam (1994), this means only we cannot (in terms of present knowledge) *conceive* what it would mean for such axioms not to hold.

extremes. In doing so it acknowledges that extreme forms of scepticism may appear consistent, but at the price of neglecting to question entitlement to doubt itself.

The unquestioning attitude to doubt is related to what are often described as Cartesian views of mind, namely that a mental agent can doubt any of the various contents of her thinking, but what she *cannot* doubt is that she is thinking in the first place; (the famous "cogito ergo sum"). Doubt of thought *contents* are in principle subject to doubt whereas the act of thinking—and doubting—are themselves incorrigible (since within the scope of the *cogito*)[24]. Such introspected items, by contrast to others, are taken as unmediated and thus incorrigible.

In contrast to these approaches that treat represent*ings* (Descartes' 'clear and distinct ideas') as unquestioned 'givens', and which collectively form the basis of mindedness on many such views, so-called non-Cartesian views of mind see the need for a fuller account of what makes representing possible in the first place; more that is, than simply the seeming transparency of such representings to mental agents. Without ignoring the uniqueness of the stance of an agent vis-à-vis their own representings (particularly in terms of *self*-knowledge) as compared to the representings of others, non-Cartesian approaches in general look to define specifically *mental* activity in more worldly or embodied terms. Instead of an activity distinguished by being unquestionable, mental activity becomes a feature of agents' 'world-involving' activities (cf. McDowell, 1994, Putnam, 1990). In other words, minds are distinguished not by states that are

[24] A great deal more can be said here to elaborate the Cartesian view of mind-as-consciousness, which hinges on the difference between represent*eds* and represent*ings*. Brandom (1994) describes this difference as involving the difference between representational content and representational purport. On Cartesian views of mind, one may doubt the representational content but not the representational purport, since the latter is taken as given. Cf. op cit, for a developed account.

unsusceptible to doubt, but by world-involving capacities such as referring to objects and states, or acting intentionally towards such objects and states.

It should be clear these are very challenging topics, even in many cases for the most current philosophy and science today. This makes it all the more remarkable that classical pragmatists such as James and Dewey were able already at that time to foresee the pitfalls of Cartesian scepticism and attempt to build a way around them by endorsing anti-scepticism in the form outlined above. There will be ample opportunity as we go along to discuss more specifically how this plays out with respect to ethical features of knowledge construction in the science classroom. For the moment it suffices simply to describe this simply as a *stance* in relation to knowledge and understanding.

This stance is indicated by the following summary: the strength of prospective claims to either the presence *or* the absence of knowledge or understanding rely equally on the kind of support that can be supplied for those claims by the one attributing or denying knowledge or understanding. And because this support may potentially arise in a variety of forms, the emphasis on justificatory support need not fall into prejudging the question of implicit knowledge or understanding. Prejudging this question occurs when we demand the agent *herself* be able to supply explicit justificatory support for what she can then be said to know or understands. These issues are revisited as important themes of Chapter 3.

The final area of pragmatism to be discussed is the rejection of the fact/value dichotomy. This topic has played and continues to play a prominent role in many major conceptual divisions in thinking about both ethics and science. These include, among others, such divisions as artificial/natural, mind/world, created/discovered,

prescription/description, and constructed/real. Questions in each of these areas are the subject of extensive discussion throughout philosophy and the social sciences related to the fact/value dichotomy (cf. Putnam, 1990).

In its most stark and general form the fact/value dichotomy states that whereas facts are either states-of-affairs of the natural world or descriptions corresponding to such states, values are neither. They are not natural states nor do they correspond to such states, but are rather evaluative states or positions of human beings. To reject this dichotomy on the pragmatist account amounts to viewing *both* facts and values as the result of human activity, notwithstanding what role they have potentially in describing more primitive states (physical or natural states, or evaluative states). In other words, pragmatism eschews the notion that either facts or values are the kinds of entities that can be usefully discussed without some consideration for the context within which they are described as facts and values, respectively, in the first place. In the Deweyan terms invoked earlier, both natural and evaluative states are understood to arise relative to *problematic situations* seeking resolution of some kind. So instead of insisting in advance that facts reflect a world unadulterated by human involvement, whereas values somehow 'taint' the purity of such knowledge, the pragmatist view sees situations as the basic unit within which inquiry takes place.

This parallels the view mentioned earlier regarding world-involving capacities. Such capacities (e.g. referring to an object or intending a course of action), are *situated* capacities, in requiring a context, whether simple or complex, within which they can be seen to arise. Insofar as proponents of the fact/value dichotomy have often believed that because facts pertain to mind-independent objects and states, their role in what counts as

a good *argument* is for that reason privileged, they have often assumed ontological status (i.e. the kind of object or state in question) can be traded in for justification of views in some general way.

The mistake here is supposing ontological status, such as facts concerning a physical state, are useful *generally*—outside the particular domains and situations wherein they play some constructive role. And this amounts to blindness regarding the context and situatedness of the claims in question. Instead, what counts as privileged in justification or argument generally are the reasons and arguments that can be supplied in defence of a given view. And which reasons or arguments work in a given case will always depend on the situation. So physics talk is indeed appropriate when questions of physics are the topic at hand, but are often out of place when discussing say, questions of values or ethics.

It is important to stress however that beyond the issue of the situatedness of argument and justification, the pragmatist denial of the fact/value dichotomy does not side one way or the other on the matter of what are the most basic kinds of states—natural or otherwise. Rather, insofar as metaphysical questions of this kind are, like other matters of knowledge, dependent on the strength of argument within a given context, it is open for those contexts of discourse to decide what counts as the best view. There are no universal arguments any more than there are physical objects whose existence alone acts as an *argument* or *position* within discourse, and for analogous reasons. Both the scope of arguments and the scope of any claimed objects in the world must defer to concrete arguments (including often evidentiary arguments) for support.

An immediate implication of this view is the idea knowledge in general is situated knowledge, whether we speak of factual knowledge or knowledge of values. In response to this, a common criticism is the suggestion this approach commits one to some variety of relativism regarding knowledge. Such a suggestion features for example in the familiar view that values are *subjective*—items that reflect only *preferences* or *attitudes*—which as such is seen to disqualify them from serving as a basis of knowledge or understanding about a mind-independent world. It should be familiar at this point what the overall pragmatist response to such criticism will be: because facts and values are *both* candidates for criticism and discussion as part of ongoing efforts to achieve the best views, there is no cause for generalized concerns of this sort.

There is much more to say on the topic of the fact/value dichotomy. But for now it suffices that we've succeeded in outlining some of the most general questions as they tie together with the view of pragmatism put forward. In effect, contemporary sophistication of the type outlined above aside, the core idea remains the Deweyan (1938/1986) view that *situations*—"disturbed relation[s] of organism-environment" (pp. 41-42)—constitute the most basic starting point for accounts or claims generally regarding knowledge and understanding.

Ethical features of school science therefore, such as those illustrated earlier through the use of the vignette, involve *particular* types of situations facing teachers and students; namely *ethical situations*. Teachers or students who grapple to resolve an indeterminate situation involving questions of what's better or worse in areas of human conduct are facing a specifically ethical situation. The scope of possible ethical situations in science classrooms is therefore wide, including everything from basic issues

of respect towards others in the classroom to the role of science teachers in privileging certain understandings over others[25]. Ethical situations confronting classroom participants within a process of ongoing inquiry (in the Deweyan sense), and spelled out in terms of the pragmatist insights above, comprise a major foundation of the present work for thinking about ethical features of science classrooms.

Constructivist Contributions

Turning now to the constructivist contributions to the present work, recall again that we are in search of an approach for understanding ethics in the science classroom, and which can accommodate both the pluralism and commonsense understandings of the science classroom. On such a basis, and in light of what has been said regarding constructivism earlier, it is tempting to suppose the desired approach should be one constructed, at least conceivably, by members of the classroom community themselves[26]; on their own terms, so to speak. In other words, suppose we look at the ethical approaches presently at play in various classrooms. Would we find a model for thinking about ethical features of school science generally?

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[25] The range of conceivable, possible ethical situations of course extends well beyond these examples. They include, as suggested, all situations where the understandings caught up in those situations implicate views regarding what's better or worse in human conduct. This is wide territory indeed!

[26] To emphasize the conceivable as opposed to actual construction of an ethical approach is meant to acknowledge the temporal and evolving nature of classroom practices. It does not mean to suggest that "anything goes" so long as a conceivable possibility exists, however small, that the option in question may come about. Rather, it is to emphasize the inescapable role of projecting sought-after ends as part of formation of ethical understanding (and understanding in general). For it is a basic feature of forming (ethical) understanding that a person projects possibilities by drawing conclusions about what follows from what. In the present effort to account for ethical features of school science, the fact that conceivable possibilities are projected as a matter of course in forming ethical understanding, is used to argue for a (prescriptively) constructivist account as what's best suited to the classroom, given the diversity of classroom participants and the cooperation implicit in classroom practices. Cf. the discussion to follow, and Rawls (2005)

The answer is that we *might*, but that this way of thinking is misleading. For we have so far left out a crucial feature in how to think about the relevant ethical features in the science classroom. This feature is *authority.* With few exceptions, were we actually to look at school classrooms, one of the chief observations in relation to ethical views we would make is the following. Only *some* ethical understandings are accommodated, while most are not, and it is the *teacher*—as the primary authority in areas of classroom management—who by role is in charge of deciding which understandings are allowed.

What this means is we need a further way to distinguish ethical approaches. On the one hand we are still interested in approaches that stress pluralism and commonsense understandings. But on the other we are now interested in approaches that distinguish the very different scenarios where: I) the types of ethical approaches that *would* be constructed in the classroom *if* participants were all similar in terms of level of management authority; and II) the types of ethical approaches that would be constructed in classes when primary management authority belongs to teachers. In effect, since classroom authority is a key consideration, and this authority is bestowed on teachers by virtue of their role in the *public* institution of the school, we are now concerned with a *political* choice in selecting an ethical approach for the science classroom.

It is at this stage that the work of John Rawls will be helpful. Rawls as a thinker is very complex, so I will restrict the discussion here to his views on political constructivism and 'public reason'. Rawls (2005) begins his discussion of constructivism by contrasting his constructivist conception of political justice with what he calls a comprehensive moral doctrine. The example he gives of a comprehensive doctrine is moral intuitionism, which holds, among other things that truth in moral matters involves

a moral order that is independent of human activity, and that moral knowledge is gained by a kind of perception of this truth (cf. pp. 91-92, op cit). A constructivist political approach, by contrast, is one where "the principles of political justice (content) may be represented as the outcome of a procedure of construction (structure)" (p. 93) and where instead of perception of truth, *conceptions* of relevant objects (e.g. a view of justice or, as we'll see below, ethics) are *produced* as a matter of practical activity.

For Rawls (2005) the importance of constructivism lies in its tie to what he calls 'public reason.' "In a democratic society public reason is the reason of equal citizens who, as a collective body, exercise final political and coercive power over one another in enacting laws and in amending their constitution" (p. 214). The core idea is that public reason is the result, when suitably worked out, of extending the basic idea of agreement between citizens who are free and equal, to the structure of society itself. Indeed, Rawls' argues the view of justice-as-fairness is itself the result of carrying through such a process. As citizens we are to envision that ideal representatives of our interests would select the principles of justice as fairness, were they suitably constrained so that decision-making was guaranteed to be fair[27]. Thus, the importance of constructivism itself is that it is defended as an instance of public reason.

We can now see how Rawls' ideas have been lurking in the background throughout the discussion so far on constructivist contributions to the present work. In effect I have sought to adapt Rawls' ideas on the **political** features of **liberal democratic**

[27] This ideal scenario is Rawls' idea of the 'original position': a device of representation to assist in conceiving of the agreement to the principles of justice so envisioned. To model the needed conditions for achieving this kind of agreement, representatives of citizens are portrayed as blind to the social and cultural location of those they represent (i.e. behind a 'veil of ignorance'). It is argued they would then choose principles that maximally benefit those who are least advantaged relative to others in society; (cf. Rawls 2005, p. 22)

societies, to the case of **ethical** features of **school science**. The question we now face is how to understand the role of classroom authority on the basis of some model of fair agreement; analogous to the one Rawls employs to argue for the case of societal authority.

By way of a possible resolution of this question, I propose the idea of *maximally public* ethical views for accommodating each of commonsense understandings, pluralism and teacher authority (in the ways these have been described, respectively)[28]. What this means is that the teacher, in their role as primary authority for classroom management, is responsible for managing the class so that the ethical understandings promoted by such management, under favourable circumstances[29], could persuade (non-coercively) other classroom participants. What are considered 'favourable circumstances' includes considerations of available time, willingness of participants to engage in a suitable discussion or process, and the capacity of those involved to view one another as capable of thoughtfulness and reasonableness[30]. Thus, the proposed suggestion is that teachers should *aim* at all times for ethical positions that, given enough time and patience among the parties concerned, the position would find agreement among other participants. In the

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[28] I.e. teacher authority in a democratic society where such authority is bestowed on teachers as representatives of the public institution of the school. Teachers in such societies are responsible for the same fairness in the face of differences in perspective among members of society as political representatives generally in such a society. Legitimate political authority on this view is authority derived from, and thus responsive to, citizens.

[29] Failing that, the parents of such individuals. The issue of when paternalism is justified towards younger members of society is a complicated one (cf. Strike, 1991). For the moment I assume that at least with students in the later years of high-school, they could be so persuaded under favourable circumstances

[30] Again I assume students (and in this case teachers) who are sufficiently capable of thoughtfulness and reasonableness that reaching agreements with others is at least possible in a range of circumstances. Failing this, considerations of paternalism likely apply, such that further parties must be imagined as needed to take the position of the one to be persuaded (or the one persuading) while assuming the interests of the person they replace.

ideal case where the teacher's ethical view or position could persuade without coercion a diverse group of students *generally*, the view is said to be maximally public[31].

With this further idea on board, let us consider briefly what kinds of broad ethical approaches may be ruled out when aiming for maximally public views in the classroom. Most notably, narrow ethical approaches focusing on a single ethical view to the exclusion of others are likely excluded from consideration. Obvious examples are positions motivated narrowly by self-interest, and those belonging exclusively to a religious or other metaphysically exclusive perspective (for example, that 'humans are a scourge and our extinction should be promoted'). Additional, slightly less obvious examples may include specific ethical theories, such as utilitarianism, deontological approaches, virtue ethics, feminist approaches and environmental ethics approaches. In each of these cases, notwithstanding the merits of the respective approaches in other circumstances, if and when the approach in question implies commitment to ideas or views the argument for which is insufficiently public (i.e. can't be argued in ways that are persuasive when the other doesn't already share core pieces of the view) it is not a maximally public approach.

Should one of these approaches, for example, be chosen as the approach underlying classroom management in a given science classroom, one could always envision societal members for whom the reasoning implied was simply unintelligible based on the background understandings they hold, and irrespective of what efforts at

[31] It is an important question to what extent the hypothetical scenario generally described here is ideal, or rather could be expected as something a teacher might be called upon to achieve. For present purposes we need only support the case that teachers are responsible in their ethical views for positions that tend towards maximal publicness. To what extent they are further responsible to provide reasons when called upon to do so by a student or class—or even as a matter of regular teaching practice—must be left for future consideration and study.

argument were undertaken. Such partisan ethical approaches on this account are considered *private* ethical views, in that those who hold them would be unable to persuade diverse others generally. For the only way such agreement could reasonably be envisioned to occur is if those others already shared enough background understandings to make the view readily intelligible. But in such case the diversity of a pluralist society is not present, contrary to the original hypothetical suggestion.

Two possible misunderstandings about the importance and role of maximally public views as presented should be addressed to avoid confusion. First, it might be supposed that on the view suggested teachers are expected to emphasize those ethical views that are maximally public with respect to a *particular* class at hand, or even consult that class (say through discussion) in determining what is maximally public. Neither is the case. Like the hypothetical scenario employed by Rawls (the 'original position'), in developing his account of justice as fairness, envisioning what is maximally public ethically for society as a whole is intended only *hypothetically*, or what he calls 'a device of representation'. It is a way to *imagine* what might be called for, *given* the high degree of pluralism of society as a whole. As such it makes no specific reference—or claim—to particular classes or whether teachers should consult classes regarding student views. Its purpose rather is to help think through what is justified in terms of teachers' ethical authority in the classroom.

Second, it might also be supposed that aiming for maximally ethical positions as a teacher rules out positions that may be ethically right and extremely important for society, but which are minority views that don't have wide support among society's members. This again is a mistake. Recall the emphasis is not on what society's members

actually *believe*, but rather on what could be envisioned to *persuade* them. Rather than emphasizing actual agreement with a sufficiently large subset of society, the emphasis on maximally public views is on what could be *reasoned* for using non-exclusive (i.e. 'public') reasons and arguments. So, for example, should an ethical position be available the reasons for which can reasonably be envisioned as convincing to most people in society, but who at present currently are ignorant of those reasons so do not hold the view, such a position is still maximally public on the view described here.

In conclusion, aiming for maximally public ethical approaches in the science classroom thus offers a powerful criterion in questions of justification surrounding teachers as ethical authorities. Combining this criterion with the earlier work of this chapter regarding implicit versus explicit ethical understanding, and the pragmatist and constructivist contributions for the study as a whole, we have in place needed foundations for the framework of practices and understandings to follow in the chapter to come.

Chapter 3: Practices and Understandings

Chapter 2 offered an overview of the scope of the issues we're interested in, and the start of a proposed framework for addressing them. In many ways this overview was a sketch: its main purpose was to set the conceptual foundations and scope of the issues raised by the research questions as they arise in the problem areas of school science teaching and science education research. The combination of research questions and problem areas produce the 'problem space' of the study. This problem space is neither simply the science classroom, nor simply a theoretical space that researchers discuss and think about. It is rather a combination of specific issues of ethics and knowledge construction arising in the science classroom, and intellectual resources for addressing these issues. The present chapter proceeds to flesh out the framework begun in the previous chapter, by anchoring this framework in a view of understandings and practices. On the view presented here, practices, as we'll see, are the organizing frames within which human activities involving understanding occur. Their organization derives from the characteristic understandings, rules, and characteristic aims, emotions and projects that are part of those activities.

Why Practices?

In the last chapter several important points were introduced that are seen to motivate a need for a view of how understandings are situated. It is towards meeting this need that the present chapter will develop a view of *practices*.

First, we are interested in *understandings* of classroom participants in ethical areas, as opposed to more strictly formal treatments of ethics, which often retain only vague or

abstract relations to actual activities of participants in a given setting. Ethical understandings, unlike ethical theory, need to be situated by reference to what specific groups of participants think and do in particular situations. Practices are a way to describe the relationships between what people understand—including, significantly, understandings underlying action—and the context within which they understand. Second, we saw in the previous chapter that constructivism as an approach to ethics emphasizes not only what people actually do but questions of authority and what *should* be done; (e.g. in response to the question 'what is best for me to do in this situation?'). A view of practices offers a way to describe the relationships between conceptions of possible behaviour, context and behaviour itself of classroom participants. Third, the contributions to understanding often come from multiple sources, including personal experience and reasoning, friends or family, experts, and institutional authorities. How these various contributions to understanding together comprise a given understanding is a task of a view of practices to make clear. Finally, the *history* of a given setting can matter to what understandings arise in that setting. Capturing the contribution of temporal features of understandings arising in the science classroom is made possible by a view of practices.

Practice therefore is a way to include in more than just a passive sense the *setting* or *context* of understanding. 'Context,' as we'll see, refers to much more than just a physical setting such as the science classroom. When referring to understanding, context may involve at once ethical, epistemic, social and institutional contributions. Moreover, these contributions are not inert. To the extent activities depend on understanding, and understandings are specific to particular contexts, practice as context shapes the agency of thought, speech and action. It is with the aim of explicating this rich sense of 'context of understanding' that the view of practice developed in this chapter is presented. Once

in place, the account of ethical constructivism, begun in Chapter 2, for addressing issues of ethical authority in the classroom, can be completed by setting it within a view of ethical understandings and classroom practices.

Given the central role of practice theory in this work, a significant part of this chapter to follow involves an overview of prominent contemporary theories of practice. This overview makes apparent that the motivation for thinking in terms of practice may arise from a number of directions. To speak of practice in terms of 'context of understanding' is only one option among others. The motivations for thinking of practice along such lines here are the promise of conceptual clarity and ease of application to the context of school science classrooms. But in terms of situating this choice in relation to other possible views, it remains important to explore briefly other ways of framing this key concept. And not surprisingly, how to approach the role of 'understanding,' as we'll see, goes hand in hand with the approach to 'practice' overall.

Habitus as Generated and Generating Dispositions: Pierre Bourdieu

French sociologist Pierre Bourdieu is widely cited as a forerunner of practice theory. Beginning with *An Outline of a Theory of Practice* (1977), and developed at length in *The Logic of Practice* (1980), a major theme of his work has been the question, "how can behaviour be regulated without being the product of obedience to rules? " (p.65). Concern with this overarching question arose initially for Bourdieu in response to what he sees as the main failure of earlier structuralist approaches to social theory, which is to suppose the social world is explained by stating the rules in accordance with which social practices are allegedly produced (Bourdieu, 1990, p. 76), a set of approaches he terms 'legalism'. Suggestive examples of such approaches as applied to classroom practices would be to describe classroom activities of teachers and students as somehow

determined necessarily to ensure the reproduction of economic and social divisions within society according to the rules of an economic and social theory; or to fulfill the biological or psychological dictates of self-interest, again according to a specific theory; or to embody a structure of meaning-making that seeks inexorably to specify new experiences in terms of a theory of existing understandings. In each case a rule is understood not only to explain the social practices and behaviours in question, but in fact in some way to 'produce' them.

Bourdieu's alternative to the tendency of structuralist approaches to account for agency within human activity by descriptions of social structures and rules, is what he calls *habitus*. Rather than social location, class, race, or gender producing this or that social behaviour, it is the habitus—"the system of structured, structuring dispositions" (Bourdieu, 1980, p. 52)—that by constituting practices in the majority of cases, acts as the mediator of practical activity. The habitus of an individual or group can thus be understood as both objective and subjective, in that the dispositions that define it are inculcated over time in response to objective conditions, and yet give rise continuously to novel experiences by *selecting* from the manifold of possible experiences what thereby become meaningful for the individual or group in question.

In Bourdieu's (1980) words:

> The *habitus*—embodied history, internalized as a second nature and so forgotten as history—is the active presence of the whole past of which it is the product. As such, it is what gives practices their relative autonomy with respect to external determinations of the immediate present. The autonomy is that of the past, enacted and acting, which, functioning as accumulated capital, produces history on the basis of history and so ensures the permanence in change that makes the individual agent a world within the world. The *habitus* is a spontaneity without consciousness or will, opposed as much to the mechanical necessity of things without history in mechanistic theories as it is to the reflexive freedom of subjects 'without inertia' in rationalist theories (p. 56).

It this way one incorporates what appear as opportunities on the basis of what is in fact a prior propensity in that direction, established over the person's history within a corresponding field of possible activity. But since the world presents "ever-renewed situations" as a result of infinite possibilities to appropriate new events (always according to some *strategy* of one's habitus) the necessity of habitus is never final or fixed. On the contrary, social behaviour on Bourdieu's view is never simply acting according to rules, in the sense in which a rule is seen to dictate or explain behaviour, but instead a match between the entire history of a habitus and its continuation in a new situation. For this reason the "rules" of habitus—what Bourdieu calls the 'logic of practice'—are best understood by analogy to the "feel for the game", where actions arise spontaneously and without conscious deliberation.

What then, on Bourdieu's account, is the role of rules, laws, reasons, and other conscious or deliberate accounts of behaviour that appear to stand behind and give rise to practical activity? Bourdieu understands each of the foregoing as examples of the codification, formalization or rationalization of practice. "To codify means to formalize and to adopt formal behaviour" (Bourdieu, 1980, p. 78). It is an "operation of symbolic ordering", the aim of which is to reduce or eliminate the vagueness or uncertainty that otherwise defines practical activity. It is at this stage that linguistic utterances and thought processes that were previously inextricably embedded in habitus become standardized through classification and categorization. This results in new 'logics' that separate out from the logic of practice by becoming rules and criteria for how to proceed or act within the field of activity in question. The nature of logic for Bourdieu is thus tied to abstracting from practical activity descriptions and accounts of practice, to allow the practice to be commodified and normalized.

Codification as such is universalization of features of practical activity. This occurs most generically in extending the scope of communication. But importantly, for Bourdieu no such process of formalization is wholly innocent in representing practical activity, since in each case it carries the "force of form" itself, the effect of which is to make legitimate what is so formalized, simply by becoming codified as what the practice in understood to entail.

Based on the foregoing analysis of practical activity it becomes clear why a major motivation underlying Bourdieu's account of habitus and practices is a concern with the practical activity of researchers working in social theory. On Bourdieu's account, the very process of giving an account of the practical activity of others is self-legitimating, by articulating means with which to assess such activity. It thus leads necessarily to misrecognition of the subject of research by failing to appreciate and account for the *researcher's* own practical activity. Indeed, on Bourdieu's view, the best one *can* do as researcher is *maximize* the objectivity of one's research, and never completely, by investigating the sources of objectivity. These include, importantly, one's own stakes as researcher. Without such an account of its sources of objectivity, social science research is forced to remain but the perpetuation of the social structures that gave rise to the research in the first place. Rather than describe the social worlds of research subjects, it instead embodies the social world of research*ers*.

Language Games: Ludwig Wittgenstein

Wittgenstein's concern over his philosophical life to articulate precisely the limits of the sayable and language generally make his work especially suited to the current aim to explore practice theory and its relevance for science education. For given the reliance on language within science education in seeking to offer accounts of the natural world, a

close look at language is clearly in order. Moreover, given the evolution of Wittgenstein's ideas over the course of his life, from an early commitment to viewing language as representation to his later views of language as behaviour, his views are instructive for the continuing reliance on representational views of the natural world within science education. While it is important to note the difference between representational approaches to the natural world and representational approaches within language, to the extent scientific statements are statements *of* language Wittgenstein's work is seen to apply equally to both.

Wittgenstein's philosophical work as a whole can be said to involve the question of how language is capable of connecting to the world outside language. The primary difference between the early and late work concerns the ways in which language is understood to connect to the world outside language. In the *Tractatus Logico-Philosophicus* (1921/1974) Wittgenstein took for granted that language was representational, such that the truth of a proposition depends on the correspondence between the proposition and what is described by the proposition. The so-called 'picture theory' of the proposition holds that the form of the proposition (the logical relations of its syntax as spelled out in Bertrand Russell's propositional calculus) corresponds to the form of reality pictured by the proposition. Names of objects are the logical 'simples' from which complex propositions are built in conjunction with logical relations between names. Names thus come to stand for the objects of the world through the application of propositions.

By assuming such a correspondence between language and the world outside language, the logical structure of language is understood in the early Wittgenstein to underwrite the capacity of language to make true claims of the world. In other words a true proposition is one that corresponds (one-one) to the world. The consequence of this

for his views on philosophy—and all uses of language in fact that do not belong to natural science—is great. For that which concerns the overall totality of things (i.e. as described by science) cannot be *said.* The reason is that to do so requires language, and as a matter of principle there is no way to get outside language and still speak. Even to formulate questions concerning the world as a whole (the totality of facts) is a mistake, since this too requires language. This leads to the view that philosophy, along with other uses of language such as poetry and ordinary language—i.e. to the extent they are not scientific—are concerned not with describing the world but with *showing* the limits of the sayable. Even to speak of objects on such a view, strictly speaking is a mistake, since the concept of object only arises *within* the proposition, resulting from the logical syntax of names; and since names are simples (the logical 'atoms') they cannot themselves be expressed by propositions, but instead must *show* what they signify.

A further feature of the *Tractatus* is that facts and values on this view are strictly opposed. Values in the *Tractatus* play the role again only of expressing something that cannot be said directly. The nature of ethics as such for Wittgenstein during this period is parallel to that of logic: both are transcendental in being outside what is sayable in rational discourse, and confined therefore to what can only be shown. The difference however, is that logic expresses what is unsayable in the relation between language and facts of the world, whereas ethics expresses the unsayable in the relation between facts of the world and the meaning of the world.

In the decades following the *Tractatus* (Wittgenstein did not publish another major work during his lifetime) the correspondence or representational view of language was given up. The posthumously published *Philosophical Investigations* articulates a view of language as tied to behaviour within language games, which in contrast to the earlier view, involve no sharp boundary or correspondence between language and the world

outside language. Instead, both the truth and meaning of language are now understood as derived from *the uses of language within a language game*, which have displaced the proposition in becoming the new unit of language according to which language makes contact with the world. The analogy to games is that language games, like games, cannot be clearly delineated using rules (i.e. there is no single definition of what a game or a language game is) but instead are distinguished only by family likeness. In addition, language games like games have no overall purpose outside of which they are directed. Rather, the diversity of language games means that only in special cases is there some *aim* to which language is directed, such as, for example, 'the communication of thoughts'.

Examples of language games given by Wittgenstein (1953/2003) include obeying and giving orders, describing the appearance of objects, giving measurements, constructing an object from a description, reporting an event, speculating about an event, forming and testing an hypothesis, presenting the results of experiments in tables and diagrams, making up stories, acting plays, telling jokes, guessing riddles, acting plays, thanking, cursing, greeting and praying (§23). Consistent with his overall position Wittgenstein illustrates the notion of language game using examples such as these, rather than offer a detailed definition. Analogous to the role of logic and the structure of language generally in his earlier views, the language game is the structure by which we describe the world in the first place. We cannot, as such, describe the nature of a language game in turn except by illustration, for to do so presupposes a position outside *all* language games, which on Wittgenstein later views is impossible.

Articulating Intelligibility: Theodore Schatzki

Theodore Schatzki has adopted and extended Wittgenstein's ideas on language and understanding in the direction of a theory of social practices broadly conceived. The key features of Wittgenstein's work that Schatzki adopts are two-fold. First, there is earlier mentioned relationship between meaning, truth, and the use of language within a language game. Since meaning and truth in general attach to language games, rather than smaller units such as propositions, the sayings and doings of a language game as a whole take precedence over the individual sayings and doings comprising the language game.

Secondly, there is Wittgenstein's view that the states (Zustandes) of a person's life—such as emotions, moods, doubt, belief—are *outer* episodes expressed directly by behaviours-in-circumstance. They do *not* correspond to states of a mental realm or substance. Though there are of course inner episodes on Wittgenstein's view—which include pains, images and seeings—the identity of these episodes derives directly from knowing (i.e. not being able to doubt) one is in that state. They are for this reason not mental *objects*, since there can be no gap between the observer and what is observed. Moreover, any inspection of these states—i.e. beyond simple awareness—depends again on outer, publicly available criteria[32].

The point is that awareness of sensation, as an *image to oneself*—in contrast to a genuine description, where an object exists against which to compare the picture—can do no more than express the *form* of language used in describing these states publicly. (The reality of the sensation itself is *mute*, so to speak). And given that identification of the sensation depends on the language game within which it plays part, the sensation in effect is not genuinely the source of its expression in language. As Wittgenstein puts it: "What

[32] This is a result of the famous 'private language' argument

I do is not, of course, to identify my sensation by criteria: but to use the same expression again. But this is not the *end* of the language game: it is the beginning" (Wittgenstein, 2003, p. 290). By this Wittgenstein means to point out, among other things, that it is not pain but rather *pain-behaviour*—including expressions of pain—that gives rise to language games using the word 'pain', and through which pain becomes something we recognize as 'pain'.

It can readily be seen how these features of Wittgenstein's work lay an impressive groundwork from which to develop a theory of social practices. Together they point in the direction of a view of understanding and action as tied *in principle* to features of embodied life that are neither simply individual (because tied to language that is *in principle* social) nor subject to conscious formulation and control. With these starting points of Wittgenstein's in place, we are ready to explore Schatzki's developments of these ideas, whose originality comes largely from having systematized Wittgenstein's observations[33].

On Schatzki's view practice refers to a manifold of human activities that are interwoven in particular ways in space and time, or what he calls a "dispersed nexus of doings and sayings". It is the *organization* of behaviour-in-circumstances—the linkage that weaves the behaviours of doing and saying together—that defines practices and is responsible for their role in governing actions. Without the linkage binding sayings and doings into a unified structure, doings and sayings would not be practices. Moreover, they would not be the doings and sayings they are as part of practices either. For it is the organization of practice that makes a given collection of doings and sayings particular doings and sayings, or in other words gives them identity. The same wave of a child's

[33] Wittgenstein's own reluctance to systemize his work (or for that matter theorize generally) belongs to his view of philosophy as concerned only with rearranging what we already know through a study of its logical or grammatical form.

hand for example, may constitute saying good-bye in one situation, and trying to get attention from a parent in another. Practices on Schatzki's view therefore are both *unifying,* as well as *constituting* of the doings and sayings that comprise them.

Practices are thus widely encompassing of human action generally on this view. To do or say in circumstances is already to participate in some practice. Not all practices however are organized in the same way. Schatzki divides practices according to the manner in which the activities in question are linked together. Practices which are relatively simple, and which occur across a variety of contexts are *dispersed practices*, whereas practices involving a more complex and distinctive organization are *integrative practices*. Questioning, responding, describing, sitting, smiling and watching are each examples of dispersed practices, and the activity in question plays a part in a wide range of other activities. Dispersed practices, as such, do not constitute a unique domain of life. By contrast, cooking practices, farming practices and teaching practices are examples of the more complex integrative practices, and the activities in question in each case define a particular domain of life activity. To perform any of these activities (i.e. to cook, to farm or to teach) will necessarily involve a host of more basic dispersed practices.

As suggested, what distinguishes a dispersed practice from an integrative practice on Schatzki's view is its manner of organization. Thus the way in which doings and sayings are linked defines not only what constitutes practice in general, but its measure of its complexity as either a dispersed or integrative practice. So how are activities linked in forming a practice? Organization of practice is seen by Schatzki to occur along three basic dimensions[34], which according with the complexity of the practice, may or may not be present in a given case. The three dimensions of the structure of practice are: 1)

[34] Schatzki (2002) adds a fourth area by breaking the dimension of understanding into practical understanding and general understanding. For the purpose of the present discussion this added distinction is more than we need.

understanding; 2) rules; and 3) teleoaffective structure. We'll deal with each dimension in turn.

Understanding for Schatzki is first and foremost the ability to carry out a particular action, to perform the X-ing in question (e.g. describing, teaching, smiling, responding, etc). To *do* these actions is to understand them. Two additional forms of understanding build from this most directly practical form. These are the ability to identify and to attribute X-ings, and the ability to prompt and respond to X-ings. These 'propositional' forms (identifying/attributing and prompting/responding to X-ings) are said to build from the earlier form of understanding (simply X-ing) because without the latter the propositional forms cannot get started. This does not mean propositional forms of understanding cannot detach themselves from nonpropositional forms, such as when a person understands X-ing without prior experience of X-ing him- or herself. What it means rather is that nonpropositional understanding is seen as what sustains the other forms, and in general cannot be completely formulated in the more explicit forms of propositional understanding.

Understanding as a dimension of practice is thus three-fold on Schatzki's view. And as mentioned, what distinguishes dispersed practices from integrative practices is that dispersed practices are linked typically by understanding(s) alone. Describing, questioning, pointing, etc., are unified *as the activities they are* by the understandings they express. In the case of integrative practices however, for example teaching or cooking practices, the situation is different. Rules and teleoaffective structures provide additional linkage organizing these practices. Let's explore briefly the role in Schatzki's approach of these further dimensions of practice.

Rules on Schatzki's view are *explicit* rules, instructions, principles, laws, regulations, etc. belonging to a practice. These structure activity both consciously and

unconsciously whenever one does what the rule, etc. enjoins. Teleoaffective structure on the other hand, refers to the order of ends, purposes, beliefs, and emotions that structure more complicated practices. For instance, within teaching practice "to assist students" can be described as a complex hierarchy of tasks and projects, emotional commitments and beliefs structuring what teachers in general do, and is thus constitutive of the practice. In contrast to explicit rules the teleoaffective structure often remains implicit in practice, only becoming visible, if at all, if something interferes with the anticipated flow of practice. Together rules and teleoaffective structure are seen by Schatzki to define the more complicated ordering constituting integrative practices.

I want now to piece together and summarize Schatzki's Wittgensteinian approach to practice. Practice on Schatzki's account is "a dispersed nexus of saying and doings". These sayings and doings, in Wittgensteinian fashion express how things are for those whose activities they are. In Schatzki's language, "behaviours-in-circumstances" express "how things stand and are going" for those involved. Moreover, these behaviours are the activities they are *not* because of the mental states of the persons involved, but as a result of the linkage between activities defining the practice. The same behaviour may mean very different things depending on the overall organization of the practice involved, which determines ultimately what is expressed in a given behaviour. For this reason, practices express "conditions of life", which is Schatzki alternative to Wittgenstein's use of the word "state" (Zustand). Conditions of life include all the many ways "things are standing or going" for a person: states of consciousness, emotions and moods, cognitive conditions, and actions. The crucial point is that these life conditions are expressed *directly* in the nexus of sayings and doings comprising practice. In important respects the content of these conditions does not lie elsewhere (in the head, from the context, etc.) but rather results from the organization of behaviour itself.

Reasoning and Representing: Robert Brandom

Robert Brandom is the first of the theorists considered so far whose work is situated squarely within contemporary analytic/post-analytic philosophical traditions. This means Brandom's work is concerned to contribute to current approaches within these philosophical traditions, particularly the philosophy of language, logic, the philosophy of mind, and epistemology. He is concerned to address these issues in the kind and degree of detail typical of approaches within these traditions. As a result Brandom's work includes a number of highly specialized and sophisticated arguments, many of which go well beyond the needs of the present discussion. In small doses however, what Brandom's work has to offer is extremely valuable. So even the following, somewhat superficial encounter with Brandom's work suffices to offer a strong foothold for conceptualizing classroom science knowledge on a practice model.

Two points of the foregoing discussion of Wittgenstein and Schatzki are helpful in beginning to consider the work of Robert Brandom. The first concerns the point just discussed regarding the relationship between language and thought. We saw that for Wittgenstein language and thought are mutually dependent on one another, in the sense that not only does thought inform language use, but conversely, the content of thought depends importantly for its definition on the sayings and doings of a language game. Such a *relational* view of the significance of language contrasts with either viewing the mind alone or viewing language alone as the locus of intentional behaviour. The second point concerns the way in which behaviours of saying and doing are seen by Wittgenstein and Schatzki to *express* "how things stand or are going", for those whose behaviours they are. In this case, rather than the *representationalist* (or Cartesian) view of mindedness, which views mental objects to stand behind intentional behaviour as their unseen cause,

the *expressivist* approaches of Wittgenstein and Schatzki sees mindedness as arising instead from the relationship between what is expressed explicitly in sayings and doings (including language *use*), and what remains implicit in behaviour.

Both the relational view of the significance of language, and the expressivist view of mind are important features of Brandom's *inferentialist* approach to reasoning and representing. Inferentialism, first of all, stands opposed to other ways of distinguishing the conceptual and the intentional. Inferences rather than representations (including mental states such as beliefs or intentions, as well as language representations such as names for objects) take over as the central features of concept-use, intentionality, and language on this account. Conceptual content is distinguished by its role in reasoning, as that which either serves as a reason or stands in need of a reason. To grasp a concept is to be able to distinguish what else one is committed to in applying the concept, what entitles one to such use, and what precludes one from such entitlement (cf. Brandom, 2000a). And whereas language-use remains a primary means to *identify* concept-use, one's behaviour will often imply a grasp of concepts which the person does not—or even in some cases *cannot*—articulate themself in language. Concepts as such are "inferentially articulated". Concept-use, moreover, is what distinguishes intentional behaviour from a mere disposition to respond in a particular way. One is intentional in performing a behaviour just in case *descriptions* of that behaviour are irreducibly tied up with concept-use and inferences.

So in Brandom's view, what is *expressed* are those features of behaviour and thought that can serve as both premise and conclusion of inferences: "Saying or thinking *that* things are thus-and-so is undertaking a distinctive kind of *inferentially* articulated

commitment: putting it forward as a fit premise for further inferences, that is, authorizing its use as such as premise, and undertaking *responsibility* to entitle oneself to that commitment, to vindicate one's authority, under suitable circumstances, paradigmatically by exhibiting it as the conclusion of an inference from other such commitments to which one is or can become entitled" (Brandom, 2000a, p.11). Propositional content therefore derives from inferential roles. To apply concepts by creating propositionally contentful assertions, beliefs and thoughts (i.e. "I believe that....", "I think that....") is to put into explicit form what otherwise remains implicit in thought, speech and other behaviours. To make explicit in this way is to put in a form that can serve as a reason or stand in need of a reason as part of inferences.

It is important to note that on Brandom's account the content itself of belief and thought—to the extent these contents are propositional—derives from the role of such contents in inferences. So instead of belief and thought states serving as explanatory givens (which on typical representationalist views of mind are then matched through correspondence relations with objects in the world), these items are themselves derivative from their roles in inferences. Inferential roles, in turn, are described by Brandom according to their *normative status*. The two species of normative status (giving propositional content to belief and thought) are *commitment* and *entitlement*, or what flows downstream as consequences of one's inferential position, and what lies upstream in positions to offer possible support for one's position, respectively. These statuses of commitment and entitlement are fundamentally normative on Brandom's view, because in order to assume a commitment (say, thinking that something is so and so) it is not enough simply to attribute a property, or in other words to *describe* thinking. One must

rather undertake or acknowledge what one attributes; one must, that is, take *responsibility* for it. The difference here is crucial for a proper understanding of both knowledge and truth on Brandom's account.

With this background in place, we can describe Brandom's view of knowledge. Knowledge on Brandom's account is a complex socially articulated normative status. What this means is that to identify what a person has as 'knowledge' we are actually doing three distinct things: 1) we are attributing to that person a commitment that can be inferentially related to other commitments; 2) we are attributing entitlement to that commitment; and 3) we are *undertaking that commitment ourselves*. These three practical attitudes are seen by Brandom to correspond to the conventional three conditions of knowledge specified by 'JTB' views of knowledge as justified true belief. On such views, to know is to hold beliefs that are both true and justified. By comparison to Brandom's view of knowledge as threefold social status, it can readily be seen how two of the three sets of conditions line up with one another. *Attributing commitments* is equivalent to *belief* on Brandom's account, whereas *attributing entitlement* is equivalent to *justification*. The truth condition however, is less obvious. On Brandom's account what one is actually doing when taking another's beliefs to be true is *endorsing* those beliefs. The *truth* condition on the conventional JTB view of knowledge thus corresponds on Brandom's account to undertaking the commitment *oneself* that one attributes to another. Since this involves a separate normative status, which, moreover, can be repeated by multiple members of knowledge community, it is available to underwrite a conventional view of truth as 'getting things right'.

It can be seen at this point that Brandom's account is through and through a social account of knowledge and truth. Indeed, given his commitment to a relational view of the significance of language, even to use *concepts* is already to form contents inferentially in ways depending on a social context. In light of this fact, and especially given the account above of truth as a form of endorsement, it may be asked whether Brandom's view can sustain a genuine account of objectivity. For it is widely recognized that tying knowledge to social factors prompts immediate questions regarding whether the account succeeds in describing non-social, *objective* features of the world. And though objectivity is presumably important for any view of knowledge, an account of objectivity is particularly important where scientific knowledge is concerned, in light of the defining focus of science on the external world (i.e. the world independent of human judgment). This holds true for *classroom* science knowledge also, given the dependence of the latter on scientific knowledge. So it is worth discussing briefly Brandom's account of objectivity before moving on.

Objectivity according to Brandom (2000a) involves the *possibility* of true claims about the world independent of claim makers: "something that could be true even if there had never been rational beings" (p. 203)[35]. On a representationalist account of knowledge, the independence of truth from truth-claimers is typically secured by the quality of relations (usually those of correspondence) between the world and its inner and linguistic representations in perception, belief, thought and language. The special significance of science on such views is in securing and maximizing the quality of such

[35] Another way Brandom put this is objectivity is a matter of *possible* endorsement of propositional contents, not *actual* endorsement (which in the absence of rational agents of course wouldn't exist). Elaborating this difference goes to the heart of very technical questions regarding the rational (i.e. not only empirical) structure, if any, to the non-human universe; and if it exists, the nature of such structure. Cf. Brandom (2000b).

relations between world and mind in terms of criteria such as accuracy, certainty, necessity or plausibility. The attractiveness of such views in many cases is the reassurance offered by attaching an account of causal necessity to an account of knowledge contents, whose certainty is thereby accordingly secured.

As we've seen however, such representational contents cannot be simply assumed. Brandom begins instead from study of how claims about the world are in fact *used*, which leads him to view inferences rather than representations as primary. The capacity to talk *about* the world is then the result of differences in social location or perspective. Given we each hold a different set of collateral commitments, so long as there are resources in language to separate *who* is speaking from *what* they are speaking about, interpreting what others mean by their statements requires distinguishing the act of saying from what is said. For what leads a person to claim their statements are *true* depends always on their collateral commitments. And as we as interpreters assess their statements we do so in turn from the perspective of *our* collateral commitments. What a person accordingly takes as true for an interpreter separates into that about which statements refer, and the act of referring itself. Objectivity on Brandom's account is for these reasons a *necessary* product of the social game of giving and asking for reasons and a sufficiently rich language (since such languages necessarily make the distinction between speaking and what is then said). Far from jeopardizing objectivity, the social dimension of reasoning and representing are what secure a grasp of objects.

Meaningful Configurations of the World: Joseph Rouse

Joseph Rouse has developed what he calls a 'cultural studies' approach to specifically scientific practices. As compared to the others discussed so far, Rouse's

approach is more resolutely naturalistic and post-humanist, in that agency of even the minimum degree necessary to respond to the behaviours of others, arises only *within* practices on Rouse's view, and those practices are understood as features of the *natural* (not just exclusively human) world[36]. Practices for Rouse (1996) are "meaningful situations or configurations of the world" (p. 30), but such that the meaning they make possible is not something *bestowed* by humans, as a result of some special responsiveness on their part, but is instead the result of the reiterated *history* of that activity. In this way practices are a more general feature of the natural world than is assumed by approaches that separate humans and the world they inhabit from the outset.

In *Engaging Science* (1996) Rouse lists 10 theses constituting his view of practice. Given the unique contribution his approach offers the present discussion, it's worth listing the full ten items. These are: (1) practices are composed of temporally extended events or processes; (2) practices are identifiable patterns of engagement with the world, but exist only through their continuation; (3) the patterns of practice are sustained through "norms", or what is taken as significant by members of the practice; (4) practices are sustained only against resistance and difference, and thus engage relations of power; (5) practices are open to continual reinterpretation; (6) practices *matter* by involving something at stake in practices; (7) participation in practices partially constitutes agency and agents; (8) practices are *meaningful* configurations of the world, i.e. within which intelligibility arises, and thus incorporate objects, bodies, and settings of action; (9) practices are at once material and discursive; and (10) practices cannot be confined within spatially and temporally bounded regions of the world.

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[36] This follows from Rouse's commitment to naturalism. However, given Rouse argues practices are also 'discursive' (cf. discussion to follow), what he means by 'natural world' clearly differs from more conventional approaches.

It will be noted that Rouse's 10 theses interrelate closely, and in many cases build from one another. Theses 1-3 are sufficiently similar to views already discussed to not require special attention. Starting with thesis 4 however, Rouse's view begins to distinguish itself strongly from the earlier views discussed. In light of the fact practices are sustained through what members of the practice *hold* as significant (Rouse's thesis 3), practices are seen to exist only against a background of resistance, which for Rouse (1996) includes "both the recalcitrance of things and the nonconformity of agents" (p. 140n27). Moreover, in light of the fact that the very identity of the practice is partly what's in question (thesis 5), such relations of difference cannot be construed merely as struggles between defenders of opposing practices. Relations of difference for Rouse naturally include relations of power, since power, similar to practices cannot be understood by separating the "natural world" from the "social world". This follows from the fact that effects of power include not only direct causal effects, but also how practices themselves are to be configured. Practices thus literally *incorporate* the very way in which objects are intelligible in practices, including everything from objects to human bodies and environmental settings (thesis 8).

The consequences of resisting a *simple* separation of the social and the natural worlds for understanding practices are far-reaching. Whereas Brandom can be said to have moved part way in this direction by making criteria of objectivity depend ultimately on the reciprocal behavioural and linguistic interactions of a community, Rouse rejects this view for its failure to appropriately acknowledge disagreement and difference. By instead placing reciprocal interaction of a community against a prior background of *differences*—that Rouse, as mentioned sees as basic in nature[37]—the result is that even

[37] Rouse (2002) more fully develops a naturalist view of action by drawing on Barad's account of *intra-action*. Barad's view is based on her interpretation of quantum measurement, arguing that the

agency and nonagency in a given situation are contested matters. Hence what constitutes the social according to Rouse cannot be assumed, for example along the lines of mutual recognition that Brandom envisions. Instead of the question of agency being decided either objectively or socially, 'who' are agents and 'what' are nonagents is itself decided by practices (thesis 7). As Rouse (1996) puts it: "The normative configurations of the world that emerge in practices must be understood as prior to any distinction between agents and their environment, the social and the natural, or the human and the nonhuman" (p. 146).

Thesis 9 extends these insights into the domain of language use. The point here is the same as we saw in the discussions of Wittgenstein and Schatzki on mental objects, signification and understanding. Recall that on such views the doings of a saying of a practice express *directly* how things stand or are going for members of a practice. The *identity* itself of such matters depends on the behaviours of expressing them. Another way of putting this is that in using language (for example to identify our sensations) the signification or what is picked out as intelligible, and the significant configuration of the world happen *together*. Without the signification made possible through language use, the sensations *themselves*—at least insofar as they have identity *as* sensations—would not exist.

Finally, with thesis 10 regarding the spatiotemporally unbounded nature of practices, Rouse is pointing to another lesson introduced above in the discussion of Schatzki. What connects practices one to another are not simply causal interactions of bodies, minds and

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boundaries of a causal system are themselves determined by their configuration in a given situation. This is seen to follow from the fact that "an effect is a 'measure' of the capacity of the cause" (p. 22). On this basis Rouse argues for a causal view of perceptual/practical intra-action: "[D]iscursive and other practical performances are not perspectives on the world from outside, but practical configurations *of* the world, which can only figure as such in the world as also partially configured by the sayings and doings of others" (p. 258).

surrounding objects in the environment, such that a more complete knowledge of neurophysiology, for example, would allow their determination. This possibility is barred on Rouse's account, for among other reasons that the constitutive norms that enforce a practice may well diverge in space and time from the causal constraints on that practice. So to continue the example, even if neurophysiology is spatiotemporally bounded, the contribution to the constitution of practice arising from what members of the practice enforce as norms, may well have very different spatiotemporal bounds. The always-open possibility of reinterpretation means the best that can be achieved in principle by accounts of practice seeking to eliminate a role for interpretation (and even this much is highly unlikely) is an account of *past* practice. The future by necessity remains open on Rouse's view.

Communities of Practice: Etienne Wenger

So far little attention has been placed in this discussion on what is unique about specific settings and practices, focusing instead on what defines practices in general. If we consider now the science *classroom* as the setting for teaching and learning practices, a feature that comes readily to light is the *community* of the classroom. Etienne Wenger (1998) supplies a framework for understanding practice in terms of "communities of practice". To begin, Wenger sees practice as "doing in a historical and social context that gives structure and meaning to what we do (p.47)". Key aspects of practice according to Wenger are "practice as meaning; practice as community; practice as learning; practice as boundary; practice as locality; and knowing in practice (pp.49-50)". Wenger elaborates each of these six features in detail, and together they comprise his view of practice—and his view of community of practice—since for Wenger practice is practice within a community (or ensemble of overlapping communities).

In suggesting ways of understanding the science class as a learning community, Wenger's account brings several features to light regarding the relationship between practice and community that otherwise remain difficult to recognize. Practice and community for Wenger are related along three dimensions: "mutual engagement, a joint enterprise, and a shared repertoire of ways of doing things" (p.49). It is well known from both educational research and teaching practice that successful learning and teaching frequently depend on the manner in which learning events are shared between students, or between students and teacher. So by spelling out these events in detail, Wenger's approach offers valuable tools for articulating concretely how even such basic educational activities as learning and knowledge formation arise as part of classroom practices.

It is useful to think of Wenger's approach to practice as a model for how to articulate in concrete, readily observable ways what it means to claim that learning generally is social learning within a community (or several communities) of practice. Wenger's (1998) detailed case study explores the day-to-day activities of claims processors. The most visible and concrete of their activities are explained in terms of the structuring elements of practice—meaning, locality, boundary, knowing, learning and community.

Practitioners: Donald Schön

Our final practice theorist for consideration is again focused on examples drawn from existing practices in the working world, which serve as the starting point for his theorizing. In addition, Donald Schön (1983) is the only theorist so far to approach practice from the perspective of practit*ioners* of various professions. The core animating idea in Schön's work is the crucial difference between what it is to know *about* or reflect

on action and what it means to know-*in*-action or reflect-*in*-action. While each are important in their own right, to overlook the special character of knowing-in-doing and reflecting-in-doing is to fundamentally misapprehend the nature of practical knowledge.

In contrast to familiar forms of knowledge such as one finds in texts or curriculum documents, knowing-in-action is what is displayed in the *performance* of a given activity. Given the opposition between these two kinds of knowledge, it may be asked whether there exists some middle area. It is here that Schön's view of reflection-in-action comes in. Whereas reflection-*on*-action is reflection taking place at a different time than the situation that is the object of reflection, reflection-*in*-action occurs in what Schön calls the "action present". The action present is defined as "the zone of time in which action can still make a difference to the situation" (p. 62). Reflection-in-action, occurring within the "action present" is a key feature of learning to overcome new or difficult situations.

Practices and Understanding

We can now outline the approach to practice adopted in the present study, which draws from each of the above views.

Practices on the view here, as Schatzki suggests, are organized sets of human activities. The activities belonging to a given practice include the characteristic ways of thinking, behaving (acting), and speaking in that practice. For example, characteristic ways of responding to questions asked by a teacher during class, chatting with neighbors, or completing odd-numbered exercises from a textbook might all be practices that science students participate in. What makes a collection of human activities belong to a particular practice is the organization linking those activities. Another way of putting this

is that activities of a practice, insofar as they are those activities and not others (or something else altogether), express the relations of the practice they belong to. Without such relations the activities in question may either lack specificity or lack distinguishing features generally.

Organization of a practice arises from understandings, rules, and the structure of projects, tasks and emotions belonging to the practice; (what Shatzki calls the 'teleoaffective' structure). Not every practice need have all of three kinds of organization, but all involve understandings. The more simple the practice, the more it may involve understandings alone, and thus lack rules, goals, projects and characteristic emotions.

Understanding is a grasp of connections between learning situations, conditions that contribute to those situations, and consequences that follow from those situations (cf. Brandom, 2000a; Dewey, 1938/1986). Understanding, furthermore, is a *conceptual* grasp of such connections, since understanding is always understanding of concepts. But in calling understanding conceptual, it should not be thought that understanding is (only) a cognitive or interior-to-the-brain grasp of connections belonging to a situation. Rather, understanding is expressed by the activities themselves, directly, insofar as the activities rely on those understandings for their intelligibility or definition.

Understanding, accordingly, is an *explanatory* concept. Since making sense of or explaining activities or behaviours where understanding plays a role, requires we attribute the understanding in question to the activity, understanding is said to explain that activity. Conversely without such an attribution of understanding the activity or behaviour would

not be recognizable as the activity or behaviour it is; understanding, again, explains the activity.

On the view outlined, since understandings are explanatory of behaviours and activities, understanding is not exclusive to conscious acts of understanding such as reflecting on an idea or articulating one's response to a question. Rather, many understandings are implicit in behaviour or activity insofar as the intelligibility of those behaviours or activities relies on the understanding so attributed. By contrast, explicit understanding is understanding that is the object of reflection or expression in language (and not always, significantly by the person whose understanding is thus made explicit).

To say that understanding is always understanding of concepts means to say that concepts are individuated according to grasps of connections in understanding. To grasp for the first time, for example, that electrons are sub-atomic particles, and thus that all atoms typically have electrons, will in ordinary cases contribute to the formation of a new concept 'electron'. Or grasping—while actually doing it—that by moving the pedals, balancing and steering at once, one rides a bicycle, constitutes possession of the concept 'riding a bicycle'. Concepts arise as one grasps—or infers—further connections to some event or state of affairs. And as the two examples show, understanding of concepts may run the gamut from purely intellectual understanding to practical understandings involving physical interaction with objects of different kinds. They are equally understanding—and conceptual at that—because understanding is an inferential grasp of connections between events or states of affairs as part of a learning situation.

In social contexts, understandings may typically involve a grasp of what others are doing. This allows new understandings to arise that are partly or even fully determined

by what others are doing, including their responses to one is doing. Language, for its part, is an unparalleled example of mutually responsive understandings. One of its chief roles is to provide means to articulate and form understandings that otherwise are not possible. Many understandings that are otherwise implicit in non-linguistic (or at least less obviously linguistic) activity can be made explicit through use of language. With this additional expressive power, many new concepts arise that simply could not exist otherwise, since there existed no way for the relevant conceptual connections to form.

In contrast to a conventional view of understanding as a cognitive grasp *preceding* activities done with understanding, understanding on the view described here is first and foremost a grasp of connections *in* activities of different sorts ('what leads to what' and 'what follows from what' in a learning situation). This difference arises, recall, because activities belonging to a practice depend for their definition on the understanding in question. Activities of a practice *are* the activities they are because of these understandings, so to attempt to conceive of choosing activities independently of the possession of the relevant understandings does not make sense. What is chosen under such circumstances can only therefore be some *other* activity, not an activity defined by possession of the understanding in question. New understandings, consequently, arise in doing, by grasping new connections to and from existing understandings[38].

Given the mutually responsive nature of understandings within a practice, in many cases understandings attain the significance they have within a practice only by virtue of how understandings are attributed to participants within the practice. One result of this is

[38] This still leaves open of course the question of how one forms one's *first* concepts and understandings, when no existing understanding are available from which to begin. This is a hotly debated topic. On the one side there is the view that certain concepts exist innately somehow in the infant mind. On the other is the view that all concepts arise only with language competence, and that all prior abilities of infants therefore are technically no more than response to stimuli, however complicated, and thus lack genuine understanding

that even in cases where participants are unable to specify themselves what they understand, understandings can be *implicit* in practice. The ability to say what one knows or understands is itself a specific activity—that expresses specific understandings—but is not a model for understanding generally. Rather, as described, understanding is first and foremost a practical ability, not some content that can be specified separately from the understanding in question. It thus appears that in terms of theory *versus* practice, pride of position is given to practical understanding. But this is apparent only. Rather, theory is itself viewed as a kind of practice, since even theoretical understanding is a practical 'doing' of grasping connections and making inferences.

Since understanding is not simply an *inner* grasp of some kind, as in models that see understanding as a manipulation of *inputs* to a mind, the variety of what is grasped in understanding is potentially large. Understandings may involve a grasp of connections between observational experience, other understandings one has had before, or the endorsement of others who are placed differently in understanding.

In addition to understanding, as mentioned, more developed practices generally include as part of their organization rules, and characteristic aims, projects and emotions. For example, in the case of learning practices in science classrooms, rules and characteristic aims, emotions and projects play significant roles in organizing activity. In addition to obvious cases of classroom management, examples of rules might include applications of formulae in chemistry or physics, lab safety procedures, or marking rubrics for lab reports. Projects and goals, for their part, might include everything from actual student projects and assignments to learning outcomes to final grades for the course. Finally, within every science classroom, there exist characteristic attitudes and

ways of feeling that define elements of the emotional landscape for participants. 'Openness to learning' or 'respect for others,' for instance, as descriptions of learners' emotional experiences in a given class, point to characteristic features of the emotional organization of learning practices of the classes in question.

In summary, understandings (i.e. an inferential grasp of connections belonging to a learning situation), rules, and characteristic aims, projects, and emotions, together define the organization of activities that comprise a practice. Understandings may be either implicit or explicit, depending on whether the understanding is subject to conscious reflection or expression in language.

To conclude this chapter, let us explore what the model of understandings and practices looks like when applied to ethical features of school science. To begin let us return to the constructivist and pragmatist approach to ethics laid out in Chapter 2. Ethics, recall, are specific views regarding what's best in the way of human conduct. Moreover, given the *public* status of school science classrooms, and what this entails for schools in general in the society, appropriate ethical approaches for endorsement by science teachers must be politically suitable. This means teachers must endorse views that are maximally public; that is, views that can be sustained reasonably from multiple positions of ethical commitment within the wider society. As much as possible, ethical positions endorsed within the public space of the science classroom, especially in cases where the teacher acts as an authority, should be suitably supportable by reasons that could persuade others in the broader society (according to a suitable hypothetical scenario, such as the one described in Chapter 2).

Ethical understanding is a specific instance of understanding generally. Namely, ethical understandings are understandings about what's best in the way of human

conduct. Grasping the implications of treating others in the classroom fairly, for example, when the issue is one of person-to-person interaction, is a matter of ethical understanding for those involved. Alternatively, the question of how best to dispose of chemical waste safely would be an example of ethical understanding that involves issues of treating others in *society* fairly. And so on. In each case ethical understanding is a grasp of 'what leads to what' and 'what follows from what' in situations where those understandings involve views of what's better or best in the way of human conduct.

Finally, ethical understandings, like understandings generally, can be either explicit or implicit, according to whether the behaviour they *explain* or *make intelligible* involves deliberate acts of reflection or expression in language or not, respectively.

Chapter 4: Case Study Methodology and School Based Research

Introduction

The current chapter presents an account of the methodology for the *empirical* component of the study, along with arguments for this choice of methodology. I remind the reader again of the role of this empirical component of the study: it is *illustrative* and *exploratory*. It is **not** intended to support empirical claims. Rather, it is meant to *illustrate* the conceptual framework developed, and to *explore* directions for future study.

With this in mind let us begin by recalling the primary research question guiding the entire study: 'How do ethical features of secondary school science relate to the construction of science understanding in the classroom?' As posed, the question admits of more than one approach to inquiry. Is an ethnographic approach that seeks to offer a rich account of local meanings most appropriate? Or do generalizable propositions that can be tested in the course of field research also play a part in the research design? Should the study be *more* or *less* interventionist?

The discussion of this chapter is broken into 4 parts: 1) Choosing the Right Methodology; 2) Case Study Methodology; 3) Defining the 'Case' and Propositions of the Study; and 4) Data Sources and Validity.

Choosing the Right Methodology

To begin it will be helpful to focus on the research questions themselves. This allows us to seek as far as possible in the questions themselves indications to guide

methodological choices. If we add to the primary question shown above the two secondary questions, the full set of research questions is as follows:

1) How do ethical features of secondary school science relate to the construction of science understanding in the classroom?
2) What, if anything, characterizes 'ethical inquiry' in these classrooms?
3) What do the specific interventions of this study, which focus on explicit ethical content of science learning and teaching, contribute to understanding ethical features of secondary science classrooms in general?

Note first of all that the primary question speaks of *relations* or *relationships* between ethical features of school science and the construction of science understanding. A significant assumption is already at work in this question, which points to the theoretical positioning of the study. In keeping with a theory of human activity that sees such activity to involve ethical aspects, which moreover contribute to the contents of thought and action[39], it is assumed that classroom activities include ethical contents. This starting point helps to clarify a point that is otherwise not explicit in the question: that the foci of the study are ethical contents whose significance includes significance *for* classroom participants. This stands opposed to contents whose significance is defined *without* reference to participants' activities, for instance by arguing for universal ethical or political significance, but where the connection to individuals remains abstract. With this in mind, an appropriate theoretical approach must specify the nature of the link between ethical contents and participants.

[39] Such theories of human activity are best characterized as non-reductionist regarding propositional or intentional contents of thought and action. What this means is that any complete account of human activity is seen to require normative vocabulary; (e.g. where intentional contents such as beliefs or thoughts are concerned, description in terms of physical or structural properties alone will necessarily leave out essential aspects of what is being described).

The approach here, in keeping with the discussion of commonsense understandings and pluralism in Chapter 2, is to employ a theoretical account of *understanding* as supplying the needed link between ethical contents and individuals and social groups. Ethical contents accordingly are contents of understanding. The proposed view of understanding furthermore is set within a theory of *practices* that encompasses both cognitive and practical forms of understanding.

What this means for research design is that ethical contents defined without reference to classroom participants' understandings do not qualify for a relationship of the kind specified in the primary research question. The study aims instead for a more concrete account of these relationships than is seen to be possible when ethical contents remain abstract relative to actual classroom participant understandings.

Given this focus, it is evident that the chosen methodology must include data sources that allow for an account of specific understandings *local* to the classroom. The prominently local character of the data suggests that a strictly quantitative study is inappropriate for this study. Qualitative methods are seen as necessary in this study both for adequate interactions with the research area, in a broad sense, and for adequate specificity within those interactions. The first point is primarily a question of the relationship between theoretical and empirical terms, whereas the second is a matter of the degree and form of research intervention required. Instead of seeking to isolate specific empirical terms, so as to quantify their role in the research questions, the focus on 'understanding' requires instead a holistic approach to empirical data. Specifically, 'understanding' (i.e. as characterized by the theoretical approach) cannot be manageably reduced to a set of empirical quantities, but depends rather on a complex mutual

dependency of a great many variables, which for all intents and purposes is intractable by approaches seeking to isolate independent contributions from different variables.

This makes the needed approach holistic in the sense of relying on interpretive methods and their focus on 'meanings'. Without wading very far into the philosophy of meaning (philosophical semantics) or its relationship to social science, it will noted that for our purposes meanings are holistic in particular ways. They cannot in general be reduced either to natural science descriptions, or atomistic meaning 'parts' below the level of language competence generally. Instead meanings depend on language 'wholes' such as triangulated relationships between self, language use by others, and world (Davidson, 1984); or relationships between language competence and conceptual understanding generally (Wittgenstein, 1953/2003; Brandom, 1994).

The specificity of the interactions required poses additional constraints on the choice of methodology. It should be clear that each of the three research questions aims at features of classroom science that would be difficult to engage by classroom observation alone. The type and degree of intervention is a question of seeking the most suitable data set for responding to the research questions. As an aim of research generally it is of course necessary to minimize those types of intervention that would obscure the focus of study (i.e. in ways that block further understanding of the research area). The type and degree of intervention instead must match the research aims.

In the case of the present study these constraints still leave a fair bit of latitude for how to proceed. In the direction of a rich ethnographic intervention, the advantage is to secure access to detailed inner-world understanding of participants who are the focus of the research questions. In the direction of a modified curriculum and set of lessons in the

study contexts, the advantages are—most notably—the less prolonged timeframe required, and to explore possibilities for making explicit understandings and practices of interest to the study. The preferred approach, as we'll see, is a balance of these two directions.

To achieve this balance in the present study of ethical features of secondary science classrooms, it is seen as very important on the one hand to preserve core features of the curricular and pedagogical approaches of the classes involved. Otherwise the findings are unlikely to pertain more generally to other science classroom settings and participants. This is particularly so given that as a researcher I am already an outsider to the classroom research sites. To retain some continuity to the issues of science education of interest here, the intervention cannot diverge too radically from existing practices.

On the other hand, in terms of the interests here in *explicit* ethical understandings and types of inquiry, as well as possibilities tied to the specific kind of intervention undertaken, it is seen as important to design an intervention that seeks as much as possible to make those issues visible and clear. In addition, while there is much of course that cannot be anticipated in advance regarding classroom outcomes at the design stage of lesson-planning, a diverse collection of classroom activities as data sources at least maximizes possibilities by avoiding reliance on a more limited set of data.

Finally, because of the considerable time limitations of typical doctoral research (and this project specifically), the kind of rich ethnography needed for in-depth learning about students' background and present understandings is largely ruled out. So despite the superiority of such an approach for any conclusive determination of students' understandings, of a sort that would allow a fuller empirical treatment of the research

questions, this option is beyond the reach of this study. Rather, what is available is to explore possibilities for future empirical study of the research questions. This means that *given* the limited timeframe for the project, the preferred methodology should include an exploratory dimension along the lines suggested.

From what's been said, the needed methodology is seen to require:

1) Qualitative study of few classroom research sites, rather than quantitative study of many;
2) A sufficiently rich involvement with the research sites to make possible a detailed reconstruction of relevant understandings of participants;
3) An intervention with sufficient continuity with existing classroom approaches to make possible (some) generalization to secondary science classrooms generally;
4) Flexibility regarding varying degrees of intervention at different stages of the study.
5) An exploratory component that looks at possibilities for future empirical research.

Case Study Methodology

With the above criteria required of the appropriate methodology in place, I proceed to defend the 'case study' approach as the preferred choice of methodology for this study. While other possibilities no doubt exist, what's needed is only that the selected methodology adequately satisfies the required criteria. Moreover, by comparison to other methodological approaches, case studies benefit from being (more or less) well defined, while retaining a high degree of flexibility. So for the remainder of this chapter the question to be discussed is "How does case study methodology make possible a convergent argument in response to the research questions concerning ethical features of classroom science?" By convergent argument I mean an account that draws

both from the conceptual framework presented and classroom field research in presenting a unified response to the research questions. I begin by exploring the nature of case studies as described by leading authorities in this area.

A high degree of agreement can be argued to exist in methodology literature regarding definitive sources for case studies. Judging from the number of citations, Yin (1994) and Stake (2003), respectively, are primary authorities regarding case studies[40]. In terms of guidance to the would-be case study researcher, the existence of two authoritative sources such as these is instructive, particularly if the sources agree on the nature of case studies. Unfortunately, they do not. Yin and Stake define case studies in somewhat different ways, each in accordance with the broad view of research they adopt, respectively. On reflection, this is expected. Given the place of methodology in debates over the status—epistemological, ontological, ethical—of knowledge and knowledge claiming, it is small wonder similar contentions arise in discussions of case study research. In the effort here to present the methodological approach of *this* study, I take advantage of this disagreement by seeking to define the preferred approach through comparison to the two sources.

Yin (1994) employs a multi-part definition for case study research:

1. A case study is an empirical inquiry that
   - investigates a contemporary phenomenon within its real-life context, especially when
   - the boundaries between phenomenon and context are not clearly evident.
2. The case study inquiry

[40] It is important to note both Stake and—especially—Yin have developed their accounts of case study research over the course of many publications. The choice of the specified publications here is made in recognition of the respective evolution within each author's work. It is well recognized, for example, that 2nd and 3rd editions of Yin's main work are substantially less positivistic in orientation than the original, thereby narrowing otherwise major differences to Stake's overall approach. Observed differences between 2nd and 3rd editions are much less marked along these lines however; hence the choice of Yin's (1994) 2nd edition as the focus here.

- copes with the technically distinctive situation in which there will be many more variables than data points, and as one result
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result
- benefits from the prior development of theoretical propositions to guide data collection and analysis. (p. 13)

Stake for his part states unequivocally that "case study is not a methodological choice, but a choice of object to be studied" (p.236). "As a form of research case study is defined by interest in particular cases, not by the methods of inquiry used" (ibid). Stake therefore defines case study research in terms of the selection of 'cases' and the interest in 'the particular' they express. For Stake a case is a bounded system, which means there are parts that somehow work together in constituting the system.

As suggested, the differences between Yin and Stake can perhaps best be described as differences in approach to research broadly. Whereas Yin remains explicitly committed to generalizability as a primary aim of scientific research, Stake sees investigation of particularity as sufficient for the explicit aim of case study research. In both cases however, as we'll see, it's a question of degree.

With Yin, case studies that seek no more than to describe the uniqueness of an object of study (the 'case' in Stake's terminology) are characterized either as exploratory or descriptive research. Exploratory research is preparatory for further research, whereas descriptive research refers to studies whose primary aim is not generalization but simply to provide a detailed research account of some kind. Even with descriptive studies however, Yin makes a point of highlighting how generalizability is what makes these studies valuable (p.4). So Yin is content to see particularity in research as ultimately subservient to generalizability, whether the latter is an explicit aim in each case or not.

For reasons such as these Stevenson (2004) characterizes Yin's approach to case studies as 'post-positivist'.

Stake's approach to case studies is in many ways the reverse of Yin on the issue of generalizability. While again allowing for a range of emphasis on generalizability, types of case studies are categorized according to whether the case is of interest on its own ('intrinsic' case study) or in terms of possible insight the case provides into an issue, or in the development of theory ('instrumental' case study). A 'collective' case study, finally, is an instrumental case study applied to more than one case. As noted, the emphasis throughout for Stake is on the particularity defining the case. Interest in the case itself is definitive in all three cases. What varies between the three forms is only the role of *additional* interests beyond that of the case alone.

With this brief account of the primary difference separating Yin's and Stake's respective approaches to case study, it is tempting to characterize Yin as one defending modernist values of clarity and universality, vis-à-vis Stake's more contemporary or 'postmodernist' values of positionality and recognition of differences. This comparison is sound, as far as it goes. In the end though, the scope of the comparison may be largely limited to differences of style. But within the bounds of preferences of style, and particularly as a researcher aiming to address what arguably is still the predominantly modernist setting of science education research, I find Yin's approach more defensible on pragmatic grounds.

This relates in part to the estimation there are good reasons to accept, and even extend, Yin's suggestion regarding the distinction of 'exploratory' versus 'descriptive' research. Specifically, many postmodernist approaches to research might usefully be

understood as exploratory, not simply with respect to respective research topics, but more generally in terms of the contribution to understanding within a given field. So while in some cases innovation involved in these efforts will no doubt play a part over coming decades in advancing understandings of 'research' broadly, such questions at this stage seem to remain for history to decide. For those who prefer less risky involvement in the 'advancement of knowledge' or, as the case in this study, address their work to more conservative research communities, siding (even if only stylistically) with approaches emphasizing the more conservative theme of generalizability is the better choice[41].

Thus, for the empirical component of this study Yin's approach to case studies serves as the main guide[42], while Stake's suggestion to remain attentive to particularity serves as an important caution to avoid unfounded or premature generalization.

Defining the 'Case' and Propositions of the Study

On Yin's account, the distinguishing mark of a study that benefits from the case study approach (i.e. in cases where other approaches would be less successful) is when "a 'how' or 'why' question is being asked about a contemporary set of events over which the investigator has little or no control" (p. 9). The primary research question makes evident that the present study fits these criteria. Specifically, we are interested in a

[41] Ironically, from the perspective of what is seen in the future to have 'advanced' understanding (assuming for the moment 'advancement of knowledge' still makes sense at that time), should it turn out that today's more typically postmodern approaches are found to have *resisted* the advancement of understanding, they would be correspondingly 'conservative' from such a perspective. Cf. Habermas (1984) for such an argument that some recent 'postmodern' approaches today are actually conservative, contrary to how they are often taken to be.

[42] In many ways the methodological description is *only* a guide, given the exploratory nature of the study. Since no empirical claims (and thus no empirical findings) are put forward, the methodological considerations of this chapter are (again) primarily suggestive of future research directions, rather than supportive of empirical claims. I repeat this point lest it appear I am making claims I can't support -- nor have intended to support.

"how" relationship between ethical features of secondary school science, and understanding construction in the science classroom. The events are contemporary—they occur in school science classrooms across today's world—and they are events over which little control is possible.

In terms of just *how* little control is possible, the second and third research questions are designed (in part) to explore this question. Belonging to the theoretical context of the study is the analysis in Chapter 3 of activities in terms of *practice*. As discussed there, an outcome of this analysis is that understandings are seen to underlie normative notions generally, including actions, beliefs and knowledge. Ethical features of school science are then particular instances of normative features belonging to practices, including classroom practices. So while practices of various kinds clearly overlap, the present study has as its focus *classroom practices of school science*, as a site of ethical understandings.

So the degree of possible control in the primary research question is itself a function of the classroom practices in question. For this reason, part of the research design for the study includes interventions designed to make classroom ethical content more explicit, as suggested by research question #3. This offers a basis of comparison with more typical instances of classroom science. In addition, since this stage of the study involves me in the role of guest classroom teacher, the range of observational data is considerably different than it would be with more passive methods. Through careful design and triangulation with other data sources, this more heavily interventionist component serves a key role in making possible a convergent argument for the study.

Research question 2, with its focus on *forms of inquiry* is designed to develop inquiry as a construct to situate within practices the varying degrees of implicit versus explicit ethical features of school science. Thus in terms of the theoretical view of practice developed, *inquiry* serves as a mid-level construct between practice and understanding: Construction of understanding occurs through a process of inquiry; and the distinguishing features of inquiry are the development of conceptual connections between an initially problematic situation and possible resolutions to that situation (cf. Dewey, 1938/1986).

With these understandings in place, which concern the broad role of the research questions in structuring research design, we may proceed to define the unit of analysis—or 'case'—and the propositions that are to serve as guides in data collection. The 'case' in this study is: "A set of sustainability lessons designed and taught by the researcher in a school science grade and subject community". Sustainability lessons and guest teaching of those lessons together comprise the 'sustainability education' focus for the study. For our purposes sustainability education is defined as educational approaches focusing on questions of what should be done (either by individuals or within society) about the future well-being of human and non-human life on the planet[43]. A grade and subject community includes all classes of students of a given grade and subject area, the teachers of such classes, and the characteristic interaction patterns that define participation in one of these classes.

[43] There is of course a large literature associated with 'sustainability' (cf. Huckle & Sterling, 1996). Even larger than this scope is the scope of references further abroad today making claim to sustainability. I hope to avoid contributing to what may be undesirable features of this band-wagon effect by keeping very clear on what I mean here by the term, and by suggesting a definition I believe shares essential features of how this term arises in some of the stronger work in this area.

This choice for unit of analysis arises directly from the discussion above of how the research questions structure the research design. The research questions, first of all, direct the focus to student understandings in the science classroom. But since we're also interested in specifically *ethical* understandings, and their relationship to science understandings, specific avenues for identifying and even eliciting these understandings are required. Conceivably this could be achieved either through analysis of existing classroom practices, or intervention of some kind into such practices. But in light of the further interest in exploring the role of *explicit* ethical understandings in classroom science, the ability to engage ethical topics deliberately through specific approaches to teaching and lessons is important.

Finally, given relationships described between understanding and practice, for me to *share* classroom practices with students through actual teaching and lessons of my own design, considerably extends the possibilities for identifying and describing student understandings, as well as for presenting relevant insights regarding science teaching. Without these shared relationships, the options along such lines would be significantly diminished. And as we'll see in the description of classroom research in Chapter 5, this role of self-reflexivity plays a key role in the account offered. For all these reasons "A set of sustainability lessons designed and taught by the researcher in a school science grade and subject community" is the appropriate definition of 'case' with which to study the research questions.

Having set out the definition of 'case,' let's turn now to the theoretical propositions for the study. The major purpose of these propositions is to structure subsequent data collection and analysis within the study (Yin, 1994). In this role they are

usefully thought of as conjectures that afford a degree of decisive empirical response, and as such can be said to encapsulate the research questions in more specifically examinable ways. A further purpose of the propositions, which indeed is their main purpose for this study, is to project ahead to future research possibilities. Because the empirical component of the study is intended here as exploratory of possibilities for future empirical research, the propositions are deliberately framed in ways that are likely to project beyond the present study. In this role therefore, they serve within the process of data analysis (of Chapter 5) to direct attention on interesting issues and themes arising from the study. Such issues and themes, while left unanswered within the present work, are collected (in Chapters 5 and 6) as findings in their own right, to await in-depth study at some later time.

So in summary, starting from the conceptual framework developed earlier, along with the accumulated expertise of the researcher, a set of propositions or conjectures have been developed which: a) respond to the research questions; and b) can potentially be supported or rejected on the basis of findings from either the present study or future research.

The set of Study Propositions is as follows:

1) Ethical understandings are inextricable features of science classroom practices;
2) Students' ethical understandings influence in specific ways the construction of those students' science understandings in the classroom;
3) Students' ethical understandings in school science vary in the degree of explicitness of sources of authority constituting those understandings;
4) The degree of explicitness in students' ethical understandings influences in specific ways the construction of science understandings in the classroom;

5) Students in classroom science attribute authority as part of their background ethical and science understandings in ways that preserve associations to their favoured views and individuals;
6) Students adopt the particular views they hold regarding the authority of science to help or hinder progress with sustainability issues based in part on the specific emphasis those views receive in science classroom practices they are part of;
7) Students' agency and sense of agency in addressing sustainability issues depends in part on the ease with which they are able to make explicit the sources of authority in their ethical and science understandings, respectively.

As suggested, the propositions are intended to serve as a form of linkage between research questions, the theoretical positioning of the study, and empirical data collection and analysis. They serve therefore as guides in the collection of *relevant* data, given that most *possible* data from the research sites is either irrelevant or incidental to the research questions and study. By seeking data that will either support or oppose the above propositions, the collected data should be capable of establishing a *convergent* argument, or in other words one that as much as possible is *conclusive* with respect to the research questions posed.

Case Selection and Data Sources

An overarching methodological strategy involved in qualitative research broadly is *triangulation*. Triangulation is defined as "the use of multiple referents to draw conclusions about what constitutes the truth" (Jackson, 2003, p.182). In the case of the present study, the aim of triangulation influenced the research design two ways: 1) in the selection of cases (quantity and variation between selected cases) and 2) in the types and quantity of data collected from each respective case. In each instance the aim was to

strike a balance between sufficient contrast for identifying relevant data, and sufficient emphasis within a case for allowing collection of that data.

With respect to the first item, given the role of contrast—not simply in cross-referencing—but *identifying* relevant data, multiple research settings were needed. The number and type of settings were selected to provide multiple sources of contrast. These included:

- Two school sites from markedly different demographic areas (both urban);
- Two grade/subject areas;
- Seven classroom communities in total:
    - Two classes of Biology 11 at one school site, studying Ecology and sharing a single teacher.
    - Five classes of Science 10 at a second school site, studying Genetics, and where:
        - three of the five classes share a teacher;
        - the remaining two classes share a different teacher; and
        - all five classes share an identical curriculum (for the class year).

It should be apparent from this list that a strategic design choice here was to employ a range of overlapping areas between settings. For example, all settings involved a distinct classroom community, yet because classes were included that have the same curriculum but different teachers, some option for comparison is possible independently for teachers and their respective classroom communities, and curriculum. This strategy extended possibilities for triangulation by varying data sources in multiple ways.

The principal data sources, in turn, were the following:

1) Curricular/pedagogical intervention with myself as curriculum designer and guest teacher;
2) Documents:
    a. Student work collected during teaching intervention;

b. Prior research studies pertaining to cases.

3) Pre-/post-intervention interviews of selected student volunteers (Biology 11);
4) Post-intervention interviews of selected student volunteers (Science 10);

The data sets supply a number of possibilities for triangulation of data. The ultimate aim of triangulation of course is to cross-reference data to establish a convergent response to the research questions. Doing so successfully however involves the entire process of data analysis: linking data to propositions and interpreting the resulting findings.

Site Selection and Choice of Interventions

It should be clear from the above that the principal rationale for the selection of sites and interventions arose from the specific research questions of the study, the definition of the 'case', and theoretical propositions laid out. It should also be clear that because the empirical component of the study was exploratory and illustrative rather than supportive of empirical claims, the selection of sites and particular interventions was not required to satisfy the same types of criteria as would be the case otherwise. For this reason, the main objective in selecting sites and particular interventions (guest lessons and interview questions) was to obtain a diverse collection of data, so as to provide a rich basis from which to explore the conceptual framework and future directions for study. With this said, the following items address the rationale for the selections made.

The school sites selected were chosen more or less arbitrarily, based only on an aim to select schools whose demographic details offered some contrast from one another.

The two schools selected were well known by teachers of the school district (including me) to involve considerable contrast socioeconomically and were chosen on this basis. Pending an interview with the principal administrators of these schools, respectively, access to and subsequent selection of interested or willing teachers was based wholly on their recommendations.

The rationale for organizing the interventions around the theme of sustainability was similarly straight-forward. Sustainability as an area is often defined to include both scientific and ethical considerations. Moreover, based again on my background as a teacher in the school district in question, I knew to expect high levels of engagement and interest from administrators, teachers, and most importantly, students. This made 'sustainability education' a natural choice for the design of the guest lessons.

Selection of the length and content of the guest lessons was based initially around the time requirements of the teacher whose classes I entered. In each case there were very specific constraints of available time and sequencing with other course content, which structured the possibilities for any proposed interventions in these classrooms. As might be expected, potentially relevant units for inclusion of a 'sustainability education' component were quite limited. 'Ecology' and 'Genetics' were chosen as obvious choices where an ethical component could be readily explored with students, but which meant very particular start and finish dates for the interventions, to fit with the existing unit sequences for the courses (and teachers) in question.

Lessons and interview questions were then designed to fit as much as possible with existing curricula, in terms of sequencing and building from earlier student learning. The focus of lessons and interview scripts around particular themes and questions (as

shown in Appendices 1-9; cf. pp. 183-217) were meant simply to engage students in a variety of ethical issues related to the topics at hand (e.g. Genetics or Ecology), in keeping with the sustainability education theme of these lessons. Given these selection criteria, it is worth noting that no claim is made here that other lesson content and teaching strategies could not also have served to achieve such an aim to engage student in ethical issues related to their science learning. Rather—again in keeping with the exploratory and illustrative focus of the study—the choice made was simply to build these lessons around topics *I* personally found compelling, and which I envisioned would be compelling for students also[44]. Of course, were more particular empirical aims expected of the research design, the freedom to select on this basis would be less justified on methodological grounds. But given the research aims of the present study it was an appropriate methodological choice.

Linking Data to Propositions and Interpretation of Findings

Connecting data to propositions is one of the more creative stages of case study research, for the reason there are no clearly defined methods for doing so (Yin, 1994, p 32). The overall approach adopted here is pattern matching (ibid, pp. 106–110), combined with generation of further research questions. As used in this study, pattern matching is defined as the iterated process of development of rival patterns and rival explanations, followed by analysis to support or oppose the proposed patterns and explanations in light of available evidence. For this component of data analysis the aim is to determine the degree of support or opposition for the study propositions outlined.

[44] From what's been said already it should go without saying that by personally compelling I have in mind, among other reasons, compelling in terms the conceptual framework, definition of the 'case' and theoretical propositions laid out.

But since the case studies here are designed not as explanatory but rather exploratory and illustrative empirical research, complementing this process of pattern matching is the generation of further questions to be researched later.

Beginning from the various research data, for each of the study propositions candidate patterns are proposed that either support or oppose, respectively, the proposition in question. Once an initial pattern is proposed and compared against evidence in the research reports, a further refining of the proposed pattern is attempted. So long as refining of the pattern is possible, the refined pattern may be compared with evidence anew, and the relationship between pattern and evidence reassessed. By repeating this process for each of the initial rival patterns, the aim is elimination of as many of rival patterns as possible. Successful support of a given pattern linking data to proposition depends in each case of the strength of available evidence, as compared to possible rival patterns.

As suggested however, based on the research design, conclusive confirmation or disconfirmation of propositions is neither likely nor expected. Instead, in situations where pattern matching reaches an end yet remains inconclusive with respect to a given proposition, further research questions for future study are then proposed based on evidence at that point.

Assessing Research Design: Validity and Reliability

Finally, to assess the overall success of the study, including both research design and the final report, several broad strategies were employed. These can best be discussed in the context of *validity* and *reliability*, which are standard criteria for research

evaluation (Palys, 1997)[45]. The relevant areas of validity for this study include two areas, so there are three areas total to be considered.

Construct Validity

Construct validity can be defined as how well theoretical constructs of a study correspond or refer to real-world phenomena they describe. In this study, the principal construct is 'understanding'. Given the centrality of this term for the study, the prospects of establishing a convergent argument vis-à-vis the research questions (whether supportive or not) depends in large part on the integrity of references to 'understanding'. Only by providing a compelling case connecting collected data to what are described as understandings based on the conceptual framework, can the needed argument go through. Without a compelling case to this effect, the study would be said to lack construct validity with respect to 'understanding'.

One of the two tactics for addressing this issue has already been discussed. This is triangulation involving multiple sources of evidence. For example, the interpretation of observed student behaviours, statements and activities to involve understandings should be consistent across the multiple sources of data for these observations. The second tactic, which so far has not been mentioned, is to involve key informants in the

[45] The choice to focus on validity and reliability as criteria of trustworthiness of the study may strike some readers as out of place in a qualitative study, particularly an exploratory study like the one here. On this question I defer in part to Yin's (1994) account of case study methodology, which provides a strong case for their suitability. I also emphasize again the projective nature of the study, in terms of *future* directions of research. Validity and reliability are thus meant as considerations for what *will* be important for that future research, combined with guides for how to think of the present (illustrative and exploratory) findings. As Yin makes clear, there is no necessary conclusion required by the conventional association of these terms with quantitative methodology. They can still usefully refer to the broad areas of methodological consideration they are meant to pick out, whether the study is qualitative or quantitative, exploratory or supportive of empirical claims. In each case the issue cannot be decided on terminological grounds alone, but rather must rely on the arguments for and interpretation of the chosen terminology. In terms of the role of these considerations in *this* study, their inclusion is felt to be adequately justified by how they are interpreted and put to use in the sections of the text to follow.

review and assessment of research reports. In terms of genuine informants, this option unfortunately does not exist for the present study, as the student informants who participated in the study were not available for consultation beyond the duration of the study.

But something at least very loosely analogous *is* possible. As a standard part of doctoral dissertation preparation the research findings of this study were shared several times with each of the three dissertation committee members, and more often with the dissertation supervisor. These members all qualify as 'experts' to varying degrees with respect to science education. They are thus eligible to serve as qualified informants of sorts—with respect to science classrooms and science education generally—in assessing the strength of the claims made regarding understandings in relation to the collected evidence. In enlisting them to this role, construct validity is better ensured.

External Validity

External validity concerns how well the findings generalize beyond the immediate case study. This issue goes to the heart of the most common criticisms of case study approaches, which take the form "How can one generalize from a single case or a handful of cases?" Given that such criticisms—which are all too common—fail to understand not only the case study approach but large areas of experimental science generally, it is important to clarify this issue. One source of this criticism was voiced by prominent social scientist Donald Campbell as follows:

> Case studies have such a total absence of control as to be of almost no scientific value.... Such studies often involve tedious collection of specific detail, careful observation, testing, and the like, and, in such instances, involve the error of *misplaced precision*... It seems well-nigh unethical at the present time to allow, as theses or dissertations .... case studies of this nature (Campbell and Stanley, 1963, cited in Palys, 1997, p. 302).

This is clearly a very serious indictment of case studies. Worse yet, Campbell's prominence as a social scientist gave it force[46]. While Campbell later recanted the criticism above (in keeping with a fuller understanding of the case study approach), many critics of case study methodology continue to express similar misgivings.

As Yin (1994) emphasizes repeatedly, the mistake made by Campbell and similar critics is to confuse the appropriate logic for case studies—what Yin calls 'logic of replication'—with that of a 'sampling logic'. The difference ties to the broader issue of analytical versus statistical generalization. In the latter case, generalization resulting from research aims at a population or universe to which the study sample belongs. By contrast, with analytical generalization, the aim is replication of expected findings in terms of some *theory*. Such replication can take either of two forms: prediction of similar results between cases (literal replication) or prediction of contrasting results, but for expected reasons (theoretical replication).

In this sense case study generalization is similar to any experiment whose aim is replication or testing of theoretical predictions, as opposed to studies that aim to represent a statistical phenomenon. So like with such experiments generally, so also with cases studies specifically: successful generalization depends on the strength of the overall combination of theory and data. To suppose all valid research must obey sampling logic is to mischaracterize grossly the variety of possible relationships between theory and data in research.

From this it should be more clear what external validity requires in the case of the present study. The success of the study in generalizing to classroom situations and

[46] Among other contributions to social science methodology, Campbell is responsible for the early development of quasi-experimental approaches as well as the term 'internal validity'.

contexts other than those studied will depend on a 'logic of replication'; how well in other words the theoretical approach and findings can be applied to correctly predict, explain, or simply facilitate understanding. For example, the validity of the generalization here regarding implicit ethical understandings in science classroom depends on how well the account applies to other instances of these understandings in other contexts. If in these contexts explanations of student activities in terms of implicit understanding so described give rise to successful prediction, this serves as prima facie evidence in support of the descriptions and framework in question.

Reliability

The final item for consideration is the reliability of the study's findings. Reliability refers to the possibility that other researchers could attain similar findings by conducting a suitably similar study. The main tactics for insuring reliability are to operationalize the key terms and to document the steps of the study, respectively, as much as possible. To operationalize in the broad sense used here means to make as explicit how key terms such as 'understanding' or 'practice' translate to particular empirical observations. As suggested earlier, this will depend largely on the success of pattern-matching in ruling out rival interpretations and explanations. So for both operationalization and documentation the aim is to leave open as little as possible to conflicting interpretations the steps taken in conducting the study.

Addressing reliability includes a range of considerations previously discussed. Framing 'understanding' so that referents of the term are as clear as possible and offering a clear account of research activities, both help to ensure reliability for the study. Finally, many of the classroom research materials are included here as appendices to the study.

Each of these factors is designed to ensure others could undertake a similar study and achieve findings consistent with those described here; thus, to ensure reliability.

Conclusion

The discussion of this chapter should make clear how a convergent argument regarding the proposed research questions is possible using a case study approach. The case is selected first of all to focus carefully the match between the research questions and the empirical unit of analysis (or 'case'). This selection sets and makes concrete the specific arena from which sources of evidence are to be drawn. Study propositions or conjectures are next developed to further assist and direct data collection and the subsequent analysis. These propositions are intended whenever possible to meet with either confirmation or disconfirmation based on the case study findings. But—and this point is all important to properly understand the exploratory component of the research—since the methodology in relation to empirical findings is primarily exploratory and illustrative, responses to the study propositions are expected to remain largely inconclusive. Rather, at this stage *new* research questions are generated to incorporate the lessons of the exploratory findings achieved thus far[47].

With this key point in mind we turn now to the empirical findings, and the directions for future research opened up in relation to such findings.

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[47] It is hoped that that the rationale is evident for how these proposed questions are seen to arise from the findings of the study. They arise similar to how research questions arise generally at the outset of a study. Based on the state of present understandings and interests in relevant fields, the researcher selects questions intended to address an area of needed research. In the case of an exploratory study however, the questions arising *from* the study are seen as further, more detailed elaborations of the original research questions of the study. They thus share in the original rationale for the study—now informed by exploratory findings—and do not require an independent rationale.

Chapter 5 – School Based Research & Study Findings

Introduction

The current chapter presents the principal findings of the empirical component of the study. In addition, as we'll see, a range of interesting directions for future work arise on the basis of these findings.

What follows below is first an account general to the two cases, of my own understandings and observations regarding the introductory sessions in each of the respective classes. (This self-reflexive component arises, recall, from the definition of the case.) As these understandings are common to all the classes in the two sites, I describe them together at the outset. The two cases are then discussed separately, for themes and findings that are particular to a single site, respectively. The chapter then concludes with a further discussion common to the two cases.

Background Practices and Understandings

The understandings of both students and teacher regarding what to expect of science classes generally, and their science class specifically, organize the events of the classroom. Students bring to the class evolving understandings of school, science class, biology, school authority, teacher authority, peer classroom socializing, student-teacher socializing and a host of understandings specific to the class itself. Ms. G., for her part, brings a long history (and attendant understandings) of biology and science teaching, understandings of public schools and Sir William in particular, understandings about

society, young people, environmental issues, world and local political issues, and a host of further understandings that come to bear on classroom life.

In addition to understandings, rules of various kinds structure what happens and can happen in the classroom. Typical school rules regarding acceptable behaviour are in most cases well enough understood by students to not require much reminder from teachers of individual classes. These rules and the implications tied to them give particular significance to various kinds of student behaviour. For many students 'school rules' are likely to reaffirm rules learned elsewhere, such as at home or in the popular media, involving matters such as treating others, and others' property with "respect". Further rules specific to Ms. G's classroom also structure behaviours, by again giving them particular significance. These include her individual management style, safety rules for a science classroom and laboratory space, and of course a multitude of rules specific to the subjects she teaches. Learning a subject area like Biology includes learning a host of conventions—for example rules of taxonomical classification, inheritance rules in genetics, the steps in the water cycle, geological time periods, and many others—which are equivalent to, especially for a new learner, 'rules' for the discipline. And as a scientific study, Biology learning also brings with it renewed, yet often evolving emphasis on conventional rules of scientific methodology, such as the 'rules of thumb' that science as a study employs experiments, reasoning, theories and/or hypotheses in reaching its conclusions.

In addition to understandings and rules, the third structuring component of the classroom practices of Ms. G's classes, are characteristic emotions, aims and projects, which also provide meaning and significance to what happens there. For students,

particularly those sharing a common attitude to a given class, or even school generally, characteristic feelings such as reluctance, boredom, excitement, challenge, surprise or discouragement contribute to making sense of how they respond and engage with events of those classes. Conversely, students and teachers who don't share such characteristic feelings are likely not to understand some behaviours or responses of these students. Similarly, one of the classes as a whole might at times share an aim—say to finish taking notes from the overhead with enough time to do something fun at the end of class—that gives sense to the pace and focus of a lesson on a particular day. Finally, projects will likewise periodically structure events in these classes. For instance, students come to understand the unique expectations and structure of "Project day' classes, including their focus on group work with less lecture time or notes.

Classroom Intervention

In beginning to work with the students at Sir William and Summit, respectively, each of the organizing features described in the view of practices in Chapter 3—of understandings, rules and characteristic emotions, aims and projects—together supply background conditions of the practices that I enter or initiate as guest teacher/researcher. Already from my first introduction to the class, these features open a space of possibility—both limits and opportunities—for what happens in the two classes. This space of possibility is the specific form of the organizing structure of practice; it is the structure of those practices either initiated or continued through the particular intervention I bring to the classes in question. It is therefore the counterpart to the earlier theoretical accounts, focusing now on actual interactions with students, on how my actions and statements in the classroom are received and responded to by the other

participants of the classroom practices. Some of these limits and opportunities of course are the same as those negotiated routinely in the act of teaching or science teaching generally, respectively. Others however are unique both to my particular teaching and science teaching, as well as the intervention itself, and all the ways it differs from typical science lessons and teaching; (most notably of course, in terms of a sustainability education component; cf. discussion below).

'Authority' as used in this study is a very helpful way to explore this space of possibility. Authority on the present view refers to the type and richness of understandings. To hold a view because the teacher says so, because one grasps the key evidence for the view, because the view will be tested later, or because it follows as a matter of deduction from something else held true, are each different on this account only according to the sources of authority of they claim. They are all nonetheless potential relations of authority for the view in question. As such, I focus the discussion below and throughout the chapter on themes of authority, as they were observed and understood to arise in practices and understandings of the two research sites.

Irrespective of the fact I enter the classes as a guest, I notice from the start I enter nonetheless as a "teacher" and "science teacher," (i.e., simply by virtue of guest teaching in a science class). Each of these roles is observed to carry particular relationships of authority for the class, respectively. First, as a teacher I find myself inheriting the management authority belonging in a particular way to teachers generally. This includes, among other kinds of authority, the power to consult the school administration. The powers of the administration to decide whether students can participate at the school, or when parents are contacted regarding their children's activities in the school, seems

understood by all students as within reach of the management authority of even a guest teacher like me. This type of student understanding is an ever-present and unavoidable condition of working within the schools. No amount of reassurance from me that students are encouraged to share freely will remove this feature of teacher authority.

In addition to the management authority of teachers generally, I am also aware of how I inherit features of management authority specific to *particular* classrooms. Relationships between the students and their permanent teachers are established prior to my intervention and persist in distinct ways throughout my involvement with the classes. These relationships are present in the moment-to-moment unfolding of events in the various classes. So, for example, during the significant portions of my teaching time when Ms. G. is in the room, management relationships between students and teacher which depend simply on Ms. G's physical presence in the room are correspondingly retained, whether in part or entirely. And at other times, insofar as students have *habits* of behaviour for the class, such habits often continue to hold sway even when Ms. G. is physically absent and I am teaching alone in the room.

Beyond issues of management authority altogether, the authority to evaluate students *academically* also usually belongs to teachers in general as part of the role "teacher". Here again I am conscientious of this contribution to my authority when addressing the students. In each of the classes I am involved with at the two schools I have been given full charge of student marks for the time we are together. So according to students' responsiveness to marks generally, I anticipate observing a similar level of responsiveness to this area of my authority. Experience as a teacher assures me this will be so; thus I remind myself to proceed with care at any time marks are mentioned or even

alluded to, so as to minimize the barriers for students' in expressing or sharing their understandings freely.

Next, as *science* teacher, statements I make in these classes early on *suggest* they are understood by the students as statements of scientific knowledge, with all the authority such knowledge holds more generally in society. I say *suggests* because it very much depends—both on the success *I* achieve in presenting myself in ways that convey authority about science to students—and quite separately, how *students* engage with the authority of science in society generally. I am aware from my experiences of science teaching that both are complicated issues. With respect to how I present as an authority regarding science, the question is in large part one of skill and background in (science) teaching, as well as specific interactions with the students in question. Background knowledge of science, presentation and facilitation skills, familiarity with these specific students' interests and concerns, responsiveness to their current levels of understanding and engagement with me and, not least, features of my personality, such as sense of humor, style of dress and use of language, all contribute to the degree of success I experience in conveying myself as authoritative for speaking about science to these students.

On the matter of how these students engage with scientific authority generally, it is again evident to me that such authority also depends on a complicated host of factors. In keeping with the theoretical approach, these factors are found to be well summarized in terms of *understanding* students hold for the authority they affirm or deny in science. Because understanding is taken as *explanatory* of behaviour, student understandings of scientific authority may be either explicit *or* implicit. I am able therefore to make sense

of situations where student behaviours show understanding but the students themselves don't seem able to articulate what they understand.

So, for example, I can imagine one of the students in these classes to hold—unconsciously, as it were—that science is authoritative overall because she trusts her father's views on science, and her father is a scientist. I imagine learning through interaction with the student that her conscious or explicit understanding appears to go no further than the statement she shares in class: "Science is the authority on this question". But since the connections grasped by the student as part of this understanding are learned to include inferential ties to her father, the trust she has in him, and his role as scientist, the understanding actually includes as the source of its authority, the authority attributed by the student to her father. The student's understanding of scientific authority and its tie to her father are thus *implicit* in these further statements or behaviours. In this way, although unconscious for the student (so not explicit), the understanding in question is implicit all the same in what the student says and does.

In assuming the role of a science teacher to these students, I am aware of inheriting a host of such relationships, through inferential connections the students hold in relation to the authority of science, and science teachers, respectively. Of course, in typical cases student understandings regarding the authority of science go deeper than only trust in the authority of influential others. The understandings of such students are then correspondingly *richer* understandings. Richer reasons for students to endorse or deny scientific authority are understood to include, among others reasons, which aims and roles of science the student takes as relevant when attributing or denying scientific authority; the evidentiary support and reasons (if any) they understand to stand behind a

given question of authority; and whether (and if so, how) alternative views are understood to stand in relation to that authority; (i.e. does the authority of the scientific view in question somehow silence or displace other deserving views). In light of the breadth of these issues it seems fair to suppose such questions likely run the gamut of analogous issues in science studies or the philosophy of science broadly. At very least one can say students' prior understandings of the authority of the science vary from richer to poorer, depending on factors similar to people's 'knowledge' of science generally[48].

Finally, beyond the issues of authority related to teaching and science teaching, I am aware of further issues of authority involved in opening for consideration and discussion with the students' questions of ethics and sustainability. While in many ways these issues overlap with the earlier ones, there are also some key differences. Like before my authority simply as a 'teacher' introduces a range of possibilities for how these students likely engage with what I say and do in the classroom. There will again be the risk that comments are given authority for no reason more than I say them. And at the other extreme there is again the challenge to present and engage students in ways that encourage richer understandings, so that whatever authority I *am* attributed by students, is based as much as possible on how I've promoted rich student understandings generally.

On the other hand, ethics and sustainability as topics are quite *a*typical for discussion or study at school. Thus the kinds of prior associations, understandings and underlying inferential connections are correspondingly different. Further, and even more

[48] Knowledge is here put in scare quotes to highlight the problematic nature of knowledge generally as a topic in philosophy and science studies. The suggestion is that difficulties in defining knowledge as they arise in these fields arise in analogous ways with the question whether students attribute authority to science legitimately or illegitimately. That said, I claim talk of 'understanding' as defined here *is* comparatively less problematic as a substitute for talk of knowledge, at very least at the level of sophistication needed for this study.

significantly, because with ethics there does not in general exist a similar type and degree of agreement as with science, or even most other school subjects (e.g. history, math, English, social studies), the relationship to widely recognized or agreed upon authority is very different. In effect it means that in the absence of such sources of authority, *teacher* authority must rely, if on anything, on something *other* than such sources. So I am often aware as I begin to speak with the classes, that without a source of widely agreed-upon conventional authority that could at least support agreements as a class, the emphasis of teaching is accordingly different.

To address this issue, instead of relying on a shared understanding as a class that strongly authoritative answers exist already, as typically the case with science learning, themes discussed are instead presented and emphasized throughout as fundamentally *questions*. The result is I encourage strongly the idea in these introductory sessions, that as students they will often need to think their positions through for themselves and in consultation with one another. In the process I am very aware that nothing quite like this exists in my past experience with science teaching. Because no expert authority or widely agreed-upon answers are available to underwrite the authority of subject matter understandings, I find myself constantly shifting the manner in which I am accustomed to presenting any authority of my teaching, so as to avoid suggesting, wittingly or not, that students adopt certain ethical understanding and not others.

So in summary, issues of authority I confront as I make introductions to the respective classes are clearly complicated. Students in the classes no doubt vary in how and why they give my teaching authority, if and when they do. At one end is what I hope: that students will tend to see any authority attributed to me primarily on the basis of

me serving as a capable teacher and spokesperson for topics discussed. This, as suggested, relates both to my success at presentation/facilitation, as well as how I present reasons of various sorts in support of my statements. It is moreover true whether the statements concern science **or** sustainability and ethics. In both cases my aim is for the students to consider views on their own merits[49]; and thus that they will be able to separate *what* I say to separate from the fact *I* say it. At the other end is the inevitable fact that these students will, or even in a sense *must* attribute authority to me at times because I am in charge of managing their respective classes and evaluating them academically in lasting ways. So I am in a situation where I have no choice but to confront on an ongoing basis in my involvement with these students the likelihood they may be compelled to treat statements of mine as authoritative because of *management* or *evaluative* authority, respectively, but separately from my authority as a *reliable spokesperson* on topics discussed; or in other words, because I am a reliable *teacher*[50].

Having considered concerns over authority many times as a teacher, I do my best to put the concerns out of my mind. I know well from experience their emphasis continues to be felt even then. So I proceed to give a brief introduction about me, my involvement in their classes over the coming classes, and the topic of 'Sustainability'. I outline that we will extend their usual science unit with study of 'sustainability,' which looks at questions such as 'How should we as individuals or as a society best address issues of human well-being, and the well-being of non-human life over coming years?'. I

[49] Merits no less, for them *personally*, as suggested.

[50] This is so notwithstanding that for many students—particularly those who are highly motivated to receive the highest possible evaluations from the teacher, both academically and with respect to classroom (management) behaviour—these areas of authority will be very hard to disentangle. This may be so moreover, not only for me as a teacher but for the student him- or herself.

elaborate the question by giving sample questions specific to the science unit under consideration for that classroom community ('ecology' in Biology 11, or genetics' in Science 10, respectively). I tell the students emphatically that with questions of this sort, by contrast to their usual science learning, "**There are no clear answers from science about how best to answer these questions. Instead we must rely on ethical understandings**".

This statement and the emphasis given are meant of course to address the concerns over authority described above. By inviting students to consider differences between topics which do, and topics which do not have clear answers, or even at times strong reasons or widespread agreement among experts in their favour, the authority is directed instead towards the students' own understandings and critical consideration. I hope to make clear from my frankness on this point that I expect students not to adopt views simply because I've suggested them. One often hopes as a teacher that such comments go without mention, but not least because I am new to these classes and seeking to discuss ethical topics, I take special care on this front.

Students in all the various classes are mostly quiet during these introductory sessions together. I am usually able to initiate only a small amount of discussion at this early stage, by prompting students to share what they understand already about the themes discussed. As I am very new to the classes, it would be odd to expect more than this. So I finish the session by proposing to students my interest in interviewing them, so as to learn more about their views on the potential role, if any, for study of sustainability in science education. I aim again to reassure them that nothing is compulsory and that

I'm only encouraging interested students to sign-up. Several students volunteer their names on a sign-up schedule sent around with times and location for the interviews.

CASE 1 – Ecology and Sustainability - Sir William Secondary

Introduction

The two classes of Biology 11 were notably different despite having the same teacher and identical curriculum. One class was comprised of a cohort of grade 10 students belonging to an enrichment program at the school. With few exceptions these students were academically inclined and presented few management issues as a class. While certainly at times social and talkative, no one in the class presented much of a challenge to the teacher's authority. By contrast, the second class was comprised of students enrolled in a non-enriched educational stream. Here the students were more mature (on average a year older) but also more exuberant as a class, making for different challenges in classroom management. In addition, because of a more pronounced range in scholastic interest or willingness among the students compared to the enriched class, several students in this class often seemed to show very little interest or willingness towards class content, or at times even the class as a whole. This presents the opposite hurdle to that of exuberance, compounding the management challenge: how to encourage the participation of every student in the class.

The teaching style of the permanent teacher, Ms. G, can be described as devoted, firm, skillful, charismatic, personable, entertaining, while at times abrupt and very serious. Frequent personal anecdotes intersperse her presentations of curricular content, as well as interesting illustrations and examples. Demonstrations involving scientific artifacts, biological specimens or other materials of interest to students, where the class

collects in a more intimate group around their teacher at the front of the room, are common in her teaching. She is generally very well-liked by students, not just for her humour and engaging style but for students' success in learning from her.

Early Student Interviews – Sir William Secondary

In the course of the early interviews[51], students were asked about their views of 'nature'—including what, if anything is **not** part of nature; how they have learned about 'nature'; the meaning of 'environment'; the meaning of 'sustainability'; any concerns they may have about environmental issues; the role of science in decision-making for different members of society in relation to environmental issues; their role *personally* in such decision-making; what else, other than science, may be important in decision-making involving environmental issues; whether 'ethical' concerns are important in societal decision-making involving environmental issues; the role, if any, for 'caring' in such decision-making; and what kinds of science education, if any, may be important for society to address in relation to environmental issues.

As can be seen, the topic territory covered in the early interviews was very broad. The overall design of the questions was to elicit student understandings around the intersecting themes of science understanding, ethics, and environment. Let's begin to explore some sample exchanges between myself and the students

> **Larson**: How important do you think science is when making decisions related to the environment?
>
> **Ann**: Very important. Science can also make a difference. I can't explain. … OK, like, science to me is a big deal, because without science we don't know, like anything, how to explain anything. Yeah, it is a big deal.

[51] See Appendix 1 (pp. 183-186) for the interview script and questions.

In this response considerable authority is attributed to science. While she struggles some to express what she means, the student even goes so far as to suggest science is *singularly* important in explanation generally. In relation to the research questions it would thus appear worthwhile to learn whether the authority so attributed complements or comes at the expense of various ethical views. Is the student for example inclined to treat democratic decision-making as less of a priority than ongoing scientific research? Or is science important rather as a contribution to such democratic decision-making processes? In effect, we are interested to learn the sources of authority for the student's understanding, or in other words on what basis she makes the suggestions she does.

As we'll see below, the questions that followed were meant in part to explore these various alternatives. But even with a range of responses from the student to the different interview questions, it was not possible to assess adequately the sources of authority in her various understandings in relation to the topics discussed. The task of making these understandings explicit went beyond the possibilities afforded by the research situation, in terms of what the student shared in her responses; (perhaps for reasons of comfort, or maybe simply because of difficulties of expression). And without the ability to assess the sources of authority in her understandings, I could not safely distinguish between what might be a rich understanding based in considered reasons or, alternatively, an impoverished understanding based in appeal to the authority of various influential people or ideas.

Here is a second student's response to the first question, and some of the exchange that followed:

Louise: I think it's very important, because the environment is the scientific structure you could say… So you have to have at least a base understanding of it in order to help... So you could think you were helping it when really you're just destroying it further.

Larson: How important do you think it is for people such as yourself to know about science when it comes to environmental issues?

Louise: Well they keep saying that we're the new generation… So I think it's very important. It's true that we're going to have to deal with everything that's left behind. So the more we know the better off we are.

Larson: Do you think human beings have certain responsibilities to help the environment?

Louise: Well, since we've destroyed it, yep. But I think it's pretty much beyond repair right now because so many species just have gone extinct because of our activities. Yeah, I think we have a huge responsibility. I don't think it'll be carried out. I don't think it'll be acted upon sufficiently. I don't think it *can* be now.

It is evident again that this student also attributes considerable authority to science in her responses. But it is again difficult to pin down the nature of these sources of authority in the responses as stated. Louise herself comments in her response that 'they keep saying that we're the new generation,' only to proceed to endorse this idea (i.e. of 'theirs') personally in the very next sentence. So it is fair to wonder whether the views she espouses in her responses come from associations she is making to influential ideas and people as opposed to richer connections she makes to support the views. A **p**otential **r**esearch **q**uestion encapsulating this query might be **PRQ1**[52]**:** "How do those school science students whose self-understanding includes belonging to a generation responsible for needed world changes, attribute authority to science in relation to this understanding?"

[52] Recall the rationale provided for these proposed questions; cf. p. 107, above.

To pursue this question and learn more specifically what comprises the sources of authority underlying Louise's and similar students' understandings would likely be possible only with a significantly longer timeframe of shared practices together. Such a timeframe of shared practices would be necessary in order to cross-reference a sufficient variety and number of the students' implicit and explicit understandings so as to locate more definitively the authority basis of their understandings. Without such a basis the sources of authority in understandings students such as Louise express by their statements remain largely indefinite.

There are however *some* more definitive understandings and relationships one can claim in relation to the exchanges looked at so far. First, the students in these interviews, independently of the exact sources of authority in their understandings, are nonetheless presenting ethical understandings in response to the questions posed. While this may appear to some as too obvious even to need comment, it pays to be clear about it so as to illustrate the possibility of more definitive empirical claims on behalf of the theoretical approach.

To see why these student statements express ethical understandings, despite indeterminacy in sources of authority, recall the definition of ethical understanding from earlier chapters. An ethical understanding is a grasp of inferential connections involving a view of what's better or worse, right or wrong in some area of human conduct. In stressing the importance of science when making decisions regarding the environment, Ann expresses a view that with respect to human conduct in areas of environmental decision-making, science plays an important, or even a necessary role. Contrasted with decision-making that doesn't include such a role for science, inclusion of science is thus

presented as ethically better, in terms of the range of possible understandings expressed by the student's response. Even to imagine, in light of the indeterminacy of interpretation, the student's actual ethical views are exactly opposed to those she appears to endorse, because of the necessary inferential connections between such hypothetical actual views and the one she states here, those views also would express ethical understandings of some kind.

Louise's responses, for their part, address the prospects of 'helping' the environment, along with issues of responsibility, whether of individuals, her generation or humanity generally. And again notwithstanding uncertainty in the *exact* sources of authority for such a proposed understanding, within definitive limits again the responses suggest only a range of possible understandings while excluding others. Since these possibilities in each case are tied inferentially to those issues of what is better and worse in human conduct appearing in the stated response, the student's response necessarily expresses ethical understanding of some kind. Analogous claims can be made in relation to <u>any</u> student classroom responses or activities, so long as the apparent understanding expressed by what the student says and does is inferentially or conceptually connected to actual understandings, which are based, as they often are, in hidden sources of authority.

A second more or less definitive finding in relation to responses such as Ann's and Louise's is that the responses express inferential relationships between ethical understandings and their respective understandings of 'science'. Issues of indeterminacy again arise in this case, and even seem to multiply, in terms of what these students understand by 'science,' whether when referred to by me or in their responses. It is clear on the one hand, for reasons similar to those just rehearsed, that the student's expressed

ethical understandings are not wholly separate from their respective 'science' understandings from school. We can observe this much from the inferential connections implicated between what the students express in relation to 'science' and what they express in relation to ethical understandings. But on the other hand, the authority attributed, often implicitly, variously to science, school science, science teachers, and different sources of ethical authority, again makes the attempt to clarify the *specific* sources of authority within these relationships extremely difficult. I am aware constantly during the interviews of difficulties in assessing and attempting to negotiate these connections to authority in students' understandings.

It is important to note that although these remain quite unsurprising claims, they are nonetheless significant in terms of the research questions of the study. On the one hand they make a clear case for the existence of particular kinds of ethical understandings, and relationships between these understandings and science understandings, for at least *these* science students (Ann and Louise). While no doubt self-selection of interviewees and the encouragement students' received from me to think about and share ethical understandings has contributed to the ethical understandings expressed, there is little reason to suppose science students generally do not similarly hold, at very least implicitly, ethical understandings with inferential ties to science understandings. Indeed, this conclusion is hard to avoid on the grounds simply that students must inferentially connect what they learn in science class with ethical understandings belonging to those classes, such as rules for permissible conduct in the science classroom.

On the other hand however, the specific understandings, as well as the degree and nature of interaction between ethical and science understandings, as mentioned remains critically underspecified, due to indeterminacy in how students attribute authority within the understandings expressed. Even with conscientious commitment on my part to support students' self-formed understandings, the reliance of their reasons on unexpressed and often invisible sources of authority, cannot be fully determined. It is in relation to this lack of determinacy that the exploratory component of the research comes to bear. It remains for future research to explore such possibilities.

In relation to practices, the understandings students hold organize the various practices they belong to, which are simply sets of activities. Surely had the students and I shared a class over the full year with me as the permanent teacher, the 'space of possibilities' for the interviews would be quite different. In such a situation there is little question a much greater mutual familiarity would exist between the students and me, supporting greater mutual understanding of one another's styles of expression, communication and ways of thinking.

But even granting this, there is no guarantee that given such a history, and the very different inferential connections fostered thereby to me as a *management* and *evaluative* authority that a new set of challenges would not arise. For we can surely imagine situations where were students actually to favour me as a teacher, say, even this could complicate the willingness or ability of some students to share understandings they felt might conflict with their teacher (me). Such pressures on students to please teachers are well known, and pose challenges for any attempt to separate the kinds of sources of authority listed above for student views. For such reasons a longer history of shared

practice, while clearly recommended for addressing the research questions, is in itself no guarantee for clearer or more in-depth sharing from students.

Notwithstanding these limitations, based on experience as a science teacher it is fair to suppose that like science teaching generally, to promote (in various ways) classroom practices where students were encouraged to reason and express their reasoning would in general contribute to both the richness of students' understandings as well as their abilities to share them explicitly. These are features of the type of classroom practices I can reasonably imagine sharing with the students were I their permanent teacher. Clearly for the research at hand however, in part because of the newness of the relationships, a higher degree of ignorance (on my part) about sources of authority within students' understandings was inevitable. It is for these reasons that future research aiming to improve on these limitations needs not only to extend the timeframe and shared practices between researcher and students, but focus within those practices both on what can be made explicit regarding relevant students' understandings, and what beyond this must remain even then implicit. A rich ethnographic study that is designed to track sources of authority in students' science and ethical understandings across many areas is thus recommended as the best option for such a research focus.

In summary, the response we are left with so far in relation to relationships between the two areas, is that although students' ethical understandings and understandings of school science no doubt interact, the exact nature of these understandings and the dependence between them will vary in accordance with the specific array of inferential connections the student in question holds. This in turn depends on the specific sources of authority within their understandings, which in many

cases is at most only implicit in what they say or do. That students are often unclear or inclined to conceal or remain reticent about just how they attribute authority is on this view an expected feature of the ways authority is structured in today's schools. And such issues are expected further to pose potentially even greater challenges with student consideration of ethical topics. For with much less by way of widely recognized conventional authority, there is much greater vulnerability to impoverished student understandings that are more about *who* holds a given view than the *reasons* that view may have in its favour.

As we go along in this chapter we'll see that these findings remain true in relation not only to the above student statements but for the many statements still to come in the chapter. It should be apparent that the findings highlight the relationship between students' participation within various practices (e.g. practices of classroom science learning, practices of media interaction involving science and/or ethics topics, and practices of discussion involving such topics) and their responses within the interviews. According to the complex webs of authority (evidential, management, evaluative, etc) within such diverse practices, so will follow the space of possibility for student ethical understandings, and thus also the prospects for making such understandings explicit in science education[53].

Before moving on to the classroom component of the Sir William site, there are a few other noteworthy interactions between science and ethical understandings expressed

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[53] Whether such prospects are desirable is of course a separate question. But judging from the often largely implicit ethical understanding implicated in many approaches to *management* and *evaluative* authority in science classrooms, there are reasons to wonder about the negatively impact on student *science* understanding by restricting students' opportunities to critically reflect on *ethical* matters. This is true independently of any further arguments in support of attending to additional ethical topics such as those studied here. Quite simply, it is fair to question whether the type and degree of critical questioning in the two areas, respectively, can be kept separate from one another.

by students in the early interviews. These included: that environmental issues facing society and/or the planet are both serious and important to address within society[54]; that there is a distinction between what is free of human intervention and what is not, which serves as a basis for what is 'natural' versus what is not; and that science is of central importance for decision-making in society—most notably for those in positions of political authority (e.g. ministers of environment), those responsible for others who are more vulnerable (e.g. parents), and those belonging to specific professions (e.g. farmers; teachers, doctors, and scientists). The students often expressed feelings of powerlessness in relation to any significant amelioration of environmental issues they could enact on their own. Avoiding littering, walking instead of driving, recycling, helping to educate others, and supporting wildlife protection organizations were typical examples cited of what they understood as within reach of them personally for enacting change or assuming more responsibility in regards to environmental issues.

These items further illustrate the breadth and range of students' ethical understandings in relation to the interview topics. There is little question that given other research circumstances the various issues raised by the students could be pursued in a number of interesting research directions. One particular theme along these lines that stands out is expressed by the question **PRQ2**: "How do science students' understandings of sustainability (science and ethical understandings, respectively) contribute, if at all, to their understandings of agency (personally and collectively as a society, respectively) in relation to sustainability issues?"

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[54] This was especially noteworthy given that nearly all students commented on it in some fashion or other, and because care was taken throughout to avoid suggesting in any way that we as a society *should* move in some direction as opposed to another when addressing environmental issues.

In terms of the organizing components of a practice, we have so far focused exclusively on understandings. The role of rules and characteristic aims, emotions, and projects in structuring practices has received little attention. This also is a limitation of the research design. In terms of their role in classroom practices these areas appear, even more so than understandings, to rely on a larger timeframe for definitive study. For each of: rules (classroom or school rules or rules of science learning); characteristic aims; characteristic emotions; and characteristic projects; much depends on what actually develops over time in the classroom practices in question. And certainly having spent as little time as I did with the students—compared to typical membership in a classroom practice—there was little opportunity either to develop clear relationships to these areas within new practices, or to observe clearly their role in existing practices.

It is thus again left for future study to explore relationships between these organizational contributions to classroom practices and the kinds of science and ethical understandings that arise within those classrooms. As a hint of prospects in this direction consider the following exchange:

> **Larson:** Can you give examples of what you think would help you and other students to learn about issues related to the environment in science class?
>
> **Harlan**: Just like, more discussion about it, instead of learning about all this unimportant stuff like DNA and stuff. It's important [but] it's not important to every single person. It's important to like maybe 2 or 3 people that are going to go on with it. I think we need to learn about stuff that is going to help our world more than stuff that's going to help 2 or 3 people. But there should be a science where you learn about just like personal issues and social issues about science..

Prior to the question asked, the student in question had elaborated a keen sense of concern for 'wild' environments, mentioning his frequent fishing and camping outings to

such places. The above comments shed light on what appeared typically as a very reluctant attitude towards the events of the classroom. The student was very keen to share what he thought could improve student experiences of science class; namely his feeling expressed regarding "stuff that is going to help our world".

In light of this example and the comments preceding, a potential research question following up in this area is **PRQ3**: "What is the contribution, if any, to students' science understandings resulting from a) providing forums for students to voice attitudes regarding science learning and issues of sustainability?; and b) incorporating suggestions when possible for changes to science teaching and learning arising from such forums?"

Classroom Guest Lessons – Sir William Secondary

The classroom guest lessons took place over a 3 week period, during which time I acted as the guest teacher of the class. The arrangement with the permanent teacher was for me to cover the ecology component of the provincial curriculum within the 3-week period, beyond which I was welcomed to use the remaining time for a 'sustainability education' component. In many ways the breakdown of class time for the two components was quite separate. Although, for example, study of the (required) ecological concept 'carrying capacity' led naturally to study of the related sustainability concept 'ecological footprint', this was a rare moment of integration of the two curricular foci. Beyond serving as mutually supporting areas, the required ecology component demanded separate class time and a separate focus from what then became a supplementary sustainability education component. This seemed to be a natural consequence of the relative priority of the two areas vis-à-vis the provincial curriculum.

The introductory session for the unit introduced students to the concept of sustainability and involved them in thinking about ethical issues related to sustainability. Sustainability was defined in two ways: first, as a study of possible responses to the question 'How should we as a society best address environmental issues?'; and second, in terms of the 3-legged stool model of sustainability that views sustainability as a balance in decision-making between ecological, social and economic aspects of an issue. Following this introduction was a brief discussion around what students understood by 'ethics', during which time I offered the simple definition that "ethics are matters of right or wrong, where if we say something is 'wrong' we mean one shouldn't do it".

The assignment to follow asked students to respond individually to a series of questions (see the handout in Appendix 2, pp. 187-189), then to pair up with 1-2 others and share those responses. The questions were designed to elicit student understandings and encourage student thinking on the themes 'nature', 'success' (as both an evolutionary and a more general concept) and ethical issues related to human-environment interactions. The class then concluded with a whole group discussion, where responses to earlier sections were shared as a class.

Responses to these questions—individually, in small groups and as a whole class—again demonstrated a range of student ethical understandings, and highlighted the organization of the practices to which these understandings belonged. In this case however, as with the classroom lessons and teaching generally, the participants included the entire class, and so the setting was more typical of usual classroom practices, as compared to the interviews. In response to the question "Is there right and wrong in nature? Why do you think so?" written responses from students included:

> "There's no right or wrong in nature, just as long as humans don't intervene" – Owen
>
> "I think there definitely is a wrong and right in nature, e.g., planting trees is right, cutting a lot of trees (wiping them out) is wrong" - Ming
>
> "I think so because right is when everything happens naturally—the way intended, wrong is something done to, or in nature artificially" – George

There is little question here that the responses above express ethical understandings, or that the understandings expressed are tied conceptually to other science understandings; for example, those related to 'nature'. In designing the questions, it was a deliberate choice to use language that admitted multiple interpretations (e.g. 'nature', 'science') so that students would be called as much as possible to take a stand themselves on how to understand the questions. This interpretational ambiguity prompted students to explore connections in understanding that otherwise were less likely to arise, such as connections to science understandings of 'nature'.

These science understandings, as described above, among other things organize practices of thinking about, learning, and studying science at school and elsewhere. Owen and George, for example, invoke a human-nature distinction; Owen and Ming in turn allude to the idea of balance in nature as a measure of what's ethically right; finally, George suggests the idea that what's 'artificial' is wrong. Each of these expressed understandings connects to a range of school science understandings, insofar as nature as a concept (at least in some of its senses) plays a part in various ways in school science.

Without doubt relationships to various sources of authority again played important roles here, along similar lines to those commented on earlier in relation to the student interviews. In whole class activities however, a further relationship to authority also appeared to arise. *Peer* authority in student understanding, or referring to what *peers*

are seen by a student to treat authoritatively, seemed for some of them a significant contribution to the responses they offered. As a facilitator/teacher, when understandings of this type seemed likely (as they were seldom explicit), I would attempt to encourage students to elaborate reasons for their understandings, in hopes of making more explicit the basis for the understanding. But as before, the limits imposed on such efforts by my role as a newcomer to the classroom, and one whose authority could also potentially obstruct possibilities for richer student understandings, significantly constrained such efforts.

Similar ethical understandings to those described earlier were expressed by students in response to the *next* pair of questions of the classroom activity: "Is acting ethically (i.e., according to what we think is right or wrong) as humans something that can possibly help nature? Can you say why?". Responses to the latter questions included:

> "No, people thinking ethically cannot help nature because that is tampering with the ecosystem, which causes more trouble than before" – Kyle.
>
> "No, because I don't really care because I believe that by the time disasters happen I'll be dead, and why not leave it to the next generation" – Bob
>
> "Acting ethically will definitely help nature. As humans we can decide what benefits all. As humans it is in our hands to know what isn't all for one species—to think about long term advantages or disadvantages" – Sara

In light of how widely terms like 'nature' or 'balance' or 'science' may refer, it is interesting to consider what further practices might stand behind student understandings in these areas. In addition to practices of learning and studying science, these questions seem tied for students to practices of thinking and reflecting on environmental issues and

problems. Within the limits of the roles I had available to me (that is, the 'space of possibilities' open to me in terms of practices I shared with these students) I was forced often to assume practices of such sorts were operating 'in the background,' as it were. Although I would often seek to better grasp these various background practices of students, their visibility was typically limited only to what was implicit very indirectly in what students said and did.

The responses of Kyle, Bob and Sara, above, along with the earlier responses of Owen, Ming and George, are positively ripe with interesting ethical issues tied to the students' science learning. In their respective responses these students showed no difficulty at all in engaging complex ethical and scientific issues. As we can see, these issues included among others the question of whether 'balance' as an ethical concept overlaps in important ways with a related ecological concept; or whether and to what degree human beings are 'natural' in relation to their capacities for major intervention in ecological systems (otherwise?) governed by natural selection; or whether and to what degree the timeframe of possible sustainability problems impacts the responsibility individuals have for addressing those problems.

It would therefore be interesting to follow-up in future on the kinds of topics raised in these responses. The following is a potential research question in this area:

PRQ4: "How does inclusion of educational content contrasting different understandings of 'nature' and 'natural' in relation to human activity and traditional ecological science, respectively, contribute to a) student science understandings; and b) student ethical understandings?"

Subsequent lessons continued many of the themes introduced above, culminating in a 'Sustainability Proposal' project which asked students to research a sustainability topic of their choice in groups, and present it to the class (see Appendix 3, pp. 190-191). The criteria for the project included a requirement that students address their topic from the perspective of each of three legs of the 'sustainability stool'—ecology, society, and economy—and to propose a group response for how best to address one or more issues in the topic area. In addition to a written proposal, the group presented their proposal to the class, where rotating groups of student respondents and judges offered informal feedback and evaluation of the proposals according to a loosely competitive structure.

The projects offered a further avenue for students to engage in ethical inquiry as part of a group activity that drew together science and ethical issues. It was hoped that a more extended opportunity for such engagement would foster a richer set of shared practices, in groups and as a class, for consideration of sustainability issues. To some extent this hope and the educational design it gave rise to were successful. There was little question that several groups engaged deeply with the issues, and took seriously suggestions to think through and supply support for (i.e. make the authority explicit for) claims present in their respective proposals.

Unfortunately however, there was also no denying that those groups who took the assignment most seriously, not just in terms of the written assignment but equally in terms of interest expressed during the group presentation component, were typically the same students who throughout were most conspicuously motivated by evaluation generally. Although there were occasional exceptions, where less obviously academically inclined students expressed high levels of interest in their sustainability

projects, overall the patterns matched the usual levels of involvement from the students in question. As a result of this pattern, it was extremely difficult to separate what was with the less motivated students a seeming *general* lack of involvement with science class or school, from more *particular* disinclination revolving around my teaching role or perhaps the project itself.

So it felt that here especially, with students whose ethical understandings and practices were likely among the most divergent with respect to popular attitudes regarding school authority[55], the capacity for me to share in student practices sufficiently to learn their understandings was significantly foreclosed, due largely (or so it seemed) to the students' inferential connections to the authority of the school, me as a teacher, and the assignment itself. In light of this observation, it would be interesting to study in future **PRQ5a**: "What correlations exist, if any, between science students' attitudes towards school and classroom sources of authority in general, and sources of authority underwriting curricular science topics?"; and the related question: **PRQ5b**: "What contribution, if any, does more explicit separation of classroom management and evaluation authority from sources of authority underwriting curricular science topics, have on students' science understandings?" It is quite likely for example that for students who are particularly averse to authority generally the seeming ethical understanding required in accepting school authority structures, interferes with science learning in cases where the authority in the two areas for them is insufficiently distinct.

[55] 'Popular' is here meant in the sense that the school administration and many teachers would likely promote as an appropriate attitude for students in relation to the authority of the school and teachers.

Later Student Interviews – Sir William Secondary

The same students from the early interview were asked later to participate in a second interview, following my involvement in their class as a guest teacher for the unit "Ecology and Sustainability". The theme of the later interviews extended the topics of the earlier interviews, but with a greater emphasis on the possible role for sustainability as a topic of school science education. By this stage I'd established relationships with the students over the course of the 3 weeks in their classes, which in turn contributed to the degree of familiarity between the students and me in conversation. It was hoped this shared history as part of common classroom practices presented new possibilities for discussion, and understandings made explicit therein. However, for the same reasons as have been discussed already, the effort to clarify sources of authority in students' understandings continued to pose challenges. These challenges included seemingly non-negotiable features attaching to implicit sources of authority (particularly my own) within student understandings, and significant difficulties in sorting out implicit and even hidden sources of authority in such understandings.

Below is a sample exchange from the later interviews[56]:

> **Larson:** Do you think that knowing science makes someone more likely to act in ways that are 'good'? Can you say why you think so?
>
> **Louise:** Well can you say first what you mean by 'good'. I think it makes them more likely to. But I think it doesn't mean they necessarily will. [K]nowing science and all the things I've been taught so far, I still go out and buy stuff that's overpackaged. I'm not helping the environment anymore than anyone who doesn't know as much as I do, so... And then there are people who know more than I do definitely—probably almost everyone. [M]ost people don't seem to be the more environmentally friendly, and they don't seem to have that lifestyle. I think it's more likely to make them act in a way that's good, but it won't necessarily make them do so.

[56] See Appendix 4 (pp.192-194) for the interview questions/script.

As we glimpse here, similar to the earlier responses the later interviews again demonstrated, not at all surprisingly, student ethical understandings, relationships between these understandings and students' science understandings, and some of the challenges and possibilities with making sources of authority in these understandings more explicit. The findings from these interviews only repeat what has already been said, so receive little discussion here. Although the increased familiarity and shared prior history together in the classroom (however limited) contributed *some* to the capacity to trace sources of authority underlying students' responses, these sources still remained sufficiently indeterminate to represent little advance in this direction over the early interviews. Given that the purpose of a second round of interviews was to probe *deeper* into science students' ethical understandings—rather than to assess *changes* in those understandings resulting from the intervention—that changes in this direction were slight suggests a different research design is needed to achieve this aim.

The above exchange with Louise is included here, not for additional gains it makes possible in responding to the research questions, but rather as an example of particularly interesting student ethical thinking. Louise appears to make explicit an understanding that despite *scientific* understanding of harms to the environment arising from particular human behaviours, this in itself is no guarantee of improved *ethical* activity in relation to those behaviours. Through the use of a personal example she demonstrates a solid understanding of the distinction between what one knows and the *will* to do something differently based on this knowledge. It would be interesting to pursue this distinction further in relation in student understandings. A potential question in this direction for possible future study is the following: **PRQ6**: "What features of

sustainability education programs most stand out in contributing to students' self-understandings of their agency in relation to sustainability issues?"

We now proceed to explore the findings of Case 2.

CASE 2 – Genetics and Sustainability – Summit Secondary

Introduction

The duration of this case was significantly shorter than that of Case 1. The guest teaching component itself lasted only two classes, and interviews were conducted following these classes, over a course of two weeks. As with Case 1, the topic ('Genetics and Sustainability') was selected to fit within existing curriculum. But in contrast to Case 1, the provincially required genetics component of the curriculum was *not* included as part of the guest teaching itself[57]. Instead the guest lessons began at a point within the existing genetics unit, as it was being taught by the regular teachers of the classes.

An additional contrast is the fact two teachers and five classes were part of the guest teaching and lessons for Case 2, as compared to one teacher and two classes for Case 1. The two teachers, Ms. James and Mr. Friedman, were responsible between their fives classes for all grade 10 science in the school. They elected to share closely with one another all planning for their classes, even to such a degree that they would frequently cover the same content in similar ways on the same day, with their respective classes. Summit Secondary School is located in the centre of one of the more affluent areas of Vancouver. The children attending the school often come from families of high-paid

[57] On the other hand it can fairly be argued that other parts of the curriculum *were* addressed. These include, for example, sections on the Nature of Science and even sustainability. These areas, though part of the provincial curriculum documents, are much less structured in prescribed learning outcomes, and so often receive little direct attention by teachers.

professionals, and most students will attend university following high school. This appeared to contribute to a different kind of relationship between students and their school, as compared to students at Sir William Secondary. Whereas on average there was a greater tendency for students at Summit to suggest in their comments scholastic achievement as a key feature of future career plans, there was also the suggestion they *depended* less on the school for serving their educational and social needs. For example, it was not uncommon for students at Summit to report access to paid tutors and other paid extracurricular opportunities. This appeared to translate to a sense that for many students at Summit, the school site was less critical to their needs in an ultimate sense, as compared to the situation for Sir William students, where the satisfaction of not only educational but social needs often seemed to depend more crucially on what happened *at* school. This difference can be summarized as an apparent sense that for Summit students, they could more easily *afford* to understand the opportunities and authority of school as optional.

Related to this difference was the relative ease on average with which students at Summit suggested an ability to envision occupying themselves positions of authority, as compared to students at Sir William. This again appeared to correspond to the average socioeconomic background of students in terms of affluence. After all, it would not be uncommon for students at Summit to have parents and other people with whom they interacted regularly, who occupy positions that are widely viewed as having authoritative status (e.g. doctors, lawyers, dentists, professors, etc.).

These characterizations of differences between the two schools are admittedly speculative. They nonetheless reflect noteworthy differences observed in the attitudes of

the respective groups over the course of the guest teaching and lessons. They belong to an attempt to articulate my understandings as researcher and teacher, drawn both from years of experience teaching in diverse areas of the city (including at the schools belonging to the two cases) and specifically as part of the cases themselves. We proceed now to look in more detail at the guest teaching and lessons at Summit Secondary.

The guest teaching and lessons component followed a somewhat different format than for Case 1. Given that with Case 2 I have no responsibility to integrate within the lessons *I* teach, the sustainability lessons and the lessons of the permanent teachers' genetics unit, each of the lessons I teach with these students is a sustainability lesson. On the first of the two days I begin with a mini-lesson to introduce the key science background that is likely important for the subsequent activities. As can be seen from the overhead slides for the lesson (see Appendix 5, pp. 195-201), this included introductory content on stem cells, cloning (including the difference between DNA cloning and organism cloning), and genetically modified organisms. I knew when preparing this mini-lesson that students had just completed a unit on genetics, including stages of mitosis and meiosis, some basic background on 'genes', DNA replication, and protein synthesis within the cell.

At this stage the focus of the lesson turned to the student activity "Ethics and Genetics… Questions to Get You Thinking," shown in Appendix 6, pp. 202-204. Students were asked to complete the first side individually, and then to pair up, and finally to meet with other pairs in completing side 2. Finally, a whole class discussion occurred at the end the lesson.

The questions were designed to involve students, individually and in groups, in thinking about ethical issues related to genetics. Some sample student responses to the question "Is there ever a definite right and wrong when it comes to what should be a part of genetic research? Or are there simply different points of view?" included the following:

> "Yes. Non-religious people don't care [about questions of right and wrong in genetics research]. Religious ones do." – Tegan
>
> "The only really wrong thing about genetics research is hiding it from the public. Like not labelling genetically modified food and cloning for private companies against the wishes of the country." – Danielle
>
> "There is no right or wrong. There's just different points of view. In ethics, there's no black and white. That's my point of view. But if it feels wrong, it is." – Rachel
>
> "You can't really tell people what's right or wrong; it's a free country, people are allowed to think whatever they want." – Pedro
>
> "There are merely points of view. 'Right' or 'wrong' in any case, is merely a point of view." - Mary

In response to whether such research should be controlled in society one student responded:

> "No, [genetic research should not be controlled in society] because a lot of society has religious beliefs that could slow down the progress of the future." – James

And in response to "Who should decide what kind of research is allowed in our society? And how should this decision be reached?," another student commented:

> "I think the public and the scientists should be able to decide, because the scientists know the most about it and the public's opinion matters." – Rhiannon

It is clear from these responses that with minimal prompting the students were able to assert a range of ethical understandings in relation to genetics research. As with

the earlier Case however, the same issues of tracking sources of authority in students' understandings manifest here. Whether it is Tegan's suggestion that only religious people are concerned about ethical right and wrong, Sara's or Mary's point that ethics reduces simply to competing points of view, or Pedro's concern to defend freedom against any tendency to tell others what's right and wrong, it is impossible on the basis available in the responses to assess what comprises these understandings in terms of sources of authority. Are students simply expressing ethical positions they've learned from their parents or the media? Are they able to defend the views more fully with reasons? Are they reacting merely to the language of 'right' and 'wrong' rather than something more substantive? Each of these questions went unanswered in the students written responses, and so remains indeterminate when attempting to place the sources of authority in the understandings expressed.

It is interesting to observe that both Tegan and James raise issues of religious disagreement in their responses. It seems likely these students were associating the questions asked with a point discussed in class not long before the assignment, involving stem-cell research and its opposition by certain religious groups. But given the seemingly antagonistic manner in which each student expresses their respective point, it is interesting to consider whether for these and similar students support for science translates in some way to limiting features of democratic decision-making (as James appears more or less to suggest directly). This would contrast with Rhiannon's response to a related question, where she emphasizes the importance of including not only scientific experts but the public also in such decision-making involving issues of genetics research.

The above considerations lead to the following potential research question **PRQ7**: "How do students' understandings involving religious topics contribute, if at all, to specific ethical and science understandings they hold regarding genetics and genetics research?"

In response to Question 5 regarding the potentially greater uncertainty and stakes related to genetics research, some sample responses were as follows:

> "We can't just stop the research simply because it's risky. We should continue the research with extra care so that our knowledge will help decreasing the risks." – Michelle
>
> "Carefully implement each solution one step at a time. Watch for changes in nature and in habitats. You could see if it works in a biodome first and then try it in nature. It wouldn't cost too much and you could probably find some rich guy to pay for it. Also, they should save all original unmodified plants in a laboratory somewhere." – Polly
>
> "Some time we just need to take the step, let them go for it. We can only wait so long before we've done what we can on mice. Just because there is no certain answer means nothing. With greater stakes there can be greater rewards…" – Laura

These responses are interesting in their negotiation of uncertainty in relation to outcomes of genetics research. Each of the students appears to grapple honestly with the possible trade-offs between potentially very beneficial scientific research, and potentially very risky research in terms of guaranteed outcomes, whether socially, biologically or economically. It would be interesting to pursue further the topic of students' understandings in regards to high stakes, low certainty decision-making, as this is at the heart of a number of important socioscientific sustainability issues. A possible question pair is **PRQ8a**: "How do science students assess and negotiate risk and possible trade-offs in decision-making over the course of a case study focused on high stakes, low certainty scientific research?"; and **PRQ8b**: "What factors (i.e. sources of authority)

contribute to student understandings in this area, and how do they evolve over the course of the case study?"

In response to the outcome of a small group discussion focused on the question how they as a mini-society might manage these issues, some sample responses are the following:

> "'No' to clones. 'Yes' to cloned organs. 'Yes' to normal genetically modified foods." – Group 1
>
> "No one should decide, because it's no one's choice. If people want to research this stuff, they will, if they're allowed to or not." – Group 2
>
> "We think that it is a bad idea because it is not a natural thing to do. Sam thinks it's a good idea because it will give us more knowledge, and may be useful in the future." – Group 3.

The above student responses contribute a new element that so far hasn't received attention in Case 2; that element is group decision-making. Group work was a prominent feature of lessons throughout the study, as it is generally in science education contexts today. In sustainability education, given both the ethical and political aspects to sustainability themes, group work potentially takes on special importance. It would be good to have a better handle on this topic in science education research: **PRQ9**: "What are likely contributions to student understandings of socioscientific issues, if any, arising from student involvement in selected group decision-making activities?"

Let's take stock of where we are in relation to the case study findings. As with Case 1, in terms of the study research questions we remain interested throughout in findings on: 1) sources of authority in student understandings and classroom practices; 2) what activities such as those in the two Cases, which focus on explicit ethical

understandings, can teach us about ethical features of school science; and 3) what, if anything, do the Cases suggest regarding ethical *inquiry* in school science?

It will be noticed that the first two of these themes received considerable treatment already in the discussion of Case 1. Many of the very same challenges in working with students at Summit Secondary, around issues of authority, confronted me again in nearly identical ways when working with students at Sir William. The only significant difference between the two cases (i.e. in terms of findings that respond to the research questions) arose in relation to the difference in duration of the two Cases. Not surprisingly it was clear that a shorter time frame for working with the students at Summit only further exacerbated challenges to achieve familiarity and shared understandings, when compared to the already significant challenges along these lines observed at Sir William. This manifest in the degree of cooperation and attention students offered to the guest lessons. Compared to how I'd observed the same students to behave with their permanent teachers, the overall levels of attention and interest I saw during my teaching, was more typical of what I'd seen from some of these students in relation to a substitute teacher. As such, the correspondingly diminished engagement overall as classes, respectively, with the themes discussed presented an additional obstacle in the way of fostering rich student understandings on the basis of the class activities during Case 2.

We may safely focus therefore on the 3rd theme. It will be apparent this theme touches closely on the 2nd of the research questions for the study. This question, recall, is: 'What, if anything characterizes "ethical inquiry" in these science classrooms?'

Because this question concerns both Cases, rather than respond now we will return to this question at the end of the chapter when discussing the Cases collectively.

The second day of the guest teaching and lessons at Summit had students involved in groups in building 'sustainability proposals' around one of four ethically contentious topic areas involving genetics, assigned to students in groups. These areas included Genetic Discrimination, Human Cloning, Genetically Modified Foods, and Biopiracy. The principal idea was similar to proposal projects at Sir William Secondary. A very brief presentation of 'sustainability' was presented, again as consisting of joint consideration of each of 3 legs of a stool, where failure to consider one of the legs meant the stool of sustainability 'falls over'; (see Appendix 7, pp. 205-206). But in contrast to the projects at Sir William, here the background research for the four topic areas was provided to the student groups on handouts (see Appendix 8, pp. 207-213) and students were asked to assemble a proposal in the course of a single 80 min. class. In preparation for thinking about their proposals students were asked to complete three questions, each aimed at one of the three sustainability areas, respectively, but specifically in relation to their assigned topic area (See Appendix 2, pp. 187-189). Finally, the last 15 minutes of the lesson were set aside for groups to present their proposals to the class.

Obviously this was a very tight timeframe for students to research, discuss, complete written responses, consult as a group and then agree on a group proposal. Very few groups were able during the oral presentation stage of their proposals at the end of the class to do more than simply express a position on their assigned issue. The written responses handed in however, nonetheless often showed in-depth consideration of the

topic and issues. Some of the student responses handed in on their worksheets included the following.

> "The consequences of patents and biopiracy is that what used to be natural and property of Mother Nature is now being stolen and claimed as if it was a piece of property." – Jacob
>
> "Clones could be thought of as lesser than "natural" people (class system). People could clone a perfect society and people with flaws would have no chance in life." – Danielle
>
> "I think that human cloning should only be accessible when absolutely necessary, not for "fun" purposes. I think it should be government funded so [as] not to divide rich/poor opportunities to use this research. In any case I believe human cloning should be strictly outlawed until we know mostly everything about it." – Chris
>
> "I think that natural resources should automatically be thought to belong to the communities that used and relied on them originally. Any request to use or market those resources should be addressed to the communities themselves so they'll benefit from what's theirs. There should also be a limit placed on the resources used, so they won't run out and there's enough for everyone." – Hannah
>
> "When developing products extended periods of testing must be done to protect nature, and they should be carried out by an unbiased party. The changes should have to be good for more things than profit (such as health and/or sustainability)." – Scarlett
>
> "I believe that cloning should not be practiced at all, mainly for the reason that you are playing God, and changing nature. There are also other major reasons, like spending a lot of money which could be spent on schools or hospitals. It's also very wrong, because the rich people would dominate the poor people even more than before, exploiting this opportunity for themselves." – Caleb
>
> "There would be a lot of discrimination just because of genetics, which is somewhat along the lines of racism today." – Sophia
>
> "Most groups of people would have a lot of consequences if they were related to cloning. I am a Christian and we do not believe in cloning. A devout Christian who cloned people would be outlawed by the Christian people." – Nina.

Aside from further suggesting the fruitfulness of further exploration into what is clearly very interesting student socioscientific ethical thinking surrounding these topics, there are three key points to observe in relation to these responses and their place in the overall study. First, the above student responses clearly reinforce many of the findings of Case 1, as mentioned earlier. Students at Summit evidently expressed a wide array of ethical understandings; these understandings connected conceptually to the students' science understandings; and students' ethical understandings were made explicit on the prompting of questions aiming to elicit such understandings. Second, because Case 2 involved a separate curricular area and school, the overall findings observed from the two Cases are clearly not restricted to the special circumstances or students at either of the schools treated individually. Finally, the empirical claims made on the basis of student responses (here Case 2 specifically) are uninformative with respect to empirical content. This, recall, is what we expected, given the illustrative and exploratory aims of the case study. The findings of the study were not intended to confirm or refute empirical claims. They were meant rather to illustrate the conceptual themes of the earlier chapters, and explore possibilities for future research. When understood from this perspective, the combination of the generic empirical claims, the self-reflexive teacher/researcher observations on themes of authority in student understandings, and proposed research questions (**PRQs**), provide significant findings towards this end.

Student Interviews – Summit Secondary

The final component of the Summit School guest teaching and lessons was the student interviews[58]. Students were again asked questions regarding their views of 'nature' and 'natural', ethics, including questions of ethics related to the natural world, and some of their views of 'science'. As with Case 1, the purpose of the interviews was, on the one hand, to explore further student ethical understandings related to the curricular science area underway, while, on the other, to do so in a context different from the school classroom. Interviewing students one-on-one and outside class time offered a further perspective with which to understand relationships between practices and the understandings expressed by the students.

The student responses from the Summit interviews are in general very interesting, in terms of the range and depth of student responses on ethical topics. However, because the type of findings arising from these interviews again repeats what has already been discussed several times in this chapter, only a few student responses are included here.

When asked "Would you say there is anything that is the *opposite* of nature?," one student replied:

> "Hmm... I think that the stuff that happens in nature is meant to happen, but what humans do is completely different than what is supposed to happen. Well nature can tend to go against itself but humans tend to add to it… Like most stuff that happens in nature goes unnoticed, because it's natural and everything natural goes with the flow, but when humans do it it's a whole new issue." – Lucien

When the same student was asked if scientists have responsibilities when it comes to nature, the following dialog occurred:

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[58] See Appendix 9 (pp. 214-217) for the interview script for these interviews.

> **Lucien**: Scientists should be careful of what they do with nature, because if you do one thing to nature its kind of a chain reaction; it happens to everything. Then it can either change, like harm, or improve the way nature goes. But in my view you should just leave nature to do its own thing.
>
> **Larson**: Do you mean not too much intervention or only interventions of certain sorts?
>
> **Lucien**: Uh-huh (student expresses agreement).

I include this exchange with Lucien because of the frequency with which students in Case 2 generally expressed the kind of cautioning seen above in relation to disrupting the 'balance' of nature through genetic research experimentation. In light of the specific social and historical location of students such as Lucien, during a time when these issues only grow in significance in terms of potential outcomes for life on the planet, the following question bears future investigation **PRQ10**: "What lessons for how best to develop sustainability education components for inclusion within conventional school science curriculum, arise through consultation with science students participating in a case study exploring specifically contemporary challenges facing socioscientific decision-making in the world today?"

Finally, in a separate interview with a different student, the following dialogue occurred:

> **Larson: ...** But there are some cases at least that you can imagine where it can be both natural and still wrong in some sense or other for what we choose as human beings to do?
>
> **Keith:** Yeah... I don't think the world's ready for cloning personally. We just got over, like, the human rights movement back in the sixties. We're just getting used to everyone being equal. Some parts of the world, even some parts of Canada, there's still racism. So if you introduced a clone into say, a very racist city in Canada or the U.S. or wherever in the world... the clone... it would probably get shot, or stoned, or mistreated. We're not ready yet.

In terms of student insights into the challenges facing socioscientific decision-making today, Keith's responses further emphasize the importance of pursuing research directions such as the one suggested in **PRQ10** above. On the basis of comments such as Keith's, there can be little doubt that some science students at least are seeking to develop rich ethical and science understandings in relation to a socioscientific topic like this one.

Learning from the Cases: Ethical Inquiry

Let's conclude the chapter by exploring a possible lesson to draw regarding the relationships between the richness of student ethical and science understandings, and practices wherein sources of authority for such understandings can at least potentially be made explicit. Such a lesson may embody a response to Research Question 2: 'What, if anything characterizes "ethical inquiry" in these science classrooms?'

We've noticed along these lines that much has been found to depend on the specific structure of classroom practices. A shared history together wherein students are supported in exploring the authority of their understandings, including acknowledgment of the ways sources of authority specific to school science structure these settings, comprises a key finding of the study in regards to supporting rich student understandings. 'Inquiry,' understood in a loosely Deweyan sense as a resolution of a problematic situation, or, again in Dewey's language, transformation of an indeterminate situation to a determinate one, offers a helpful way to respond to Research Question 2: Ethical inquiry in these classrooms is characterized by classroom practices that foster the development of rich ethical understandings. Furthermore, in cases where students' ethical understandings are impoverished due to a *specific* implicit or unconscious reliance on sources of

authority that the student fails to recognize, making this reliance explicit in understanding is an instance of what Dewey's describes as transforming an indeterminate situation to one that is determinate. Ethical inquiry, therefore, seeks to assist students in making explicit the sources of authority in cases where this transformation belongs to enriching understanding. But because implicit understandings are not always impoverished understandings (implicit understandings can often be very rich), making sources of authority explicit as part of ethical inquiry is specific to only *some* implicit understandings.

What distinguishes the two, and the corresponding importance in some cases of making sources of authority explicit, is the richness of the understandings in question. Impoverished implicit understandings are indeterminate in Dewey's sense, we might say, because lacking sufficient conceptual resources with which to respond to problems presented to those understandings. It is one of the tasks of science education to present problems to—or in other words *problematize*—impoverished student understandings in cases when doing so belongs to promoting desired student learning outcomes. In terms of classroom practices and science learning, it is noteworthy that corresponding to what Dewey considers an indeterminate situation, on the view here are features of *shared* classroom practices. One of the chief elements of the role of teachers in facilitating rich student understandings generally, is on this view to participate in encouraging students to confront 'indeterminate' situations of the sort giving rise to rich understandings.

Activities that have students involved in questioning sources of authority in their ethical understandings, when appropriate to educational aims (including examples from this study), are thus understood here as approaches providing students with indeterminate

situations in the Deweyan sense. In the case of science education they are activities that foster *ethical inquiry* in the science classroom. The main ethical situations presented to classes in the two Cases were deliberately selected by me for their role in presenting potential problems for existing ethical understandings of classroom participants (including, importantly, me as the teacher). But depending on the educational aims of the particular classroom contexts in question, so of course will depend the ethical situations most relevant to explore together as a class. It is the suggestion here that due both to the associations generally between students' ethical and science understandings and the specific importance of sustainability issues for education today, increased attention is clearly called for within science education contexts on ethical inquiry along the lines described above.

We turn now to the final chapter, where I summarize the responses to the research questions, explore how the present work is situated in relation to related work in science education, and lastly, explore further some of the many promising directions for future research.

Chapter 6 – Discussion of Findings & Directions for Future Research

Responding to the Research Questions

This study has explored the role of ethical understandings in school science. Throughout the main interest has been to construct an account of understanding that succeeds on the one hand to bring ethical issues in the typical science classroom into better focus, for both teachers and researchers, and on the other to place such understandings within a view of science understandings generally. Central to this account, moreover, has been the insistence to construct the account first and foremost from activities and behaviours of classroom participants, rather than disregarding these activities or imposing on them interpretations that deny or contradict the involvement of participants. This has led to an account of practices as the needed complement to the view of understanding put forward.

Let us return again to the research questions of this study:

1) How do ethical features of secondary school science relate to the construction of science understanding in the classroom?
2) What, if anything, characterizes 'ethical inquiry' in these classrooms?
3) What do the specific interventions of this study, which focus on explicit ethical content of science learning and teaching, contribute to understanding ethical features of secondary science classrooms in general?

I claim to have answered Research Question 1 primarily on theoretical grounds, with the conceptual framework of practices and understandings presented in Chapters 3, and illustrated through the case studies of Chapter 5. The generic empirical claims presented in Chapter 5 are then meant as a secondary response to Research Question 1.

Finally, the series of proposed research questions (**PRQs**) of Chapter 5 explore possibilities for the future in extending empirical work on this question.

The end of the last chapter also saw a response to Research Question 2 on ethical inquiry. Drawing from the lessons of the two Cases ethical inquiry was there described as the process of resolving specific ethical situations presented to classroom participants by making explicit as needed—i.e. when understandings are impoverished relative the capacity to resolve situations at hand—sources of authority in participants' ethical understanding.

We can now turn to Research Question 3. As noted above, the empirical claims made on the basis of the case studies are quite generic. These limitations extend to Research Question 3. But in addition to the generic empirical findings, the case studies served to generate a host of proposed research questions (**PRQ**, cf. Chapter 5), in keeping with the exploratory nature of the case study research performed. So in lieu of providing a determinate empirical response to Research Question 3 on the basis of the present work, the findings of the case study are projected into the **PRQ** for future study. For the sake of convenience the 10 **PRQ** are summarized in Appendix 10 (pp. 218-220).

Situating the Study in Science Education Literature

In this section the present work is situated in relation to related work in science education research. This has been postponed until now so as to gain a fuller understanding of the theoretical approach, beginning in Chapters 2 and 3, and later illustrated in Chapter 5. The section is divided into 'Ethical Features of Science Education', 'Conceptions of Knowledge and Understanding', and 'Practices'.

Ethical Features of Science Education

In science education research in recent decades no one has written more on moral reasoning and moral features of science education generally than Dana Zeidler. Indeed, as we'll look at below, outside Zeidler's (and his co-authors') contributions, a focus on *specifically* ethical or moral features of science education is only very minimally represented in science education research journals.

Zeidler and Schafer (1984) compared the moral reasoning of environmental science majors at university with non-science majors through the use of a quantitative study involving 4 test instruments (Phase 1), followed by a qualitative study where pairs of the original respondents converse with one another, with the task of reaching agreement on a position representing their collective moral view (Phase 2). The results compare scored levels of moral judgements between the groups, as well as suggest likely mediating factors for moral reasoning (including attitudes, commitment and comprehension pertaining to the overall area in which the moral dilemma occurs). Zeidler and Shafer's paper makes important contributions to understanding ethical features of science education, particularly in highlighting the role of background attitudes and commitments in mediating ethical understandings.

This agrees well with the present study in terms of the role of understandings (including background understandings) and characteristic emotions, aims and projects in organizing practices to which students belong. The practice approach, however, by contrast presents a model for understanding *conceptually* the various interactions among types of understanding. In addition, by focusing on university students, and on

judgments and reasoning that are seen to be independent of happenings of the classroom, the detailed exploration of classroom science contexts and understandings provided by the present study fills needed gaps in these areas.

Zeidler (1985), by focusing on the principled moral reasoning of grade 10 science students, can be said to address in part one of these gaps. But again with this study, moral reasoning is not described specifically in relation to classroom events. Moreover, both the earlier (1984) study and this one seek to represent student reasoning in terms of hierarchical stages of development, consistent with Kohlberg's stage theory of moral development. This background theoretical commitment has been notably criticised for its apparent gender bias (Gilligan, 1982; Noddings, 1992). By offering a framework that is sensitive to both the specific happenings of the classroom as well as background understandings of students, the present study offers a needed supplement to the work of Zeidler described.

Zeidler (1984) argues for reform in science education by insisting that science education aimed at scientific literacy must include a more explicit role for ethical components in the science curriculum. Such an approach would be interdisciplinary and focused on "role-taking opportunities, intellectual stimulation, responsibility, cognitive-moral conflict, peer interaction, and a democratic communicative environment" (p.415). Zeidler does an excellent job in highlighting the kinds of ethical features of science education that are implicated if we take seriously the commitments stated in various science education policy documents surrounding scientific literacy. This can be understood as a call for consistency between stated goals and existing practices in science education. Analogously, in Chapter 2 I presented an argument to the effect that science

teachers should be prepared to present accounts of the ethical positions they undertake in the classroom, and specifically in ways which are public—presented in ways students (and their parents) can conceivably be expected to grasp and find persuasive. In both cases a closer match is recommended between existing aims and practices. However, by addressing the recommendation at the level of classroom practices and offering an account of such practices, the present study helps to shift the focus within reach of *comprehensible* changes for practicing teachers and researchers in science education.

Zeidler et al. (2002) and Sadler and Zeidler (2004) focus attention on socioscientific issues, and interactions between students' nature of science (NOS) views and their ethical views in science education. Similar to earlier work by Zeidler in terms of exploring multiple education/age levels, the earlier study explores college students' responses to genetic engineering issues, whereas the later study looks at secondary level science students' responses to a selection of socioscientific issues. Some of the more interesting findings are that student views were found to shift in response to explicit involvement in thinking about and discussing the issue, and (with respect to the college-level study) students' views of genetic engineering are significantly informed by moral considerations when it comes to decision-making in response to the issue. These findings are clearly in agreement with the present work, which in turn can be understood to offer a needed explanation for why such findings suggest what they do.

Finally, Zeidler's and his respective co-authors' most recent papers provide the closest points of comparison so far to the present study. Zeidler et al. (2005) present a 'Socioscientific Issues' (SSI) curricular framework which the authors suggest as a replacement for STS education. The framework is comprised of four principle

pedagogical contributions, the collective focus of which is the 'personal cognitive and moral development' of students (p. 361). These four areas are: discourse issues (i.e. 'peer interaction and its impact on reasoning'); case-based issues; nature of science issues; and cultural issues. Together these contributions to the intellectual development of students are seen to foster what the authors call 'functional scientific literacy', or in other words scientific literacy that—as suggested—recognizes the personal moral and cognitive development of students.

It should be clear that the conceptual framework proposed by these authors provides is an excellent companion to the framework proposed in the present study. In particular, the conceptual framework of the preceding chapters offers a needed avenue for placing ethical and science understandings of students more carefully in their respective contexts–i.e. according to the view of understandings and practices suggested. The importance of such a framework is hinted at from many directions in Zeidler et al. (2005) but without a sufficiently rich account of understanding and practice (or equivalent concepts), the details remain unclear and difficult to bring to focus.

Sadler and Zeidler (2005) updates the earlier (2004) work by the same authors—exploring students' responses to socioscientific issues—by attempting to provide a more rigorous empirical basis for students' informal reasoning in such domains. Employing qualitative analysis of interviews with 30 post-secondary biology students, the authors identify 3 core areas of informal reasoning, and begin to lay out some relationships between the areas. The 3 areas proposed are: 'intuitive', 'rationalistic' and 'emotive'. Again this work fits extremely well with the present work: first, in describing (i.e. on empirical grounds) distinct areas of ethical understanding, which could very usefully

benefit from an analysis and further study in terms of 'authority in understanding' and the framework of practices and understanding suggested here; and second, in furthering empirical approaches for studying ethical understandings generally. Both are excellent starting points for future study of the framework proposed in this study. This framework, as suggested, is seen to offer the needed theoretical detail for further exploration of relationships between types of reasoning, and contextual factors belonging to students' background understandings as science students.

Let us now turn to the other main exceptions to the overall dearth of publications looking at moral features of science education.

Two major areas which deal at least indirectly with moral issues in science education are Multicultural Science Education (MSE) and Science-Technology-Society (STS) approaches in science education. Possible connections to ethics in these research areas occur at several levels, including philosophical issues surrounding universalism in science (Hodson, 1993; Atwater and Riley, 1993; Stanley and Brickhouse, 1994); the role of the surrounding educational and political structures when seeking to understand competing calls to *replace* versus *respect* students' views (Gaskell, 2003); and interactions between science learning and societal issues related to science and technology (Solomon and Aikenhead, 1994). While all of this research clearly suggests a host of significant ethical issues involving science learning and teaching, the ethical as such is almost never specifically discussed. This makes the characterization of ethical features arising in relation to this work, as well as possible prospects to address in terms of ethics some of the concerns raised in this work, unclear.

Andrew and Robottom (2001) make *environmental ethics* a specific focus of their article "Science and Ethics: Some Issues for Education". The authors present an introduction to some key ideas and thinkers in environmental ethics, then proceed to discuss, in terms of an intersection of scientific and environmental values, the challenges of a specific rural community to manage the feral rabbit population of the local environment. A discussion then follows for how issues such as those described may best be handled in science education. The article does a good job of discussing how both scientific and ethical features of science education are important when exploring topics such as animal management in the science classroom. The authors define environmental ethics as "about value or moral judgements to do with the ethical responsibility of humans towards the natural environment or aspects of the natural environments" (p. 170). Since this definition however itself makes reference both to *moral* judgement and *ethical* responsibility, the further question of how in turn to understand *these* terms is not made clear. Moreover, a more detailed account of how ethical or moral understandings interact with or can be seen either to compare or to contrast to science understanding, is not attempted by the authors.

By contrast, Jackson et al. (1995) attempt to discuss in detail at least <u>one</u> area of common interaction between ethical and science understandings for a significant number students; namely, they discuss the interactions between Christian understandings of human origins and evolutionary thinking in science. The principal aim of this paper is to highlight some of the possible dangers attending excessively one-sided, cognitive accounts of conceptual change. They point to the importance of making space for the non-cognitive components of science learning, such as through dialogue between

opposing viewpoints. By serving as a means to develop mutual respect and understanding, this can minimize any possible harm to students that accompanies science learning if teachers' are insensitive to conflicts with background understandings. Here again however, ethics are not discussed as such by the authors, and no account is presented for how to think about such interactions in other cases or generally.

Finally, Michael Martin (1986) makes a case for the mutual relevance of moral education and science education. Proceeding in steps, he first presents an overview of moral education on the model of Frankena (1966, cited in Martin, 1986). He then details how science education should be seen as relevant to moral education, followed by how moral education should be seen as relevant to science education. Lastly, a plan is presented for combining moral and science education on the basis of their mutual relevance. With the exception of much of Zeidler's (and his various co-authors') work, Martin's article is the most explicit of any discussed here on the issue of an actual definition of ethics in relation to science education. However, his *choice* in doing so, adopted from Frankena, focuses on "knowledge of good and evil" (p. 103). In addition to the fact this definition will almost certainly alienate many readers in science education[59] it is moreover difficult to envision sufficient overlap generally between contemporary science classrooms and Martin's vision of moral education. As such the argument ends up sounding more prescriptive in relation to its *claimed* relevance for science education than itself a means from which to better understand the ethical features of existing science education.

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[59] It is perhaps no surprise therefore that Martin (1986) was originally published in the *Journal for moral education*. It was only later reprinted in Matthews (1991).

Conceptions of Knowledge and Understanding

With the attention given here to *understanding* in science classrooms, it is important to ask how this work is situated with respect to views of understanding or related concepts in science education research. Here again there is a surprising absence of detailed attention on what exactly 'understanding' is meant to be. This notwithstanding the familiar ways understanding features in the vocabulary of science teachers (and educators generally), and within educational reform initiatives suggesting the move towards "teaching for understanding," in school contexts[60] (cf. Wallace and Louden, 2003 for a list of such reform documents).

Writing in the *Journal of Curriculum Studies,* Wallace and Louden (2003) cite these reform documents and make the point that given uncertainties surrounding the idea of 'understanding' itself, greater attention to this apparently prior conceptual issue is called for in any talk of 'teaching for understanding'. They proceed to address this need by looking at types of understanding featured in science education research, and arguing that 'teaching for understanding' bears relevant similarities to discussions in science education research on 'active learning' and constructivist learning and teaching. Among their four principal conclusions are two that compare significantly to the effort here to provide an account of understanding in the context of a view of practices. First, understanding as a concept is often underspecified because of a dependence on the object of understanding, prior understandings, and epistemological, language and explanatory frameworks. Second, a host of contextual factors are relevant to any aim to 'teach for understanding, which include "schools, examinations, scientific discourse, and authorized

[60] I.e., *away* from approaches that rely on transmission teaching and learning

analogies" (p. 563). These points suggest poignantly ways in which the present work offers a welcome contribution to research in the area, by offering a needed means for *specifying* the sensitivity when forming understanding, to prior understandings, frameworks of understanding (i.e. *practices*), and contextual factors such as those mentioned.

Whereas Wallace and Louden's (2003) study focuses on the more general issue of what it means to 'teach for understanding,' there is a parallel debate in science education research on the Nature of Science in (NOS), concerning competing *goals* for science teaching and learning. The contenders as goals in the debate are 'belief', 'knowledge' and 'understanding', and the various positions advocated resemble similar debates to be found, respectively, in the psychology of education (belief vs. knowledge; cf. Southerland et al., 2001) and the philosophy of science proper (knowledge vs. understanding or understanding as epistemic vs. understanding as non-epistemic; cf. Trout, 2002; de Regt, 2003). Indeed, in light of these debates elsewhere, it is no surprise to find they arise in the context of science education research.

In crude outline, the debate can be summarised in the following way. Concerning 'belief' and 'knowledge,' the core issue is whether knowledge per se can be distinguished from belief either by degree or in principle. For example, is knowledge to be understood as a different species than belief? (e.g. science education seeks to build knowledge and replace belief); a special type of belief? (e.g. justified and true beliefs, or JTB), or actually simply another word for the same thing? (e.g. the only distinctions between belief and knowledge are pragmatic and/or terminological). Arguments from psychology

question "whether the theoretical distinctions have any psychological reality" (Southerland et al., 2001).

For different reasons, but with the same end result, Cobern (2000) suggests both belief and knowledge are equally a function of presuppositions, and so neither can claim privileged status vis-à-vis the other. For Cobern, "the distinction between belief and knowledge... is an artificial construction in the typical science classroom that eventually creates more difficulties than it solves," (p. 241) for the reason that beliefs as much as knowledge have *reasons* for students. Among other concerns, Cobern wishes to validate student beliefs as legitimate because grounded in reasons, and therefore opposes the move by some science educators to simply replace such beliefs without due sensitivity to the reasons students hold their views in the first place.

Not surprisingly, this view has been challenged. Smith and Siegel (2004) defend, *pace* Coburn, the classical distinction between belief as a *necessary* but not *sufficient* condition for knowledge, and knowledge, which is to be seen as a special kind of belief. For these authors something central to the idea of science as part of the knowledge building enterprise is lost when mere belief rather than knowledge and understanding becomes the goal for science education. While acknowledging that multiple and often conflicting meanings for belief and knowledge are a typical part of the speech of both students and teachers (e.g. "I know the theory of evolution but I don't believe it" or "I know Ptolemaic astronomy but I don't believe it"), they maintain nonetheless that preserving clarity regarding the distinction between these concepts is "central to understanding the nature of science" (p.562). So rather than abandon the philosophical distinction between belief and knowledge the authors recommend instead remedying the

issue of multiple conflicting meanings for these words by incorporating *understanding* as a further aim of science education in addition to *knowledge.*

Understanding for Smith and Siegel (2004) is defined by four overlapping criteria. These include 1) connectedness, or the ability to link ideas together; 2) sense-making, or in other words attributing meaning; 3) application, the ability to apply what is understood; and 4) justification, an appraisal of at least some of the reasons that can justify a claim. As suggested, understanding for these authors is meant to take up the slack where possible conflicts between knowledge and belief statements arise. As suggested above, a paradigm example is "in special circumstances a person can indeed understand a theory and simultaneously refuse to believe it" (p.565). This is intended to make room for the possibility of refusing to endorse the wider implications of a view even at the same time as understanding that view. According to Smith and Siegel, in cases such as these the appropriate aim for science education is student *understanding* as opposed to student knowledge.

Although the invocation of understanding is a welcome addition to science education discourse (particularly given its scarce focus of attention otherwise), Smith and Siegel (2004) run into difficulties attempting as they do to split the difference between maintaining the classical focus on knowledge as justified true belief, while making room for the possibility to understand but endorse a view. Davson-Galle (2004) presents a compelling criticism of Smith and Siegel's (2004) definition of understanding, arguing that as defined it is too robust to allow the middle ground the authors intend. Davon-Galle's suggestions are instead to be meticulous on the one hand about stating objects of knowledge (carelessness regarding which he suggests is responsible for the conflicts

Smith and Siegel's cite), while allowing on the other hand that students at times will have only limited justification for their views.

In summary, the debate over competing goals in science education has discussed two key topics that bear directly on the issue of 'understanding' in science education research and the present work. The first is the importance of retaining in some form at least the key distinction between beliefs that are better informed with respect to evidentiary standards, versus those that are not. This in the end is the core idea behind the JTB account of knowledge, insofar as both the truth condition and the justification condition arise from this basis. Belief, as outlined in Chapter 2, can be thought on the model of *endorsing* some content as true, i.e. as a taking-true. According to the strength of reasons—or in the language of understanding—to the richness of inferential connections, so depends the difference between what has traditionally been the distinction of belief and knowledge.

The second key topic raised in the above discussion is issue of understanding specifically. While Davson-Galle's (2004) criticisms of Smith and Siegel (2004) strike me as sound, this fact alone may put into question the importance of understanding as a goal for science education in the way the latter authors recommend. For if Davson-Galle is correct, Smith and Siegel's suggested motivation for understanding as a goal has been significantly undermined. The claim here is that understanding *is* a needed goal, and moreover one that can be employed to do all of the conceptual work for which knowledge is currently put to use. However, this claim goes well beyond what can be adequately supported here; a beginning however is suggested below in '(Further) Directions for Future Research'.

Practices

The final area to explore in terms of how the present work is situated with respect to science education research is the area of practices. I will consider three separate directions of work in this area. The first is the work of J. L. Lemke and the sociocultural approach to education. The second is the work of Wolff-Michael Roth and his work on social practices. The final direction is the work of Leif Östman and his work on discourse change and companion meanings.

J. L. Lemke's (1990) *Talking Science: Language, Learning and Values* presented a thorough-going analysis of classroom science from the perspective of social semiotics, or in more familiar language, meaning-making in a social context. Following the lead of social linguist Michael Halliday, Lemke considers social semiotics the basic framework for social science of the future (cf. p. 183), by providing tools with which to analyse the meaning constructed in any social context. The principal tool, not surprisingly, is an analysis of communication broadly, including language, gestures, body language and any other use of signs for conveying meaning. In Lemke (1990) this occurs by applying the concepts of *register, genre,* and *semantic network* to connect local classroom interactions with global contexts of culture, and a lexical and grammatical analysis of transcripts of classroom speech.

In terms of connecting Lemke's earlier work with the view of practices presented here, the following quote is suggestive:

> An action that makes a socially recognizable meaning in a community is a semiotic *practice*... [A] social group or community can be defined indexically by the typical (probable) patterns of action of different types of people under different circumstances in that community. In this sense, a community is

> not composed of people per se, but of people acting. It is made up, not of individual biological organisms, but of interconnected life-processes (p. 190, italics added).

As can be seen, there are many overlapping themes between Lemke's analysis of classroom life in terms of social semiotics and social formations, and the present analysis in terms of practices and understandings. In both cases the focus is squarely on the construction of meaning, and by reference continually to context including importantly, social context. Lemke's tools for analyzing meaning construction using linguistic discourse analysis can be seen as valuable resources in examining possible understandings of students and teachers.

However, there exists a fundamental difference in basic orientation between Lemke's approach and the one described here. Lemke (1990) is inclined to analyse understandings by reference always to the social construction of meaning at various levels. It can therefore be described as *sceptical* with respect to both self-understanding and any variety of realism. This tendency continues in his most recent work, involving what he now calls a "sociocultural perspective" on education (Lemke, 2001), which can be seen as a direct extension of the earlier work. The difference in orientation might be summarized as follows. For Lemke, each of science, philosophy and commonsense self-understandings is itself the site of a construction of meaning, whose meanings therefore must defer to such an analysis. In the present work, by contrast, understanding does not simply defer to larger meaning structures. Rather, what is grasped in understanding within a practice can be described as <u>final</u> in the very specific sense that no further points of reference for meaning are necessarily implied beyond what is connected in particular acts of understanding within a practice (or practices) to which the understanding

belong(s). As a result, whereas the practice view described here can be said to agree with Lemke's sociocultural perspective on the issue of meaning construction within social formations, the practice view is felt to preserve greater room for self-understanding, by resisting the tendency to collapse all explanation to the social level. This, it is claimed, preserves more options for scientific and commonsense realisms, including, in the latter case, what is claimed to be needed for a robust type of self-understanding.

Whereas Lemke prefers to speak of *communities* and *social formations* rather than practices, the language of social practices is taken up explicitly in the work of Wolff-Michael Roth (Roth et al., 1997; Roth et al., 2000). Drawing on Bourdieu's view of habitus, Roth's work on practices emphasizes two principal themes. The first is what he calls the 'temporality of practice'[61]. In the words of Roth et al. (2000): "Analysis requires freezing the activity. Descriptions are necessarily static and lead to the specifications of techniques; in turn practice gets represented as assemblies of techniques to be used in deliberation" (p. 7). An appreciation of the difference between the time in which activities such as teaching practice occur in the classroom, on the one hand, and reflections or descriptions of such practice, on the other, is central to Roth's views of practice. The second theme is the context specific nature of social practices which, in the case of teaching specifically, means what is intelligible or comprehensible to a given class depends always on the meanings in play within that particular discourse community (cf. Roth et al., 1997, p. 530).

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[61] In Roth et al.'s (2000) view temporality is absent from other theories of practice (cf. *op cit*, p. 5). In light of Roth et al.'s (1997) reference to Schön, this claim is somewhat surprising. For Schön's (1983) distinction between reflection-in-action and reflection-on-action seems meant precisely to focus on the issue of temporality. An analogous distinction is present in Bourdieu's (1990) views on theory and practice.

The work of Wolff-Michael Roth on social practice, so far as it goes, finds welcome agreement with the conceptual framework of practices and understandings described here. The issue of how meanings are situated with respect to practices has been articulated on the present view in terms of the particular grasp of connections in understanding, which may include contributions variously from background understandings, perceived authority, observations, and features of physical setting (cf. Chapters 3 and 5). Moreover, by describing understanding as an explanatory concept whose importance is first and foremost to attribute meaning to *activities* and *behaviours*, the emphasis on temporality that Roth focuses on is accommodated as a natural consequence of the larger integrity of the view presented. The distinction between the time of doings or activities and the time of description or reflection, or what Schön (1983) calls reflection-*in*-action and reflection-*on*-action, becomes here a distinction between implicit and explicit understandings. That the account of practices and understanding presented in this work can easily accommodate these insights while at once offering a rich framework with which to explore connections to understandings generally, rules and affective dimensions bodes well for the prospects of the view in addressing the kinds of questions Roth raises in his work on social practices.

The final work to explore in relation to similar views of practice in science education research is the work of Leif Östman, who presents a view of learning as discourse change. Östman (1998) defines discourse as "[A] systematic process of inclusion and exclusion, regarding what to say and what *not* to say, how it should be said and how it should *not*" (p. 55). Meanings, accordingly, are a function of "what *is* said in relation to what *could have been* said, *how* it is said in relation to *how it could have been*

said" (p. 55). Also central to Östman's account is the notion of *subject focus*, which is the attribution of values to nature through the choice of language. Examples he cites of subject foci include *Human Being as a Threat* and *Survival of Homo Sapiens,* whereas examples of attributed values include 'epistemological value', 'practical-technical value', and 'moral value' (cf. op cit. pp. 66-67). Östman employs these concepts to explore "possible socialization consequences of science education" (p. 68).

Östman's account again parallels the account here, specifically in terms of drawing attention to how meaning is constructed within the classroom, and exploring the relationship to authority and power. However, similar to Lemke's views, the account is primarily negative from the perspective of students' autonomy in understanding. Attention to student meanings is limited to how curriculum and the choices of focus within it limit the possibilities for student meaning. As important as this attention is, it is lopsided without a parallel account of what students can understand independently of such constraints.

(Further) Directions for Future Research

We turn now, finally, to 'further' directions for future research based on the present work. It will be noted that directions for future *empirical* work have already suggested—the 10 'proposed research questions' **(PRQ)** described earlier (cf. Appendix 10, pp. 218-220). We focus here therefore on suggestions for future *theoretical* work in relation to the present study.

'Knowledge' Versus 'Understandings' in Science Education

In the wider philosophical literature 'understanding' has a history of association with continental philosophy, particularly the work of Kant, Hegel and the phenomenological tradition (cf. Franklin, 1981; Franklin, 1983). This appears to have marred somewhat its reputation in angloamerican philosophy, including much of mainstream philosophy of science. Trout (2002) for example, argues that the sense of understanding is irrelevant to scientific explanation and prone furthermore to the psychological conditions of overconfidence and hindsight. By contrast, de Regt (2003) defends a pragmatic account of understanding against Trout, arguing that a correct account of understanding is not only epistemic but also context-sensitive in ways needed for scientific knowledge. By incorporating a role for the *intelligibility* of theories, understanding on de Regt's pragmatic account makes understanding not only analytically reputable but necessary to a viable account of scientific explanation.

Analogously, the account of understandings and practices presented here is seen as capable of fulfilling the many conceptual roles currently expected of 'knowledge'. On the one hand, the account of understanding supplied is specific enough to sustain a view of empirical observation and justification, as is clearly important for science education. On the other hand, because of the context specificity articulated here in terms of the notion of practice, the view easily extends to accommodate such important issues as ethical views, issues of authority and power, background understandings, and practical skills and knowledge. No other view in science education research on knowledge and understanding appears to hold similar prospects in serving such multi-faceted needs.

Knowledge-Understanding Transfer

The question of how much overlap is needed between distinct practices to sustain successful transfer of understanding from one area to another is interesting to contemplate on the basis of the present work. The account of the *organization* of practices along the 3 dimensions of understandings, rules, and characteristic emotions, aims and projects holds the prospect of forming an inventory to represent a practice in terms of these dimensions. Such inventories could then be used to explore transfer of knowledge- understandings and skills-understandings across practices, as represented by their respective inventories. If successful, this could develop into a predictive feature of practice theory so described.

Skills and Practical Knowledge

The present account has described understanding as an explanatory concept for analyzing activity and behaviours. This leads naturally to the view that practical skills or knowledge be described in terms of *implicit* understanding, as compared to the *explicit* understandings of propositional or declarative knowledge. Such a view holds great promise for a unified account of these otherwise divergent areas of science education research.

Metacognition

When does it serve teaching and learning objectives in science education to make implicit understandings—such as those belonging to problem solving or laboratory skills—*explicit* in deliberate acts of reflection or statements in language? Research on

metacognition in science education appears at times to take for granted that such explicit understanding is necessarily valuable to learners. The present account allows a more nuanced analysis in terms of the particular aims or projects of the practices in question.

Ethical Practices and Teacher Self-Understanding

Finally, I suggest the work described here holds the potential to address what can reasonably be described as a *profound* need for increased self-understanding among teachers regarding ethical issues and their roles as science educators in democratic society. By sharing the account here of ethical understanding and practices with pre- and in-service teachers, questions of resulting increased teacher self-efficacy and confidence in dealing with ethical topics can be explored.

This concludes the present study on ethical and science understandings in school science.

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APPENDIX 1: Early Interview Questions – Sir William Secondary

I. Ways of Understanding Science

1. In your view, and using your own words, what would you say 'science' is?

2. Do you think it's important for you personally to understand science? <If yes> In what way is it important? <If no> What is the best reason you can think of for learning science, and why is this reason not so relevant for your life?

3. Can you think of examples from your life where you've needed science to make important choices?; for example, choices related to health or medical help or what products you buy and whether they are safe for you and others? [pause for response] Are there examples in society where you think it's important for other people making decisions to know science?; for example a mother caring for her family, a farmer tending to the crops he or she is growing, a grocery store clerk, or a teacher? [pause for response] Imagine now that you are 10 years older. What do you think it will be important for you to know about science in order to make the choices you will be making?

4. What are some ways of learning science that have worked well for you, and what was good about them for you? [pause for response] What are some ways that haven't worked well, and what was not so good about them for you?

II. Ways of Understanding Nature

5. Using your own words, can you describe what "nature" means to you? [pause for response] Can you give examples of nature? <If "examples" puzzles them, ask> What is part of nature? [pause for response] Can you give examples of what is *not* nature? [pause for response]

6. In what ways have you learned about nature? [pause for response] What are some of the most useful things you've learned about nature, and where and how did you learn them? [pause for response] Would you say there are many ways

to learn about nature, just a few different ways, or only one way? [pause for response] <If more than one> What are some of the different ways to learn about nature in your view? [pause for response] What would you say is the *best* way to learn about nature?

7. Can you describe memorable experiences of nature you have had? <if necessary to elaborate ask> Can you describe memorable experiences of nature that stand out from all the rest?

III. Environment and Sustainability

8. Can you describe what the word "environment" means to you?

9. Is there a difference in your view between "nature" and "environment"? [pause for response] <If so> Can you describe what the difference is?

10. Have you heard of "sustainability" before? [pause for response] <If so> Can you describe what sustainability means to you? <If not> Can you guess what sustainability might mean, perhaps by thinking of what it means to "sustain" something?

11. Do you think there are there problems with the environment? [pause for response] <If so> Can you describe the kind of problems you think are most serious? <If not> Why don't you think there are problems?

12. How do you think problems related to the environment should be dealt with by society? [pause for response] [Prompt, if necessary:] Can you say more? [pause for response] Do you feel you yourself play a part in helping with issues related to the environment? [pause for response] <If a part> Can you describe what sort of part you play with respect to issues related to the environment? <If no part> Can you say more why you see it this way? [pause for response] If you were able to do more with respect to environmental issues, what are some things you might do?

13. How important do you think science is when making decisions related to the environment? [pause for response] How important do you think it is for people such as yourself to know about science when it comes to environmental issues?

14. Are there *other* matters than just science to consider when making decisions about the environment? [pause for response] <If so> Can you describe what else should be considered?

15. In your view, is caring about nature important to helping the environment? [pause for response] <If so> What role does caring have in helping the environment? <If not> Why isn't caring important?

16. Do you think decisions related to the environment include a moral or ethical component? [pause for response] <if so> Can you say more about what this ethical component is? <if not> Why don't you think there is an ethical component?

17. Do you think human beings have certain responsibilities to help the environment? [pause for response] <If so> Can you say more about what kind of responsibilities? <If not> Can you say more why not?

18. Can you give examples of what you think would help you and other students to learn about issues related to the environment in science class?

APPENDIX 2: 'What's Natural?' Assignment – Sir William Secondary

These questions are to explore ways of understanding "natural", and whether for humans it's natural to be ethical.

Thinking in terms of Ecology

1. What are some features of evolutionary success? (Hint: what must species and organisms do if they are to survive over long periods of time?)

2. Is human success different from evolutionary success? Can you say why you think this?

3. Is "balance" important in nature? Is balance the same as health in nature?

Thinking In Terms of Ethics...

4. Is there right and wrong in nature? Why do you think so?

5. Is acting ethically (i.e., according to what we think is right or wrong) as humans something that can possibly help nature? Can you say why?

6. How do ethical choices humans make relate to the balance of nature? Does this mean acting ethically, at least in some cases, is *natural?*

Its simple. Here's how it works:

(1) First reflect on or think about your responses alone.

(2) Next pair up with at least one other person.

(3) Last, share your responses, noting at least one interesting thing the other person said.

Who did you share with?

List one or more comment(s) from each of your partners.

Comments

APPENDIX 3: Ecology/Sustainability Project Description – Sir William Secondary

Ecology - Sustainability Proposal **Description**

- Work in groups of 2-4
- Choose a topic related to some area of ecological sensitivity: an area requiring balance between human activity and nature.
- Research and construct a proposal for how humans interact with nature in future in your topic area.
- Specify an audience for your proposal. Possibilities include: your school administration; a community action group (specify which group); a city council meeting; a meeting of provincial government people; a meeting of federal government people (e.g. Ministry of Environment people); or, another appropriate audience of your choice (and which you specify).

Criteria and due dates - Proposals must include the following to get full marks:

Item	**Due Date**	*Amount*
Title of proposal	Nov. 29th	1 mark
Description of proposal	Nov. 29th	3 marks
Intended Audience	Nov. 29th	1 mark
Ethics Related to Issue – 1 paragraph minimum using at least 2 ethics terms from class (a list of terms will be provided in class).	Dec. 5th	15 marks
2 QUEST scenarios comparing possible outcomes for your topic. Completed in class Dec. 9th & 11th on 'Scenario Sheet' hand-outs.	Dec.9th & Dec. 11th	20 marks [2x10 marks]
Ecology Related to Issue – 2 paragraphs minimum using at least 5 ecology terms from class (a list of terms will be provided in class).	Dec.17th	20 marks [3x5 marks]
Conclusion – Why is your proposal a good approach to the issue?	Dec.19th	10 marks

/70 marks total

Possible Suggestions for Projects (for those who don't feel creative):

- Farmed salmon in the Georgia Strait: What are some of the issues?
- Over-fishing: Challenges in predicting population levels and what this means for fish quotas.
- Housing in Vancouver: Community and urban planning issues.
- Kyoto Accord: Possible implications for transportation and industry in BC.
- Oil spill off the coast of Spain: "What if a similar event happened in the Georgia Strait?"
- Forests: Old growth versus secondary growth forests **or** Jobs versus ecosystems.
- Water: Urbanization and Water Quality **or** International Trade of Hydro Power.
- Garbage: Dumps and Domesticization of Wild Mammals **or** Toxic Waste Sites

APPENDIX 4: Final Interview Questions – Sir William Secondary

Sustainability and Science

1. Think back to the unit on ecology and sustainability. Is there anything that stands out as something you will remember about what you studied? What was memorable about it? <or> Why do you think none of that unit was memorable for you?
2. Can you describe the difference, if any, between the study of ecology and the study of sustainability?
3. How important in your view is the study sustainability for learning science?
4. Did anything surprise you in what was studied on sustainability? Can you describe what it was that surprised you? Why did it surprise you?
5. Recall when we studied sustainability, there were often different views on what should be done about an issue. How important do you feel it is to discuss opposing points of view when studying science?

Science, sustainability, ethics and society

6. Have any of your thought about what science is changed as a result studying sustainability?
7. In deciding what should be done about sustainability issues, what is the role of science and scientific experts in your view? Is *knowing* science in such cases all that is important to make the right decisions? If not, what else is important in your view?
8. What about other people in society, like you and me, who are not scientists? What role should we have in deciding what should be done about sustainability issues?
9. Do you think that knowing science makes someone more likely to act in ways that are good? Can you say why you think so?

Science education

10. In your view how important are feelings to learning science? For example, is learning about what it might mean to care for nature, something you see as important in learning science? Can you say more about why you think so?

11. Do you feel there can be a conflict at times between learning a lot of facts in science and learning what is best for the world or society? Can you say more?

12. How do you think a person's interest in science depends on his/her grades in science? Can you describe how your attitude to science might change if there were no grades when learning science?

13. If you could have any kind of science class, what would it look like?

QUEST

14. What were your first impressions of the QUEST program?

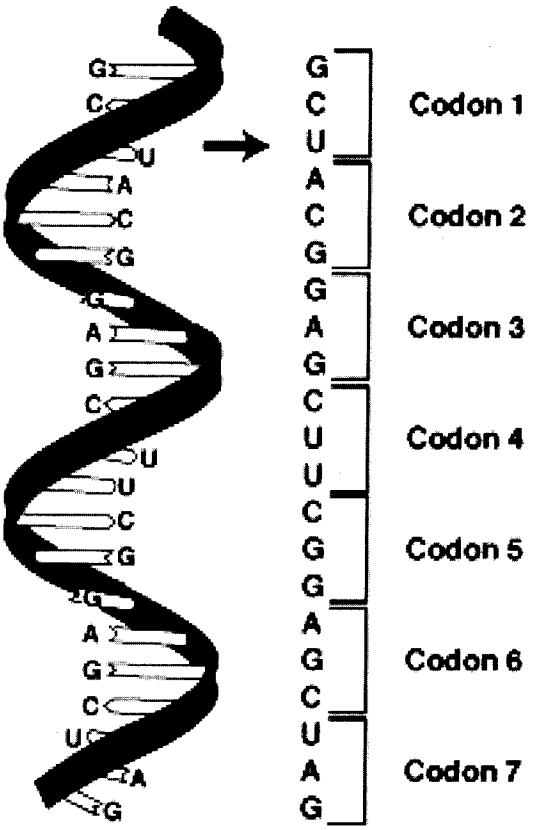
15. Are there certain things you liked or didn't like about QUEST? Can you say what they were?

16. Are there ways that computer programs like QUEST can help us to think about issues of sustainability? If so, can you describe how?

APPENDIX 5 : Genetics Mini-lecture – Summit Secondary

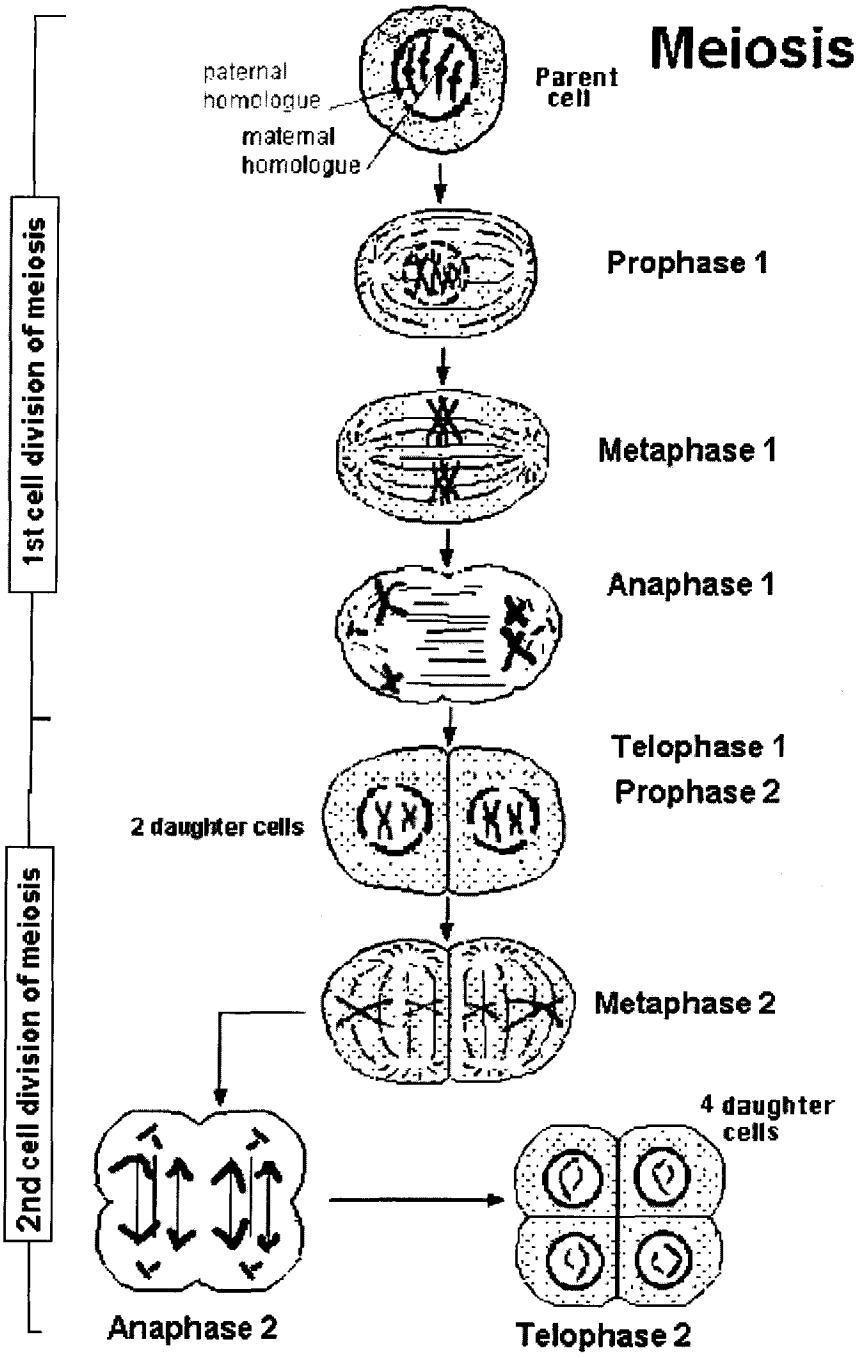
MOLECULAR GENETICS BASICS:

- A ***gene*** is an instruction to produce a ***protein***
- A ***protein*** is made up of ***amino acids***
- An ***amino acid*** is made according to instructions on DNA called a ***codon***
- A ***codon*** is three units of the ***genetic code***
- The ***genetic code*** is the exact order of four bases (a kind of chemical molecule) that make up a DNA or RNA sequence.



RNA

Ribonucleic acid


Meiosis
paternal homologue
maternal homologue
Parent cell
Prophase 1
Metaphase 1
Anaphase 1
Telophase 1
Prophase 2
2 daughter cells
Metaphase 2
4 daughter cells
Anaphase 2
Telophase 2
1st cell division of meiosis
2nd cell division of meiosis

Why every offspring is (usually) different

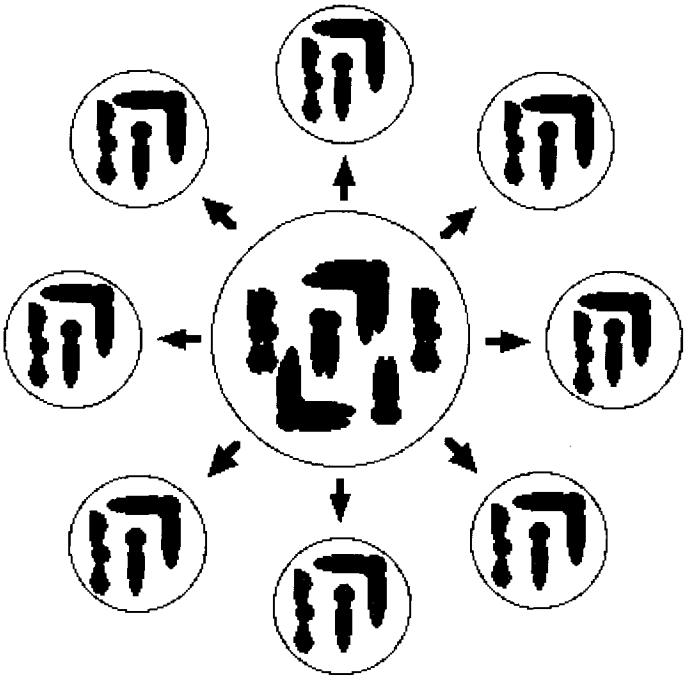
- There are 3 principal sources of diversity in offspring:

    1. ***Random Assortment of Chromosomes*** from Mom and Dad during meiosis;

    2. ***Crossing Over*** during meiosis

    3. ***Fertilization***

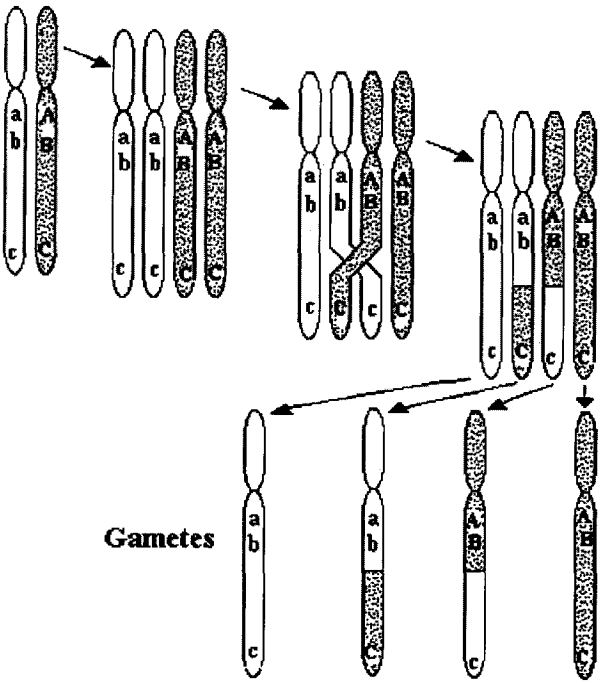
- ***Random Assortment of Chromosomes*** from Mommy and Daddy occurs during meiosis…



- ***For example:*** for the 3 pairs of chromosomes shown at left - 3 from Mom and 3 from Dad – there are 8 possible combinations for the sperms or eggs produced (these are shown around the outside of the central circle)...

- But for all 23 pairs in humans, there are 8,388,608 possible combinations of chromosomes for a single sperm or egg!

- ON TOP OF THAT, no chromosomes is exactly the same as EITHER Mom's OR Dad's, since there is also what's called ***crossing over*** - or ***recombinance*** - of the chromosomes!



Crossing-over and recombination during meiosis

- ***Crossing Over*** is where analogous sections of DNA on sister chromatids are swapped during meiosis, as shown at right

Gene splicing – How it works

-

- ***Plasmids*** are sections of non-chromosomal DNA; often a circular shape

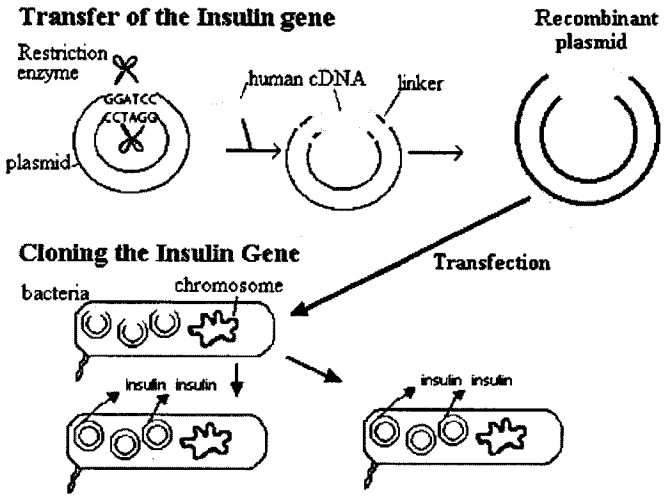
- ***Phages*** are viruses that infect bacteria

- ***Vectors*** are used to transfer modified or foreign gene into a new host cell or group of cells. ***Plasmids*** and ***phages*** are the two main kinds of vectors used in gene-splicing research. Desired plasmids for use in research are usually antibiotic resistant (see below).

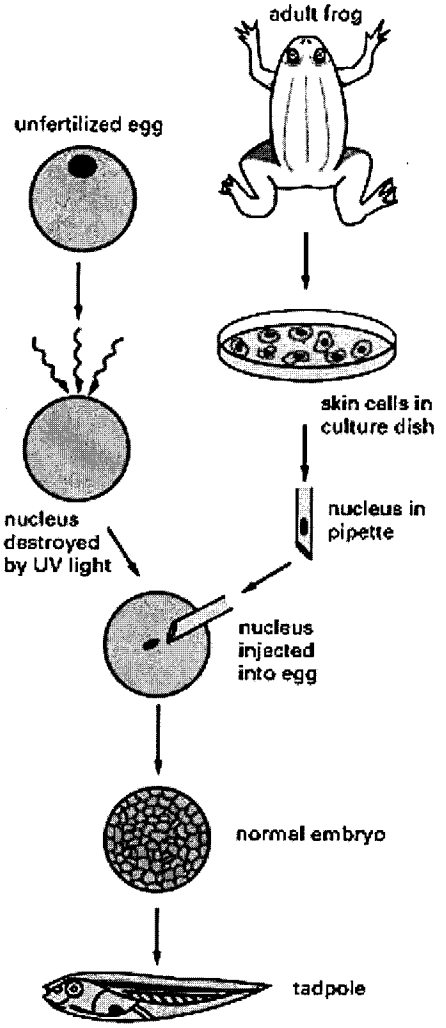
- ***Modified DNA is replicated in the new host*** (usually bacteria), along with the rest of the host's DNA.

- Host cells are grown (reproduce) in a cell culture; antibiotics can be used to identify and purify the culture (get rid of non-cloned cells).

2 kinds of cloning:
dna vs. organism cloning



Transfer and cloning of the Insulin gene



dna cloning

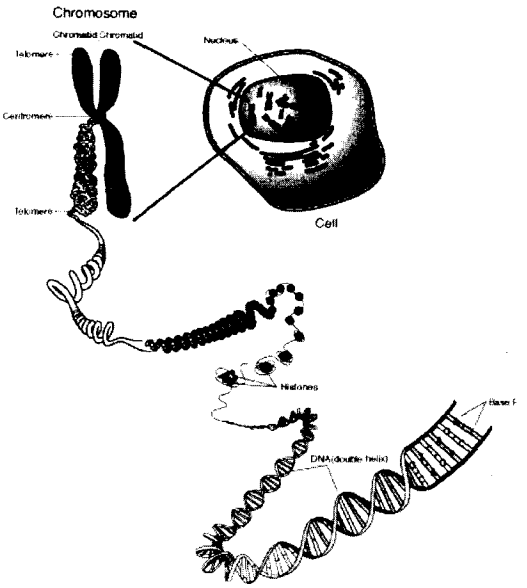
organism cloning

3/4

APPENDIX 6: 'Ethics and Genetics' Assignment – Summit Secondary

Ethics and Genetics **Questions To Get You Thinking...**

From what you've heard today about gene-splicing and genetic research, what are some of your initial thoughts about this research and its role for the future?



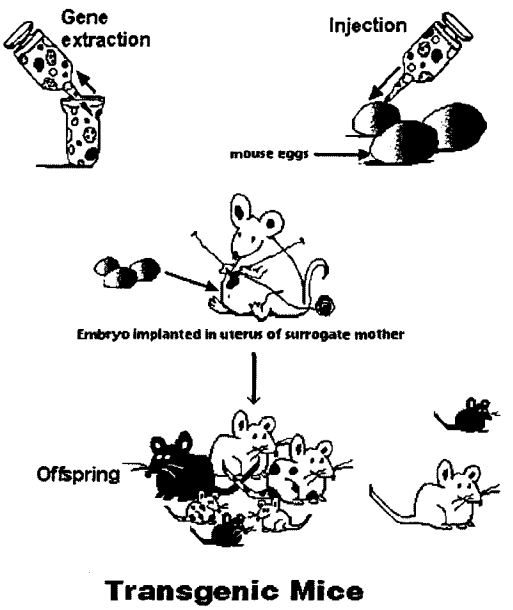
1. Is genetic research something that should be controlled in society? If so, why? If not, why not?

2. Who should decide what kind of research is allowed in our society? And how should this decision be reached?

3. Is there ever a definite right and wrong when it comes to what should be a part of genetic research? Or are there simply different points of view? Explain your response.

4. The outcomes of genetic research at times are described as involving potentially *higher* amounts of uncertainty and *greater* stakes for the world, than other kinds of science. If scientists are not able to say what will happen, and where the consequences could be very serious, how should we deal with such situations as a society?

Interview someone else about their responses... **Write your notes in the space below:**



What differences and/or similarities did you note between your views and those of your partner's?

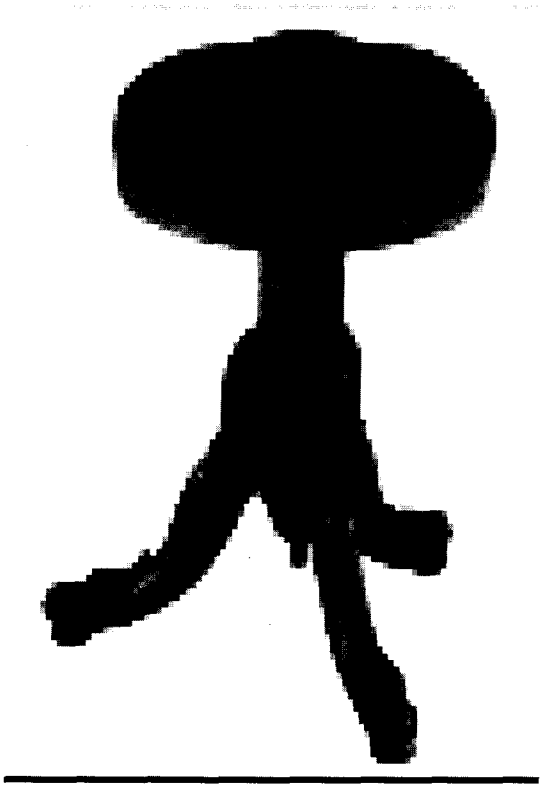
Now team up with two other pairs of partners. Discuss as a group your various points of view, and see if you can come to any agreement on the issues discussed. If your small group is seen as a mini-society, how would describe your ability to come to an agreement about how genetics research should be managed in society?

APPENDIX 7: '3-Legged Stool' Model of Sustainability – Summit Secondary

Are Developments in Genetics of Equal Value to Everyone?

Developing scientific knowledge can be expensive, and at times leads to technologies that harm the world. Such concerns as these raise the following question: **'How do we assess the value of different kinds of scientific research?'**

One way to answer this question is to look at how *sustainable* the knowledge is for the future.



To develop ***sustainable*** knowledge means 3 areas of consideration:

- ***Nature*** - How will the natural world be affected by the research?
- ***People*** – How will people be affected? And how will important decisions be made surrounding the research??
- ***Money*** - How is the research paid for? And who benefits as a result?
-

3 legs of the sustainability stool: In pursuing a particular direction of knowledge failing adequately to consider each of *nature*, *people*, and *money* is likely to lead to increased problems for the future; (in other words, without all 3 legs the sustainability stool falls over!)

APPENDIX 8: 'Sustainability Proposal' Assignment – Summit Secondary

Your task is to develop a 'sustainability' proposal for your topic area

Begin by answering the following questions:

1. *What are possible consequences for the natural world related to your topic? OR What are possible consequences for what is seen as 'natural' related to your topic?*

2. *What are some consequences for different groups of people related to this topic? Think of all groups who are likely affected (including groups in the future, if appropriate) and different consequences for each of them.*

3. *What are some of the money issues related to this topic? Are different groups of people (or countries) likely to benefit differently depending on how much money they have?*

4. *Based on your responses to questions 1-3, describe a proposal for how best to deal with this issue. Include considerations of each of nature, people and money.*

- Scientists working with the Council for Responsible Genetics have documented hundreds of cases where healthy people have been denied insurance or employment based on genetic "predictions."
- Most genetic tests cannot tell us if a genetic mutation will become manifest; if it does do so, it cannot tell us when in life this will occur; and if it happens, how severe the condition will be.
- Many genetic conditions can be controlled or treated by interventions and environmental changes; that is why governments mandate testing newborns for PKU (the inability to metabolize the amino acid phenylanaline; which if untreated at birth results in severe mental retardation).
- Examples of genetic discrimination:
    - A pregnant woman, whose fetus tested positive for cystic fibrosis, was told by her health insurance company that it would be willing to cover the cost of an abortion but would not cover the infant under the family's medical policy if she elected to carry the pregnancy to term.
    - A healthy boy, who carried a gene predisposing him to a heart disorder, was denied health coverage by his parents' insurance company, even though the boy took medication that eliminated his risk of heart disease.
    - A well woman in her 30s whose genetic test indicated a 70 to 90 per cent risk of developing cancer. Despite having regular screening for cancer, her life insurance was cancelled.

- Those who oppose human cloning point to the disgust of a style of reproduction with such profound potential for vanity (i.e. reproducing oneself), arguing that the freedom of children and nature of the family are in danger.
- Proponents of cloning suggested it might serve as a new, unusual but perhaps effective treatment for infertility, enabling those unable to pass genes to future generations to do so in a way that is at least analogous to the familial linkage of twins.
- As has been pointed out by scholars and politicians, early human experiments are likely to result in a number of clinical failures and lead to miscarriage, the necessity of dozens or even hundreds of abortions, or births of massively deformed offspring. Recent study of mammalian cloning also suggests that a number of defects often created in the reprogramming of the egg do not manifest themselves until later in the life of the resulting clone, so that mature clones have often undergone spectacular, unforeseen deaths.
- Legal scholars have argued that cloning may violate a child's "right to an open future" (i.e. to its own life); others have argued that no child has an open future.

- When food-crops are genetically modified, one or more genes are incorporated into the crop's genome. Data on the safety of these are scarce even though they can affect the safety of the GM crop. For example:
    - DNA does not always fully break down during digestion. Gut bacteria can take up genes and modified bacterial DNA

and this opens up the possibility of the spread of antibiotic resistance, making it difficult to treat infections.

- Insertion of genes into the genome can also result in unintended effects, since some of the ways the inserted genes express themselves in the host or the way they affect the functioning of the crop's own genes are unpredictable. This may lead to the development of unknown toxic/allergenic components.

- GM tomatoes: The first and only safety evaluation of a GM crop, the FLAVR SAVRTM tomato, was commissioned by the company who invented it, as required by the FDA (Food and Drug Administration). This GM tomato was produced by inserting bacterial genes into a tomato. .The results of the test claim there were no significant alterations in total protein, vitamins and mineral contents and in toxins. Therefore, the GM and unmodified tomatoes were deemed to be "substantially equivalent". However:
  - In toxicity studies with male/female rats which were tube-fed GM tomatoes, seven out of forty rats fed on GM tomatoes died within two weeks for unstated reasons.
  - These studies were poorly designed and therefore the conclusion that FLAVR SAVRTM tomatoes were safe does not rest on good science.
- While billions of dollars are spent developing commercial crops for Western countries to withstand pests, the companies have done little research on crops vital to developing nations. To fill that gap, some public organizations are creating food crops with nutritional benefits, such as "golden rice." Rich in beta carotene,

the rice can prevent blindness in children. . The problem is that the company Monsanto owns the patent.

- The central debate here concerns ownership of resources and how to reconcile the patenting system of the developed world with the community-held knowledge systems of poorer countries.
- If foreign researchers and TNCs can patent indigenous crop plants without compensating the communities who provided them, there are fears that farmers will end up paying royalties on the products of their own knowledge, products on which they rely for survival. The following are examples of such patents:
- In 1994, two researchers from the University of Colorado received a US patent on male sterile plants of a traditional Bolivian 'Apelawa' quinoa grain. They claim they were the first to identify and use a reliable system of male sterility in quinoa for the production of hybrids, although Andean farmers have long known that the male flower of the Apelawa variety is sterile. Quinoa is a high protein cereal and an important dietary component in Andean countries.
- In September 1997, the US company Ricetec, Inc., was granted a patent on Basmati rice. The patent is for a variety achieved by the crossing of Indian Basmati with semi-dwarf varieties, and it covers Basmati grown anywhere in the Western hemisphere. Ricetec also claims the right to use the Basmati name. The Indian government has challenged Ricetec's claim, arguing that the patent jeopardizes India's annual Basmati export market of around US$277 million, and threatens the livelihood of thousands of Punjabi farmers.

APPENDIX 9: Interview Questions – Summit Secondary

1. Using your own words can you describe what you think nature is?

2. If someone says something is or isn't 'natural', what does this mean in your view? How does this relate, if at all, to what nature is?

3. Would you say there anything that is the opposite of nature? Does this relate to what is the opposite of 'natural'? Can you say more?

4. What are some ways you've learned what nature or natural mean?

5. In your view is there right and wrong in nature? <wait> For example, would you ever say: 'That's wrong because it's not natural?' What are some possible examples?

6. Are humans different when it comes to ethics or what's right and wrong for us to do? How would you describe the difference? <or> Why not?

7. Do humans have responsibilities to help nature? Do humans have responsibilities to help other humans? Can you say more about why you think so?

8. Let's turn now to science. Using your own words, what would you say science is?

9. How would you say science helps us, if at all, to understand nature?

10. Do scientists have responsibilities when it comes to nature? How would you describe these responsibilities? <or> Why not?

11. What are your first impressions when you think of genetic research today?

12. Where have you learned or heard about genetics and genetic research other than science class?

13. Do you have concerns about what's happening in genetic research? What sort of concerns do you have? <or> Can you say more about why genetic research is not a source of concern for you?

14. In your view are genes part of nature? Are genes that a scientist has modified part of nature? Can you say more about the difference <or> similarity?

15. How should people in society decide what scientists should and should not be allowed to do when it comes to genetic research?

16. What recommendations would you make if you were deciding how we in society should manage controversial issues related to science?

17. What role should science classes have in your view, in discussing what scientists should and should not do?

18. Final comments?

APPENDIX 10: Proposed Empirical Research Questions for Future Study

Ten Proposed Research Questions (PRQ) for Future Empirical Study

PRQ1: How do those school science students whose self-understanding includes belonging to a generation responsible for needed world changes, attribute authority to science in relation to this understanding?

PRQ2: How do science students' understandings of sustainability (science and ethical understandings, respectively) contribute, if at all, to their understandings of agency (personally and collectively as a society, respectively) in relation to sustainability issues?

PRQ3: What is the contribution, if any, to students' science understandings resulting from a) providing forums for students to voice attitudes regarding science learning and issues of sustainability?; and b) incorporating suggestions when possible for changes to science teaching and learning arising from such forums?

PRQ4: How does inclusion of educational content contrasting different understandings of 'nature' and 'natural' in relation to human activity and traditional ecological science, respectively, contribute to a) student science understandings; and b) student ethical understandings?

PRQ5a: What correlations exist, if any, between science students' attitudes towards school and classroom sources of authority in general, and sources of authority underwriting curricular science topics?

b: What contribution, if any, does more explicit separation of classroom management and evaluation authority from sources of authority underwriting curricular science topics, have on students' science understandings?

PRQ6: What features of sustainability education programs most stand out in contributing to students' self-understandings of their agency in relation to sustainability issues?

PRQ7: How do students' understandings involving religious topics contribute, if at all, to specific ethical and science understandings they hold regarding genetics and genetics research?

PRQ8a: How do science students assess and negotiate risk and possible trade-offs in decision-making over the course of a case study focused on high stakes, low certainty scientific research?

b: What factors (i.e. sources of authority) contribute to student understandings in this area, and how do they evolve over the course of the case study?

PRQ9: What are likely contributions to student understandings of socioscientific issues, if any, arising from student involvement in selected group decision-making activities?

PRQ10: What lessons for how best to develop sustainability education components for inclusion within conventional school science curriculum, arise through consultation with science students participating in a case study exploring specifically contemporary challenges facing socioscientific decision-making in the world today?

The University of British Columbia
Office of Research Services and Administration
Behavioural Research Ethics Board

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	NUMBER
Erickson, G.L.	Curriculum Studies	**B01-0481**

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

Public Schools , UBC Campus,

CO-INVESTIGATORS:

Andruske, Cynthia, Educational Studies; Doughty, Nicola, Educational Studies; Moore, Janet, Educational Studies; Rogers, Larson, Educational Studies

SPONSORING AGENCIES

Social Sciences & Humanities Research Council

TITLE :

Sustainability Education Initiative of the Georgia Basin Futures Project

APPROVAL RENEWED DATE	TERM (YEARS)	AMENDMENT:	AMENDMENT APPROVED:
MAR 2 6 2003	1	March 4, 2003, New PI	

CERTIFICATION:

The protocol describing the above-named project has been reviewed by the Committee and the experimental procedures were found to be acceptable on ethical grounds for research involving human subjects.

Approval of the Behavioural Research Ethics Board by one of the following:
Dr. James Frankish, Chair,
Dr. Cay Holbrook, Associate Chair,
Dr. Joe Belanger, Associate Chair

This Certificate of Approval is valid for the above term provided there is no change in the experimental procedures