RETURN TO REALITY: A CAUSAL REALIST APPROACH TO RE-CONSTRUCTION IN SCIENCE TEACHING.

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Declaration

This thesis does not contain material which has been accepted for any other degree in any University. To the best of my knowledge and belief, this thesis contains no material previously published or written by any other person, except where due reference is given in the text.

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Abstract

Science education is an intellectual and practical discipline and should indeed remain so. But the question is, should we allow philosophical arguments about science education's social foundations, for example the possibility of knowledge, capture us too much? It is my contention that simplicity in meta-theoretical issues is a good strategy. If a simple platform for science teaching and research could be formulated and accepted, more time and energy could be devoted to the main objectives of the discipline to do with explanations of the development and impact of science in society.

Because of their mysterious connotations and general vagueness, both positivism and ultra-relativism in social constructivism tend to necessitate years of cumbersome philosophical studies. Realism does not have these implications. "Realism" was employed to signify ontological assumptions; in particular the epistemological position that we have provides at least partial access to social reality, enabling valid but fallible knowledge about it. "Causal" in causal realism is employed to suggest a general orientation in science education research - to explain by identifying generative mechanisms. The concepts of mechanism, causality, and explanation must be recaptured from the positivistic tradition. In particular, they must be tied to ontology, not simply epistemology.

In the second section I examined the ongoing debate between "cognitive" and "situated learning" teaching approaches, in terms of methodological individualism, holism, and micro- and macro-sociology. By way of the natural sciences, I suggested a way out of these dilemmas is simply to start with accepting that what is happening in science
education is work being conducted on several levels - discourses, agency, and structures - producing relevant knowledge and plausible explanations. Through the analysis of one specific science education program Science, Technology and Society, I attempt to understand and reveal the oversights or issues that are inherent in this platform, so as to provide a stronger theoretical model for future curriculum reform within science education and future science education research directions.

I argue that a socially grounded science education would benefit from employing ontology and an attempt to seek to identify specific objects of knowledge for each level. This would mean that new, theoretically informed research tasks would be developed for science education at each level. A level division would enable science educators to focus more exclusively on puzzles of his or her favourite level: it would facilitate comparability between rival explanatory modes at the same level, it would favour cumulatively, and it would lead to a deepening of specific theories. If science education is to retain its autonomy, avoid turning into social statistics, and/or ethnology, and/or quasi-philosophy, it is important that it raises its ambitions. Since "there is nothing as practical as a good theory", theoretical advances would most likely facilitate transformation of science education into a more strategic, interventionist social science. It is argued that a transformational model of teacher agency coupled with a causal approach probably constitutes one of several possible first steps towards the epistemological break that is necessary if science education wants to leave its present phase of natural philosophy and become a genuinely explanatory (social) science.
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Chapter 1

Research Approach to the Study of the STS Movement in terms of its Understanding of Learning within a Social Context and Transformational Model of Social Action for Teachers.

The main purpose of this thesis is to contribute a critical realist foundation for science teaching and research. To strengthen the social theory building of those teachers and educators who seek to reconstruct science education for all in a social context. To meet what is frequently claimed to be an internal crisis\(^1\). In the thesis I present arguments based on critical realism further to explain the apparent failure of the Science, Technology and Society (STS) movement as a transformational model of social action in science education reform. The structuration theory of Bhaskar (1978) and transformational model of the society – person connection rightly insists on reuniting structure and agency. But the idea that social structures are continually reproduced and modified by knowledgeable agents, who nevertheless do so unintentionally, does not by itself furnish answers to the question of when and how agents can intentionally change society.

For this, a further form of knowledge ability is clearly required, as is a change in practice, which breaks with the ongoing round of accidental social reproduction. 1

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\(^1\) In my opinion, it is erroneous to say that science education finds itself in a special acute crisis today. The situation was the same ten, twenty and thirty years ago. Of course this all depends on how we define the concept of crisis, as we know, Kuhn defined crisis as a departure from normal science. During a crisis practitioners begin examining basic assumptions of their discipline, as philosophic assumptions and methodological principles and start looking for paradigm candidates. The crisis ends when the main presuppositions of the discipline are again taken for granted. Now I do not think that science education even has been or will become a normal science in this sense. Clearly, however, the end of the 1960s was characterised by the proliferation of paradigm candidates that have persisted in different forms.
agree here with New\textsuperscript{2} that ever in this extraordinarily volatile era, deliberate social transformation is within the scope of individuals and collective agency.

To achieve this I will take a step back to the debate on the nature of structure and agency and the socio-scientific theories that have been developed in this area, and the more widely understood and central debate between situated and cognitive learning in the field. My argument is grounded in two convictions:

1. Science education badly needs a new philosophy of science that can provide a complete platform and shared general goal for its practitioners.

2. Contemporary science education research must be strengthened as regards social theory and not merely theory borrowed from other areas\textsuperscript{1}. Science education research must seek to be an explanatory science, implying a deepening of its own theoretical knowledge. A corollary belief is that a critical preparation for improving theory developed is theoretical elaboration of the object of science education.

By the object of science education I refer to the delineation and definition of the reality science education purports to explain, which is not the same as spontaneously observed reality but rather in mediated form in specific objects of knowledge, or models of science teaching and learning. Two such models are situated and cognitive

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\textsuperscript{2} Our identity can no longer reside in a common methodology. Our methods and techniques of data collection – interviews and surveys, public statistics, statistical elaboration and so forth are shared with most social scientific disciplines. Neither is it a particular subject matter or area that provides identity – our object of study, such as formal organizations (political science), interaction (psychology), cultural artifacts, experiences and mores (ethnology), tradition and social settings (history and sociology) – are habituated by others. Our identity resides in our particular perspectives and conceptual frameworks and our own models of explanation, that is in our theories of science education—teaching and learning.
teaching and learning. They are objects of knowledge, presuppositions for explanation that may allow us to define the domain in which a causal relation will be able to be located⁴.

I seek to reveal possible oversights or mistakes of purpose within the STS platform and in doing so will provide a stronger theoretical model for future curriculum reform in science education. I want to mention that originally the idea of this thesis was to present one consistent line of thought and refrain from going into details, anticipating possible objections and so forth – to philosophise with an axe not tweezers!

However, some discussions of my topic have taught me that this is almost impossible, strident objections creep up, diverting attention from the main issues. Therefore, this thesis has a number of footnotes where I reflect on some critical comments. Perhaps I should also mention that “nothing new” is presented here, rather, guided by the two convictions above, I rearrange old issues.

The purpose of this introduction then is to link this contemporary debate specifically to models of science teaching. The debate between the socially constructed situated learning and the in-the-mind data representations of cognitive learning provides a springboard for the more philosophically challenging analysis of critical realism in social systems. These theories, initially developed by Bhaskar (1978, 1983, 1986, 1989, 1993) in the mid 1970s, and further developed since then have yet to have a

⁴ As we know by now, reality is not observed directly but in mediated form, in both of these models of learning, hence the concept of “object of knowledge”, also called “transitive object”, “problematic” and more. Presumably the simplest concept is “model”; although it may give mistaken associations since “model” is also employed for more contingent constructions of conceptual systems. “Object of knowledge” refers to basic and shared images of a subject matter constituting the platform for a generation or school of researchers or students. Thus it refers to something that is theoretically elaborated, not “spontaneously observed” reality. Teaching and learning models are objects of knowledge in science education forming the presuppositions for explanation and defining more precisely domains in which teachers and researchers have sought causal relations.
major impact in educational circles. Critical realism, the debate it generated, and subsequent theories that have more recently been developed, such as those of Giddens (1979, 1984) and Archer (1995, 1996) have changed the ontological and epistemological landscape of the social sciences. Critical realism describes the fundamental underpinning of situated learning; as such, it is essential I believe, that sociological theories of social interaction, construction, participation, reproduction and transformation be applied to science teaching.

The critical realist theories of society evolved from a backlash against the application of science and scientific methods and theories to explanations of society. If science teaching is a social activity performed by actors (teachers and students) who act in particularly socially defined ways, it would appear to be imperative that science educators understand and implement a critical realist stance to curriculum development. To exemplify this contention, I will study the literature that exists on social theories, present it in a form that can be easily applied to science teaching and learning, and use a critical realist stance to examine the Science, Technology and Society movement. By applying a critical realist model or program to the STS schema I aim to understand the nature of science teaching reform, and to reveal the aspects of social theory that need to be understood and applied to science curriculum reform—in order to effect its intentional transformation and avoid unintentional reproduction.
1.1 Philosophies of science and science education

A philosophy of science constitutes a super-structure to a specific science, a theoretical framework that the science in question is perceived and understood, and by which scientific criteria are formulated. A theoretical structure is both constraining and enabling. It points out what is scientific and what is not, what counts as legitimate methods, proper modes of solution, relevant problems and so forth—in brief, it presents a number of criteria, rules, demands and ways of procedure. During one phase a philosophy of science can exert a progressive influence, but later turn into having stagnating or even degenerative effects on a given discipline.

Logical positivism as formulated by the Vienna Circle during the 1920s constituted a powerful reaction to neo-romanticism and to loose speculations of the 19th century, often Hegel-inspired. As a contrast to metaphysical speculation it emphasized certainty and empirical verifiability. In this sense positivism was progressive, simultaneously constraining the scope of scientific discourse and opening a rigorous field of possibility by insisting on empirical anchorage. More recently, however, positivism in social science, such as science education, has come to be equated with observability, quantification and measurement, often for its own sake.

The critique of positivism launched in the sixties can be explained in many ways, for example. Socio-politically, but the critique also indicates that in several areas, positivism had changed from progressive to a dogmatic, stagnating meta-theory. The anti-positivist reactions sought to liberate the science from stereotypes about a neutral and objective observational basis in order to enable theories that "produced" new
types of observations, in science education. The results of Thomas Kuhn’s and especially Paul Feyerabend’s critiques of positivism and critical rationalism, also empiricist, were transformed into extremely relativist philosophies of science in the seventies.

These two traditions, which without further qualification are summarised as positivism, and a set of epistemological relativisms, continue to dominate the science education arena. They constitute opposing poles in discussions of the purpose of science education. Positivism has evolved into "social statistics", which should be separated from a theory of science education with explanatory ambitions. Ultra-relativism has resulted in post-modernism, post-structuralism, social constructivism, discourse analysis, linguistic, and cultural turns. Common to the latter is the denial of scientific criteria and also sometimes denial that scientific conceptual systems have any reference to external reality whatsoever. In these cases, science is understood as discourses involving concepts the objects of which do not exist or are constructed in the scientific process; the referent is merely one more reified construction.

Solomon who has an interest in the impact of constructivist ideas on science education (Solomon, 1994, 2000) has commented on problems associated with constructivism as a method of teaching science and various brands of constructivism, her worry about the impact on science education of the 'science wars' between the scientific realists and the relativists, and basic uncertainty about how to respond in the teaching context. She concludes for example in the later work:

"Students actively discussing ideas about the meaning of experiences, whether their

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own or others, seemed to be so near to the heart of the whole educational enterprise that, whatever the drawbacks of constructivism in action, it made constructivism continue to seem attractive."

When this is said it should be admitted that it is very difficult to pinpoint what "positivism" and "ultra-relativism" actually stand for; both these -isms are characteristically vague. To my mind, however, ultra-relativism can in many respects be understood as a reaction to, even the other side of the coin of positivism. Methodologically, we have on the one hand empirical variable analysis and a general emphasis on quantitative methodology, on the other discourse analysis, narrative, and a general emphasis on qualitative methods. Both provide highly constraining rules; on the one hand, non-observable entities are forbidden, on the other, all accounts of the social must be based on, for instance, the intentions of the acting subjects.

Epistemologically, while one side sharply demarcates scientific knowledge from other forms of knowledge, the other denies the existence and the possibility of demarcations.

While one underscores the superiority of science, the other underscores the relativity and indeed the equality of all knowledge claims. Ontologically, one side is phenomenalist the other tends towards idealism. Politically, the early positivists as well as modern relativists see themselves as radical, itself a claim that can be questioned. Nowadays at least positivism is frequently associated with elitism and ethnocentrism, and relativism's denial of the possibility of superior knowledge seems to undercut the possibility of rational societal critique, turning us back to the old
"might is right". Feyerabend\(^7\) concludes explicitly: "Objectivism and relativism not only are untenable as philosophies, they are bad guides for a fruitful cultural collaboration". Sutton\(^8\) argues that in the science classroom the use to which language is employed both embodies and embeds a philosophy of science—a exclusive emphasis on a labeling function reinforces an objectivist position while an interpretive function emphasises a relativist orientation.

1.2 Meta-theoretical Requirements

We need a conception of science education as science that does not hamper the research process and educational imagination and yet promotes a reasonable common effort towards certain general and shared goals—a theoretical superstructure facilitating cumulative research.

This need is not lived up to by extant philosophies of science. Hence the term "meta-theory", which stands in for a general philosophy of many sciences and a particular science. What needs should such a superstructure of science education fulfill? I think the following three requirements are crucial:

1. A meta-theory should be simple and straightforward as possible, without therefore being unsophisticated. By "not unsophisticated" I mean that it must take due notice of the most basic findings in philosophy of science, such as the thesis of the theory-dependence of facts, the existence of paradigms, that there are no absolute criteria in criteria of theory choice or truth, and link these to conditions and needs.


of the empirical discipline. "Simple" or straightforward implies that a science education meta-theory should not lead to years of cumbersome philosophical studies but rather constitute a platform guiding researchers towards the essential goal of their discipline (see below). Science education is an intellectual discipline and must indeed remain so, but basically in its own domain — too much diversification implies too much complexity, when we get too complex, we are unhappy. And when we are unhappy, our luck runs out!

2. A meta-theory for science education must, in view of the present fragmented status of the discipline, remain agnostic in regards to single theories and a method; that is it must advocate theoretical and methodological pluralism. At the same time, it must be able to point out general conditions and objectives for the discipline, regardless of specific theories and methods.

3. A meta-theory should emphasize that science education research must be of both disciplinary and social relevance. We can imagine these two demands as poles in a continuum. Research lacking social relevance deals with internal, esoteric puzzles. Of course, such kind of research is sometimes also crucial, but mainstream science education should concern issues of social and political relevance. The opposite, no disciplinary relevance, can be exemplified by public reports or politically or institutionally significant articles written by science education researchers in which no competence in science education is discernible; the report could have been written by anyone. The main part of studies in science education should seek to find an optimal balance between these two poles.

1.3 Causal Realism
Let me offer a simple outline of what I call "causal realism". The label seeks to distinguish the alternative from other meta-theories with labels like naive realism, empirical realism, scientific realism, and others.

Although there are clear influences from, in particular, critical realism, the proposed alternative is different.\(^9\)

The philosophical debates about various forms of realism (or materialism) and idealism appear perpetual in science education, and there are indeed no obvious philosophical or other methods to terminate them. I will not attempt any deep sea diving here but instead state four postulates or axioms of the causal realism that may suffice to allow me to proceed:

1. There is a reality existing independently of our representations or awareness of it. (ontological postulate).

1a. There is a social reality existing independently of social scientists’, including science educators’, representations or awareness of it (ontological postulate for science education)

2. It is possible to experience this reality (phenomenological postulate).

\(^9\)Here I regard critical realism as the most promising philosophy for the social science of science education today, and for the purposes of the present thesis I might as well have used this concept. The problem of critical realism does not reside in its basic content but in its terminology and some of its claims that I will refer to later. The term "critical" serves to relate science to an emancipatory ideal. However, neither Blakser nor Archer on whose scholarship it is usually grounded, has succeeded in establishing a link between critical realism or science and a political program, be it socialism or emancipation. The basic reason is, to put it simply, that it is not possible to establish such a connection except in the general sense that correct knowledge of conditions and causal relations is a useful instrument for attaining desired goals. This insight is not specific to realism (or materialism), or to any particular political program. Not even critical realism succeeds in transcending the divide between facts and values. Secondly I regard the term "causal" a better prefix to realism since it is the ontological recognition of underlying, unobservable, generative causal mechanisms that constitutes one of the distinguishing marks between realism and most other philosophies of science.
3. It is possible to achieve knowledge about this reality (epistemological postulate).

4. All knowledge is fallible and correctable (methodological postulate).\textsuperscript{10}

Causality, mechanism and stratified reality are three core concepts that require some specification here to clarify my position on each briefly.

First, causality is not defined as law-like universal regularities between observables, A and B. Brante\textsuperscript{11} points out that the bulk of science consists of \textit{causal explanations without laws}. Second, in practice causality occurs as tendencies, partly because causalities can counteract, entailing that expected effects or net-effects are not necessarily manifest in empirically observable effects. Third, we should admit the concept of causal capacity as a referent to a disposition or liability of an object or actor. Fourthly, presumably due to the extant positivistic conception of causality as constant conjunction, science education text are replete with “sensitising” connecting terms like “influences”, “affects”, “hangs together with”, “is correlated to”. Thus causality is intimately connected with understanding and explanation.\textsuperscript{12}

\textsuperscript{10}Postulate 1 serves to put an end to general discussions regarding whether science education really exists, if it exists only in the mind, and so forth. However the postulate does not imply that only “the material” exists. Science education reality is material and mental and meaning is stratified in sensibilities or culture, agency or actuality and structures or possibilities. Postulates 2 and 3 put an end to questions about the general possibility of science education, affirming or taking for granted that scholars in the past and up to the present day do say something about their objects of study; genuine science education knowledge exists. Postulate 4 seeks to take seriously the achievements made in philosophy of science: under-determination, theory-dependence, no truth-absolute criteria, paradigms and so forth. Postulate 3 also implies that scientific concepts in science may be constructed in the sense of having no real, external referent. However, the principal issue of reference is not a principal issue that can be resolved \textit{a priori} as many proponents of social constructivism seem to believe. On the contrary, it is something that has to be carefully empirically investigated in each case.


\textsuperscript{12}The relation between understanding and explanation is important.
My premise is that in science teaching and research we may have become too accustomed to thinking of the body as a purely physical entity, which is separate from the mind and from culture. Merleau-Ponty's\(^\text{13}\) phenomenology suggests that consciousness is not the product of some disembodied mind located somewhere outside the material world, beyond time and space; nor is it simply the result of a body reacting on its surroundings.

Instead consciousness may be considered part of the active relationship between humans and their world, so that prior to the Cartesian 'I think, therefore I exist' there is an 'I can', a practical cogito which structures not only our relationship to the world, but also the ways we think about it.

We are interested to explore how far we can argue that the transformation of meaning in classrooms may be seen as an integral process achieved through artifacts including words which mediate the relation between humans and the non-human world. In the work of Ilyenkov\(^\text{14}\), a Russian contemporary of Vygotsky's we found an understanding of this relation and the transformative power of artifacts such as the computer, symbols, signs and language, and how, along the way, they change the experience of embodiment of non human objects.

Observed regularities as such are not explanations. In order to understand regularities of the kind that we observe in, for instance lower literacy in science among children from lower social groups, it is necessary to identify social mechanisms that preserve real inequality. Most often this implies going beyond the surface of statistical


regularity. As Cartwright\textsuperscript{15} expresses it: “If only laws of association are admitted, the length of the shadow can as well explain the height of the flagpole as the reverse.” “Causal” in causal realism is employed to suggest a general orientation in science education research – to explain by identifying generative mechanisms.

The suggestion implies that concepts of mechanism, causality and explanation must be recaptured from the positivistic tradition. In particular, they must be tied to ontology, not merely epistemology (Nash\textsuperscript{16}). The concept of causality suggested here differs drastically from the positivistic conception since it is not overtly constricted by epistemological anxieties but is based on ontological concerns making it more open, admitting non-observable causes, structural causality, causes that are never manifested in observable effects, causes that appear only once, perhaps functional causality, and so forth.\textsuperscript{17}

To summarise this summary: instead of departing from a constraining positivist philosophy of causality implying skepticism and doubt it may be more suitable to set out from postulate 3 above. This means that we acknowledge that science education is indeed capable of obtaining and expressing genuine knowledge of social reality and


\textsuperscript{17} Granted such a concept of causality, a well-known difference between physical and social science can be formulated in a new manner. Physical science explains material structures and processes by means of discipline-specific conceptual apparatuses. During the course of history new concepts emerge while others are discarded. A primary reason for the rejection of some concepts is that they are shown not to denote real causal processes. For instance, the concept of phlogiston was rejected from chemistry at the end of the eighteenth century. It explained nothing since it did not denote a material phenomenon. In social science, by contrast, concepts with no material reference may have very strong explanatory force since beliefs and experiences can be strong causal powers. In other words, both material and mental causal mechanisms belong to the object of social science; both material and mental explanations are not merely permitted but indeed indispensable. This is the perspective from which sociological trends like social constructivism should be understood, that is as focusing upon the dialectics between material reality and mental or conceptual beliefs, how these mutually influence and “construct” one another. The common denominator of both movements is precisely causality – how reality is formed by out thoughts and vice versa.
then ask ourselves: if this is the case, what kind of world, what kind of causality, and what explanatory mechanisms must exist? We commence from science education's own knowledge, not from philosophical principles.

This means that science education should not deprive itself of the concept of causality because of the positivistic definition, positivism has no monopoly on this concept. On the contrary science education should accept causal relations such as structural causality, expressive causality, reciprocal causality, causal feedback loops, intentional causality, mechanism, explanation, cumulatively and the like are, duly redefined, indispensable. Ontologically, this position implies that not only observation but also causal capacity is a criterion of existence, which is one major reason for the label causal realism.

Science, be it natural or social - has no possibilities and no ambitions to describe or explain all causal mechanisms. The task of science education is to identify the relatively enduring structures and mechanisms that to a greater or lesser extent produce surface phenomena. A mechanism can thus be defined as the modus operandi that makes a situation transform into something else. Hence the importance attached to Bhaskar's Transformational Model of Social Action (TMSA) in critical realism and causal realism and to accounts of the social behaviour of science teachers in this thesis and the focus on the relationship between agential and structural forces in social science.

This introduces the third core concept in causal realism – stratified reality. Science has divided nature into a large number of subject areas and sub areas, corresponding
to an equally large number of academic specialties and subspecialties. This division has not been arbitrary – it is not an effect of academic competition and political decision. Indeed, there seems to be a historical and logical, or rather ontological, order for the divisions. The order indicates that nature is divided into levels. First come mathematics, then physics, chemistry and biology. These broad categories can be divided into subcategories, providing us with an evolutionist stratification of nature in a subatomic level, a molecular level, a cellular level, an organism level, and so on upwards. The logic is that each lower level is a precondition for the existence of each higher level. The higher levels constitute surroundings or environments that may have causal impact on phenomena at lower levels. This differs drastically from the numerous attempts to reduce reality to one ultimate level characterizing the mechanical educationists of the early nineteenth century, recurring in logical positivism's notion of a unitary scientific language. The reductionists tried to find the basic formula, the law by which all aspects of reality could be accounted for, the ultimate level of all levels. Science education may be situated in a position paralleling the phase of natural science of the early nineteenth century in the rupture between encyclopaedic knowledge and reduction. At present in social science there is widespread conviction that social reality can be reduced to one level, to one formula.\textsuperscript{18}

\textsuperscript{18} In contemporary science education to claim that the levels are autonomous is one thing, to say that they are real is another. To my mind, however nothing can be called autonomous if it is not in some sense real. So are the levels that I propose real? First it should be pointed out that the easy way out of this query is to say that levels are merely "analytic devises". That answer silences most people. How can an analytical device explain anything? I would agree that to proceed without taking into account the constraints of higher level social organization is to fail science education. However often this acknowledgement is left not to call for any special assertions about reality, but rest on the need for higher-level organizing constructs necessary for comprehensive explanations while acknowledging at the same time that other levels of reality are analytically as important as for example the person. Macro-structures seem to be both analytic devises and real – a clear contradiction in most senses of these terms. I think we should accept Durkheim's (1964) advice: treat social facts as if they were things. So in this sense structures are real. They have strong effects or potentialities that are utterly noticeable particularly when violated – life is governed by external, constraining and enabling.
Karl Popper expresses his version of the so-called methodological individualism in the following well-known manner:

"All social phenomena and especially the functioning of all social institutions, should always be understood as resulting from the decisions, actions, attitudes etc., of human individuals, and that we should ever be satisfied by an explanation in terms of so-called collectives"\(^{19}\).

All that is social must be explained at the individual level. A contrary position is found in for example Foucault’s structuralism:

"It is not man himself who thinks but he is thought by the thought system he happens to be caught in, he does not speak but is spoken to by the language he is born into, he does not act but is acted by the social, economic, political systems he belongs to. These changing structures perform as his master and destiny."\(^{20}\).

These two positions are examples of downward and upward reduction. They may be seen as extreme poles in a continuum between micro- and macro-social science, and they remain very common today. A similar issue is the agent-structure problematic introduced above. The most frequent attempt to resolve this problem involves

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suggesting a middle-position or synthesis. One of the most familiar examples is Gidden's theory of structuration, which by the formula “Structures are both the medium and the result of social action” claims to strike a balance between actor and structure by including both. The same goes for Bourdieu's concept of habitus, which merely rephrases an analytical problem. Formulas of this kind resolve nothing but rather conceal the problem by labeling it, drawing a tarpaulin over it.

Through an analysis of the selected writing of a key writer in the important Science, Technology and Society (STS) movement's attempt to restructure science education I hope to illustrate the usefulness of causal realism as a foundation for future research towards this end.

1.4 The Analysis

The analysis will investigate the underlying ontological assumptions about learning within the schema developed by the Science Technology and Society movement. This curriculum reform movement originated as a tertiary teaching project -Science in a Social Context (SICON) - undertaken during the early 1970's in the UK and elsewhere (principally the USA). This initiative was further developed both in the UK, USA and Canada, finally becoming a coherent science education and curriculum program. For the purposes of this study I am using the work of Joan Solomon, specifically her book Teaching Science, Technology and Society (1993), to represent the philosophy, program and pedagogy of the STS movement. To achieve this it is necessary to conduct a realist analysis of the societal rhetoric and schooling practices.

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referred to in the curriculum document itself and also the model of teaching and learning espoused. Solomon’s extensive publications give more access than others writing supporting the STS platform, to advise to teachers and also Solomon, has had a sustained interest in defining the philosophical foundations of science education.

Schwab (1983) attempted a complex account at the institutional level of the social organisation of curriculum and the professional development of experienced teachers or the Deweyan facilitators, what has variously been called educational commonplace perceptions or cultural universals. Others have dealt with the historical macro-conceptualisation and often-tortuous path taken to curriculum reform by American reform movements’ – academic humanist, social meliorist, child developmentalist and social efficiency, and the underlying social assumptions of these movements.

However, little of their work has elaborated on transformational models of social action useful in curriculum reform.

Many speakers for the STS movement have made comparisons between the curriculum frameworks in place around the world, for example the American Project 2061 developed by the American Association for the Advancement of Science (AAAS) (1994); Jenkins, (1992, 1996) on the British National Curriculum; Cross (1995), Fensham (1995) and Cross and Fensham (1996), along with a number of other Australian academics have made comparisons with the Science Victorian Curriculum and Standards Framework. However, this work has predominately been in terms of contrasting the outcomes and recommendations of the various government curriculum policy documents, rather than from the perspective of the underlying social theories that were embodied by the documents and collaboratively held by the document.
authors and implementing teachers. Much “top-down” social analysis has also been carried out into the evolution of each curriculum framework document, historical precedents and the political climate during the implementation and development of these documents (for example by; Fensham 1995).

Little of this science education research focused upon the holistic interaction of teacher agency and social structures. This thesis seeks to develop a critical realist model for understanding the relation between the realm of science education and science curriculum reform.

The thesis attempts a critique of embeddedness within the development, implementation, and aims of the STS movement – and its curriculum reform agenda within a realist analysis of learning theory and the social realm of science teaching. The research will be interpretive, making use of documentary and textual analysis. This will require the development of a framework from which the discursive behaviour can be investigated. I do not aim to research or comment on the actualisation of the written documents in terms of actual classroom as this is beyond the scope of this undertaking. I am trying to understand what it was that the STS curriculum writers and designers understood about the nature of science, science education and their vision of teacher agency, and how this affected the STS platform, its implementation, and the lasting influence on science teaching.

I treat here the development of curriculum schemata as politically embedded processes, which seek to promote and represent science in certain ways. What underlying assumptions, if any, did the STS movement, characterised by Solomon’s
work hold about the process, purpose and utility of student learning, and what vision existed for teacher agency within the pre-existing social constructs? These it is assumed should be evident in the finished documents.

This last point is an essential consideration, and it would be naive of me to think that I could represent the theories or beliefs that were held collectively and individually by the researchers who wrote for an STS platform. The key here is what was actually produced as models of social action in science curriculum reform. As Eisner and Vallance argue, the documents embody the assumptions, which they are built upon:

"The answers to the major questions in curriculum—and indeed the questions themselves—are most often couched in terms of the assumptions embedded in each orientation."\(^{23}\)

The extent to which different theories of learning are evident or assumed in the final curriculum document will be taken to be indicative of the relative importance given to them during development. The polemic within the STS documents indicates that they have been written with passion—often their rhetoric is appealing. This alone is commendable but not a reason to espouse them without developing a critical picture of what it might take to achieve the vision of science and science teaching that is put forward within the STS framework. All curricula are written with the aim of directing the way teachers teach, and all try to monitor both this change and the downstream implementation. I will not only attempt to understand the framework via the text of

the document and the political climate during its development but also against a climate of criticism by science and curriculum theorists.

The tension between cognitive and situated approaches to learning will always exist in curriculum schemata; this manifests itself, for example, in the difference in social analysis between the democratic representation of executive intelligence sought through a science-for-citizenship platform and the functional necessity to reproduce and expand a scientific technical class. A functional analysis of science curriculum frameworks will reveal that neither perspective ever completely disappears from the central thrust of the curriculum schemata—rather one paradigm is used in preference to the other.

The aims of the study are to provide a research model for future curriculum framework development, both at a localised school and at a state or national level. To challenge science educators to justify curriculum development, not only in terms of learning outcomes but also in the best traditions of scientific methodology, and to do so with due consideration of the underlying assumptions and theories which underpin the very undertaking that curriculum purports to represent. All this while maintaining a vision for teacher agency within a socially determined structure.

There is good support and precedent for this form of discursive interpretive research:

"My interpretation of research is as the process of finding out new information and explicating the associated
meanings, thus building new knowledge, or of making new connections between existing knowledges.\textsuperscript{24}

There are a number of issues that confront comparative interpretive research of this type; the issue of subjectivity is difficult to overcome in any form of research, let alone investigations into ethnographic or documentary analysis. I have deliberately situated myself as classroom teacher in this investigation, and as such understand that the realist analysis that I will perform will be constructed from within my own professional context.

Issues of subjectivity and decontextualisation also need to be considered. The analysis will be of my interpretation of other scholars’ work. As such, representing all of the meanings or implications, which were intended in the initial work, give rise to problems associated with misrepresentation. This is, however, a problematic aspect of all scholarly discourse. The debate between Greeno (1997) and Anderson et al. (1996, 1997), along with that of Goodman (1995) are cogent examples. Each person in the debate complained of being misrepresented, and then attempted to show where and how this had happened and could be overcome. Neither side, however, could agree on the differences let alone the possible solutions. This is an example of the ‘Tower of Babel’ problem, which arises when people with different paradigms treat similar issues, but from their own paradigmatic perspective. Although concerned with issues of misrepresentation, Goodman does not see this as a critical problem in discourse; rather, it is almost an inevitable result of commentary or discourse:

“Scholarship is always, on some level, a matter of interpretation and reinterpretation. ... By offering opportunities for scholarly exchange of ideas, the problem of representation can be addressed within a particularistic context. After all, it is this type of discourse that makes a field of study vibrant and alive. It is also these discourses that can foster the development of new thought collectives.”

Eisner and Vallance (1974) contend that many of the disagreements about curriculum direction and evolution, at least at a school-based level, can be traced to “a failure to recognise conflicting conceptions of the curriculum. Public educational discourse frequently does not bother to examine its conceptual underpinnings.”

The orientations and fallacies are put forward with supporting literature and explanations in order to simplify and organise the complex field of science education. Taken in conjunction with an analysis of competing learning theories, the data processing versus situated cognition models, and informed and determined by critical realism, I aim to unpack the STS manifestation and reveal the dominant paradigms or themes, which predicate the implementation of this curriculum framework.

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Chapter 2

The STS Movement

2.1 Genesis and Methodology of Implementation

The STS movement, as has been well described by Joan Solomon\(^7\), evolved through a growing awareness of and concern with the social impact of science and science education, from Bernal though to the Club of Rome and onwards. The STS movement as we now know it originated in a teaching project undertaken during the 70s in the UK, SISCON (Science In a Social CONtext)\(^8\). This, combined with the work of Aikenhead in Canada, Yager in the USA and other projects in developed countries has resulted in a broad philosophy that promotes:

"(1) An understanding of the environmental threats, including global ones, to the quality of life. (2) The economic and industrial aspects of technology. (3) Some understanding of the fallible nature of science. (4) Discussion of personal opinion and values, as well as democratic action. (5) A multi-cultural dimension."\(^9\)

The STS reforms grew from a visionary aspiration for what could be achieved in society. It nurtured the Deweyian concept of the power of ideas and sought to make links between students, society, science and technology.

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Interaction between members of society, science and technology was a fundamental underpinning of the relativist program. In addition to this, the constructionist theories of knowledge allowed the STS movement greater influence and claim over the positivist program. Situated learning theories have gained wider acceptance, and knowledge has been seen to become less definite, more situated within interpersonal interactions, shared assumptions, and commonly held modes of operating. It is important to emphasise here the link that socially situated learning has with both STS and the work of the social scientists: writers such as Archer, Bhaskar, Harré and Giddens have addressed social interactional theories similar to the pragmatic objections to Cartesian philosophy that was definitively critiqued by Peirce.

Although, the STS movement implicitly espoused the notion of tacit social knowledge it failed to address the problems inherent in the Cartesian mind/body divide for example the neglect of the transformational power of the artifact in science education. Such an artifact designed with transformational intent is material energy and change. Science education has many such artifacts, which have not been adequately researched as objects of knowledge in the sense defined in this paper as possessing causal power, capable of transforming the relationship between agency and social structure.

2.2 A Coordinated Methodology

One of the fundamental tenets of the STS movement was the insistence of its founders that the implementation of an STS program should be in conjunction with the traditional science curriculum. Solomon (1993) placed particular emphasis on this aspect of the design of the program.
"There is absolutely no conflict between teaching orthodox conceptual science for understanding, and teaching STS."\textsuperscript{30}

During the design of a new program with a radical stance and approach to the communication of knowledge, the creators appear to have deliberately set out to present and package the program in a manner that would minimise the challenge to the different nature of this approach. I interpret this as something that was considered strategic for the adoption of the STS program by academic authorities and mainstream teachers. By stressing the normality of this approach, and that it was not designed to overthrow established teaching methods or practices rather to complement or value add to the existing paradigm of school science, the authors of STS may have unwittingly undermined its appeal and authority.

"The 'science' in STS education is school science and it will be taught in just that spirit."\textsuperscript{31}

The STS program was built on a number of premises about the nature of science teaching and science content. It was a response to the lack of a real world perspective, the lack of connectivity and relevance to both actual scientific development and its wider meaning in society. There was a very real and genuine concern for the gulf between classroom instruction, the values driving social transformation that the learners were engaged in, and the rapid development and advancement of science and technology.

\textsuperscript{30} Solomon J. (1993), op. cit., p. 37 (emphasis in text)
\textsuperscript{31} Solomon, J. ibid, p. 37 (emphasis in text).
The purpose of science education was seen to be linked exclusively to the reproduction of a technical class in a capitalist society, increasingly dependent upon the development and exploitation of opportunities arising from technology and scientific knowledge.

Strategically the STS movement probably strategically saw that science education, or the science of science itself had become caught up in an ever-reducing cycle of societal rhetoric and reductionist practice of self-reproduction and continuity. Scientific theories were increasingly being thought of as entities on their own, isolated in time and space, not as representations of and participants in a wider schema. The teaching of science had, as a result, become the ritual teaching of a series of discrete theories and concepts divorced from the meaning that they were representing. The historical, cultural, embodied meaning and significance of the theory had been lost in a headlong rush to cover content, in effect, to train minds. This entrenched Cartesian dualism of science education divides, I believe, scientific theory and real-world context.

In addition to this problem with traditional science teaching, there remained deeper issues about the practice of science and science education that the STS movement generally recognised as not receiving the type of exposure or consideration that they deserved. The strength of the realist platform of science education reform is the focus of my approach. The idealist fallacies exposed by the work of Bhaskar (1983, 1986, 1989, 1993) and Archer (1995, 1996) are, it will be argued, the underlying causes of the visible failure of the teaching of science.
On the surface, the STS movement was responding to the apparently blind rule-following of taught scientific knowledge as truth, the lack of connectivity and relevance to the objects and phenomena that the content of normal science teaching described, and the lack of a social conscience in science.

School science and technology were seen by the STS movement as operating in a social policy vacuum, unresponsive to social considerations and importantly changing and shaping the direction of society without any consideration of how, why, or any ethical or responsible approaches to society. These identifiable issues with the institution of science can be seen as the results or outcomes of ontological issues within science and specifically science education. The aspects of science outlined above, which the STS movement specifically set out to redress, were not causes but outcomes; transforming these outcomes would logically require science teaching to address and analyse the causes. A solution that did not seek to transform the fundamental underlying assumptions, self-representation and performance of science teaching could not hope to prevent the conscious or unconscious reproduction of the culture.

During the development of the STS framework there was no specific reference to this critical and fundamental philosophical agential structuration. The STS movement did not arise from an epistemological analysis of the traditional practice of science teaching. It did not identify methodological failings in the established paradigm of science teaching. There appears to have been very little analysis in the STS literature of the language or semioses of the traditional classroom, the ontological and phenomenological dimensions, the role of models and representations, or the debates
in the social sciences surrounding structure and agency. As such, STS curriculum reforms did not address the fundamental issues or problems inherent in understanding the social behaviour of teacher or student in science education. Rather, it developed as a sociological response to what was seen as a rigid, structured curriculum, alienating a segment of society, by reinforcing existing divides and introducing new divisions. "(B)oth traditional and Nuffield courses were about science for the intellectually elite." Solomon goes on to cite Malcolm Skilbeck relating the need to develop and implement STS programs on the basis of 'social reconstruction' and 'cultural transmission.'

"This new phrase implied that every generation had the right to act, within the constraints of the democratic process, in order to re-shape society. If an absence of scientific knowledge prevented people from thinking and acting on issues they cared about, then science education had seriously failed them. Both these educational arguments – about equality of opportunity within the curriculum, and about citizen empowerment – were tantamount to a new invitation. STS, with its emphasis on social responsibility, was needed inside the curriculum to complement the more traditional approach to education."

This is as close as Solomon gets to considering structure and agency, where society is both cause and outcome of human agency through social production and reproduction. This argument was not elaborated, nor was it the fundamental justification for the proposed new approach to science education.

17 Solomon, 1993, op cit., p.16
19 Solomon, 1993, op cit., p. 16
The fundamental reasons given by Solomon for the development of STS were more akin to a moral political stance; equality of opportunity, empowerment for all, addressing global problems, democratic action, acknowledgement of multiculturalism, while at the same time promoting academic science so that more young people will become scientists and increasing technical expertise. Seen in this light, there can be little surprise that the advocates of STS in the 1980s supported a coordinated methodology, whereby STS stood science teaching alongside traditional science and attempted to fit it into the established scientific paradigm. However, the political implications of STS were considered to be just too threatening to the established traditional hierarchical approach of science teaching. Any emphasis of STS on social emancipation through scientific literacy became lost in this political stance. It is not my intention to criticise the ideals of the STS program, instead I am interested in investigating its social agenda for science teaching in order to understand why it failed, given the widespread support it received from teachers. It appears that the perceived political sensitivity of the STS movement and the position that was taken to overcoming resistance amongst science teachers may have contributed to the reproduction of pre-existing structure and educational order.

During the inception of the STS movement in the 1980s there was a discussion about the epistemological and ontic fallacies that were being perpetuated within the science curriculum (Aikenhead, 1975, 1987; Bodmer, 1985; Shayer and Adey, 1981 and Yager, 1980). Indeed, this criticism was not new, having been rehearsed in the general science movement of the 1930s by Hogben (1938) among others.
If the STS curriculum was not to replace existing science courses, but rather to exist within and alongside, complementing and supplementing existing curriculum goals, how could it hope to have a transformative effect on either science teaching or social action? The published social aims of the movement are hard to define in practice, as the commitments are so broad and overarching; however, social transformation or adaptation appears to underpin all of the literature.

“Special features within science education include:

- An understanding of the environmental threats, including global ones, to the quality of life.
- The economic and industrial aspects of technology.
- Some understanding of the fallible nature of science.
- Discussion of personal opinion and values, as well as democratic action.
- A multi-cultural dimension.”

Other groups were actively campaigning on the platform of public awareness and social reconstruction or transformation during the promulgation of the STS agenda in science education in the mid 1980s. The Public Understanding of Science movement, the Club of Rome, the AAAS (1994), and many other groups and their publications promoted the positive role of science within society – and the need for a science education that would reduce suspicion of science as a social force shaping social features. These groups spoke from the idealist liberal platform of intellectual autonomy and moral agency, and failed to address any realist transformational model of the person as science teacher or student in agency and social structuration. They collectively lacked any transformational model of social action.

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In calls to transform public understanding, personal embodiment was neglected. In this we observe that the Cartesian divide between mind and body and Humean reductionism have remained dominant in the public perception of the psychological operation of science and science teaching.

2.3 Integrating Individual and Social Psychological Modes of Learning: Situated Learning and STS

In order to move beyond coordinated models to an integrated model of learning it is important to reappraise the uses made of learning theory in the STS program. Although not specifically referred to as situated learning, the psychological mode of the STS program can be seen as broadly situated learning. “Because societies differ, the complexion of their STS education will always have features peculiar to the education system and economic situation of the society concerned.”36 Not only did the STS movement emphasize the place of science and the role of technology in society, and the need for connections to be drawn from actual events or processes in the real world, but it also turned over to individual teachers, schools, districts or regions the responsibility for defining what was meant by STS in each specific context. STS defied the trend of exporting first world western science into other cultures; the program attempted to include all societies and nations within its purview.

The strong social justice and science-for-all stance of the STS movement encouraged developing nations to consider and, in places, implement a culturally sensitive approach to science education. In her explanations of STS application for very young

and primary aged pupils, Solomon clearly places herself in the situated learning camp. She identifies the environment of school and home, and specifically television, as being fundamental to the development of a child’s early perceptions of and orientation to science. In order to comprehend and study STS the learners, she says, will need an ‘understanding of self and others’, a ‘sense of responsibility and justice’. In a later section, Solomon appears to be particularly concerned about students’ perceptions of scientists and their socio-historical role in the construction of public knowledge.

Although there is some discussion of STS and primary aged students, the main focus of STS programs was the secondary school where top-down curricula with a cognitive learning mode are enseonced.

The underlying belief in situated learning is again evident in the explanations and support given to STS programs in the secondary school. Without direct reference to or justifications for situated learning, a fundamental tenet of the STS program was the creation of a curriculum that was time-place situated and drew upon both global and local issues and examples. Teachers were empowered to generate their own responses and approaches to presenting the learning outcomes. This movement was a direct descendant of earlier bottom-up curriculum reforms such as general science.

Under an STS framework, students were seen as participating in social structures, both within the physical domain of the classroom and with the wider community. Participation in the second of these two areas was in two respects. Firstly, it was assumed that teachers would have both chosen prior to the unit and allowed to develop naturally from the unit, a number of wider sphere social issues. Secondly, the STS program specifically called on teachers to challenge the students by placing the
context of their learning firmly in a global social perspective. Social responsibility and the impact of science on society were fundamental to any STS framework. From a situational perspective a science classroom can be seen as an environment that is time-space specific, and one in which individual students participate in and contribute to the development of their scientific knowledge. This process is inherently a social one. It involves interaction with others within the classroom environment, and is influenced by wider external social factors and framing constraints. It is fundamentally an exercise of language, a discursive practice laden with semioses, symbolism and positioning. The learning within the class is inherent within the participatory frameworks of the classroom. One of the epistemological processes within the STS framework was to bring the wider social world into the classroom, through the use of identifiable social challenges and issues—in an attempt through Vygotskian (1978) type scaffolding to animate the classroom within a wider social context. Simultaneously, the STS agenda was to export a specific type of knowledge and perspective from the classroom to both the wider society and the scientific community. Through a ‘cautionary tale’ approach to the fallibility of science and scientists, the creators of STS attempted to transform societal images of science, and perhaps the philosophical stance of scientists.

It can be seen that these are two of the major epistemological tenets of the STS program. STS attempts to situate science teaching and learning in a real-world setting, and to give life to otherwise isolated and unrelated concepts and theories, on the one hand, and on the other it strives to empower the wider public through increased scientific knowledge. Ideally future scientists will transform society by raising awareness of the social responsibility of science.
In addition to the commitment to situated learning as the model of learning that the STS framework both requires and supports, a similar commitment to situated learning is required of the teachers creating the curriculum under STS guidelines. It is interesting to theorize why the STS founders placed the development of STS programs so firmly in the teachers’ domain. Solomon provides a number of examples or vignettes on the implementation and development of an STS program within a school context. Solomon presents a table\textsuperscript{17} that she uses as to support and justify teacher-based curriculum reform; in it she uses the term ‘agent’ and ‘agencies of change’. Unfortunately, the use of these terms is never elaborated, expanded or referred to during a description of the table; they seem to be placed there without a firm understanding of their relevance. This is unsurprising given the generally poor understanding of agency in terms of teaching and learning that is held by teachers.

It is my contention that at this moment in her book, Solomon touched on the key aspect of reform and transformation within science teaching but missed the opportunity to employ it. Rather, the table is used to support the contention that teachers are the major reform agents for both classroom teaching and pupil learning. Apart from the fact that the table is naïve in its interpretation of agency and structure from a perspective of critical realism and transformational social action, it is also over simplified.

\textsuperscript{17} Solomon, (1993), op cit., p.29
The STS movement focuses firmly on teacher-instigated reform and development in order to generate change within the classroom. Teachers were expected to situate the reductionist, traditional teaching of science into a context that they themselves were unfamiliar with. Teachers are most likely to feel comfortable working to a style similar to their embodied experience of accepted practice. The pedagogy employed by teachers is invariably the dominant paradigm. This recreation of social structures through unintentional agency is a fundamental component of Bhaskar's Transformational Model for Social Action (hereafter referred to as TMSA). Given the predominance of similar textbooks, resources and curriculum materials, to say nothing of the externally imposed curriculum designed to assess students on a series of content-based indicators, it is little wonder that the majority of science teachers recreate existing structures. This recreation is neither intentional nor deliberate, rather an unintentional outcome of the pre-existing institutional practices, rules and resources. These social structures within science education are informed, and in part created, as an outcome of the perception of both the reductionist and exclusive—rather than inclusive—nature of scientific knowledge, and the consequent view of science held by the wider 'lay' community.

Science teachers are inducted into a community through a process that defines both themselves and the community. Science teachers are in effect part of a structure. Through the induction process that must be undertaken, a misanthropic view of themselves, the society of science, the wider community and, most importantly, the role of science teachers becomes structured. Initially the STS movement hoped to
harness and appeal to a small community of teachers to whom the social responsibility of science, and ethical role of science in society would appeal:

"Changing from teaching 'valid' science of the type that lives on its own on a textbook page, to teaching STS where the science is intertwined with technological response to individual needs and cultural values, is a big step. Somewhere along the line there has to be someone who has seen the world of teaching and learning through new eyes."³⁸

This science teacher is elsewhere described as a person 'with a bee in the bonnet' who would presumably utilise one of the suggested implementation models, and work to introduce an STS program within his school. This type of process is fraught with challenges and problems. In the first place there are the visionary teachers themselves. To what extent they understood the nature of science teaching that they were involved with, and the unintentional social reproduction and concept of agency, is highly questionable. It was never enunciated in STS documentation. It seems responsible to assume that the transformation of social structure through agency requires at the least, an intimate understanding of the nature of agency and structure within teaching and science.

Given that this may have been the case – although I consider it to be very unlikely–there remains a myriad of social structures and individually constructed but universally held beliefs and knowledge systems held by other teachers, that would constitute and manifest themselves as structures within the learning community. At best, all that can be expected is a token, ineffectual result that would not transform science education but unintentionally reproduce existing structures.

³⁸Solomon, (1993), op Cit. p. 29
2.5 STS and Teacher Professional Development

It is certainly possible that the STS model for teacher renewal and professional development by teachers in collaborative groups could be very effective under certain conditions. It is also likely that through raising the consciousness of science teachers and drawing their attention to the role of science within society, that many positive teaching outcomes could be achieved in some schools. Much of the STS program outlined by Solomon is indeed aimed at individual teachers, in an effort to excite and inspire them to make positive changes within their own teaching and school. The case studies are designed to empower teachers to implement the changes and to act as catalysts to affect other teachers and their practices. Professional development is an important aspect of refreshing and updating practice in the teaching profession. The type of motivated team approach advocated in the STS literature is also widely supported as an effective strategy. However, I do not believe that the aim of the STS movement was to be a professional development tool. Rather, it was designed to be implemented in a specific and dedicated way, coordinated into the curriculum thus changing teaching methodology, teacher beliefs and student learning.

This was intended not just for a small-scale uptake, but a broad implementation across the educational spectrum. This approach begs a very important question, one that has far reaching implications for education reform. Is lasting and radical transformation of social structures within teaching possible through professional development of teachers that focuses on collective responsibility and local accountability, without
fundamental transformation of teacher agency within the social structure and school structure?

In order to gain insight into this question it is pertinent, at this time, to analyse the actual impact on the lived curriculum of schools post STS. It can reasonably be argued that the teaching of the place of science in society, and the social responsibility of science, are now more widely acknowledged within the school science curriculum than prior to the STS movement, (see for example, Cross and Price, 1992). This acknowledgement however, is often just that, a vague background to occasional units of work or teacher initiated discussions, and this certainly is not true for all teachers or courses of study. To teach an STS program requires an acceptance of professional risk and a substantial challenge for the teachers concerned. Secure and safe teaching, that is non-threatening for teachers is an examination-directed, traditional content-based, theory-laden unit—occasionally supported with practical experiments or other resources from ‘authentic’ textual authorities such as educational videos. Cooperative learning and collaborative planning remain dominant normative themes within teacher professional development, yet they are rarely practiced. The STS pedagogy, with an emphasis on cooperation and shared understandings developed from discussion of social issues, has been adopted and apparently subsumed into the peer-based learning paradigm.

Social issues and the wider relevance or implications of science are often included on course outlines or work unit guidelines; these, however, are usually the last aspect to be covered—a ‘feel good’ add on—covered in a very perfunctory manner, if at all. This was not the vision of the STS program; social and technological issues were to be at
the forefront of knowledge development, framing and structuring the learners’ consciousness. There remains a reluctance on the part of teachers to allow the social context to share ground with the ‘real science’ – concepts, theories, processes, data, and models. This is not surprising, given the requirement of assessment, something that has a very strong influence on the nature of classroom teaching, and the pre-existing understandings and structures that exist within the environment and society that teachers work in. These factors have a direct discursive framing influence on their teaching.

It was proposed that STS programs coordinate within existing science teaching methodologies and the existing traditional conceptions in pedagogical practices of science. Teachers would make socially responsible decisions about the importance of, and need for, socially active scientists and scientifically literate societies. All this would occur in the absence of any top-down curriculum initiative and direction, in an environment of strengthening directive control. The radical change, or gestalt switch, required of teachers, in order to ‘see the world in a new light’ is all well and good in theory, and even I hope possible in practice. However, without justifying the change in terms of a fundamental understanding of the nature of agency and structure, a renouncing of the mind/body divide, and an understanding of reproduction/transformation of social structures, this revelation of socially responsible science teaching would be powerless against the pervasive influences that frame and situate science teaching and may unconsciously serve to reproduce and reinforce existing culture. The strength of both external structures and the in-the-mind representations of science teaching collectively held by the society of scientists and science teachers cannot be underestimated. These powerful situative factors will
determine the actions and processes undertaken within the classroom, just as they and
other socially constructed factors and structures will determine the nature of the
learning experienced by the student. In the absence of a coherent, shared
understanding of the fallacies inherent in traditional representations of science and
science teaching, and of the role and influence of social structures and agency in
terms of social reproduction/transformation, initiatives such as the STS movement are
destined to do no more than reproduce the existing social structures—both within
science teaching, science learning and the wider society as a whole.

2.6 Program Implementation Strategy

The STS movement attempted to reinvigorate teaching by providing vignettes of
classes, or suggested strategies, rather than imposing a structure from above—as well
as endeavouring to make the science knowledge more relevant to current societal
needs. It was clearly hoped that teachers would come together in collaborative, skill-
sharing groups to work towards the realization of common ideals, in much the same
way that the STS curriculum set out to do for the learners. In the previously
mentioned table\textsuperscript{39}, Solomon argues that teachers themselves should be responsible for
the development and implementation of curriculum initiatives, and be intimately
involved in the whole process. This argument certainly supports a situationalist
paradigm, and one that arguably provides an effective formula for teacher
professional development. However, as we will see in the next section, I contend that
Solomon’s concept of the teacher as conscious agent of change (from the table) and
structure, as from Giddens (1979), or agency within a critical realist paradigm of

\textsuperscript{39} Solomon, (1993), op. cit., p. 29.
social science such as Bhaskar's TMSA (1983) are not compatible. This leads to the suspicion that the failure of STS was a failure of analysis. A failure that occurred within the STS concept and program, one that stemmed from a lack of understanding of agency, structure and the link with social reproduction. A feeble social analysis and inability to explain, justify or even comprehend the nature of teacher agency may go a long way to explaining the failure of the STS movement to provoke critical self-analysis in science education.
Chapter 3

The Place of Cognition in Explanations of Science Teaching: an analysis of interpretive and cognitive approaches.

In my teaching, I have struggled with the notion of knowledge construction, the process by which students arrive at understanding. Despite the best efforts of educational theorists, I felt the answer to this question would not be found in a reductionist, single, and all encompassing theory. Rather, one must acknowledge the complexity of human behavior and accept that some answers can, at best, be approximations of the truth. It is my fear, as both a scientist and educator that the reductionist approach, which has seen prominence in science, continues to have a strong following amongst science education researchers and policy makers. Social scientists are not dealing with non-intentional systems with a limited number of variables. Behavior at the best of times is notoriously hard to describe, within a classroom it becomes more complex, a diverse array of assumed, defined and undefined factors. This complexity and its impact on learning and the collective knowledge of a classroom needs to be appreciated if teachers are to provide the optimum conditions for learning within their specific setting.

Global theories about teacher practice or professionalisation criteria which purport to describe the qualities of ‘good’ teachers and ‘good’ teacher practice are inherently flawed and limited as they fail to acknowledge the greatest quality of education; diversity. Diversity of students, learning styles, cultural and economic standing.
ethnicity and religion, curriculum, resources and most importantly the diversity of teachers themselves, their background, thoughts and views. I contend that a tacit acknowledgment of the many factors, which affect the educative process, is necessary for an understanding of student learning and teacher professionalism. These factors all combine to form the setting in which education takes place.

The analysis in this chapter is designed to illustrate and exemplify some of the current arguments in teaching, between interpretive and cognitive approaches to explanations of science teaching. In doing so I hope to arrive at a position in relation to current science teaching practices. The modern curriculum leader must look not just to the actual curriculum, or subject design, but also to the environment of teacher practice, current theories of knowledge acquisition and learning and the sociological theories of social interaction.

3.1 What is cognition—Situated Activity or Mental Processing?

Historically cognition—the action of knowing or perceiving—has been considered to be a process which did not include a consideration of the place in which the cognition occurred or was acquired. In this distinction I am expressly considering teachers as vehicles for cognition—as teachers play a vital role in shaping the knowledge of the future. In this respect it is necessary to look not only at the cognition of the teacher in the place of teaching but also the cognition of the teacher in the place of their learning. Many current articles focus on the ontology of teachers and learners in an immediate sense. For the purpose of this research I will begin with an analysis along these lines, moving later to the framing of the teachers' own experience and
cognition. This must be taken into account in any comprehensive discourse on the curriculum and methodology, whether you take a situated or a mental processing model.

While distinction between teaching and learning is apparently obvious and straightforward, it has led to a number of approaches to studies in the area. In her article ‘On Two Metaphors for Learning and the Dangers of Choosing Just One’,[40] Anna Sfard presents a balanced approach to the debate between the acquisition and participation metaphors in theories of learning. This analysis is solely from the perspective of learning. Sfard contends that this learner-centered approach can illustrate some of the fundamental assumptions or models that underlie both teaching and learning. This contrasts markedly with the approach of Packer and Winne[41], whose article presents the contrasts between interpretive and cognitive approaches of teachers, their behaviors and thoughts. Both approaches look similar but analyse the problem from different ends of the spectrum—one from the perspective of learning driving the presentation of information so that they, the learner, can best learn, the other from an ontological and epistemological approach to teachers and teaching research. There is an interesting and perhaps not unexpected similarity between the main arguments for both sides of the debate.

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3.2 Cognition as Mental Processing.

The act of knowing implicitly assumes mental processing (see figure 1). The learner carries with him/her a memory of a priori experience and data; together these combine to form knowledge. This combination is a solely mental operation, it is performed by individuals but can collectively result in similar systems of knowledge or paradigms. Cognition can be seen as a process by which new experience or data is added to the mental map or store carried in the mind of the learner:

"The mind (or "the understanding") is described in Locke's writings in passive terms-the mind is a receptacle ... for storing whatever ideas come from experience."\(^\text{42}\)

This new information is then assessed in the light of past knowledge, which is then refined in the light of the new knowledge. This building process of cognition is the nature of learning. A researcher can quantify the process, based on the researcher's prior experience, his/her observations and feedback in relation to the subject (teacher) under study. This is an important component of the theory that cognition is individual mental processing of individually held information and structures. This assumption allows researchers to reduce observed behavior to descriptions and hence predictive statements about future actions.

One of the biggest problems is the question of cognition itself as it refers, not only to actions that result from thought, but also to objects or structures of the thoughts themselves; these objective concepts are individual and not quantified necessarily by the resultant behavior. Cognition is by nature ephemeral, as such models, which explain both the process and product of cognition, are required to assist understanding and direct both teaching and learning.

3.3 Cognition as Situated Activity.

Modern hermeneutic theory has struggled to overcome the research dilemma that has been faced and acknowledged by scientists and philosophers of science for some time. Explanatory research is invariably carried out into areas, or on subjects, where pre-existing theories or understanding already exist. This dilemma of requiring some preconceived ideas of the subject of research prior to the commencement of study is a similar dilemma to the well-known Meno dialogue by Plato. How can we want to acquire knowledge of something we don’t know exists? Or, with a different emphasis, how is it possible to research the unknown unless that unknown is already known? In terms of cognition, Packer (1995)\(^43\) points out that the actions of humans are already understood in a pragmatic and semantic way by the person who produced the action before it is analysed by the researcher. This approach seems to indicate the context of action is more likely to shape the action, so researchers cannot explain one without a consideration of the other.

Cognition is socially distributed; the actions and collective knowledge of different groups vary from place to place, as does the situation of the cognition within a previously defined paradigm:

"Situated learning emphasises the idea that much of what is learned is specific to the situation in which it is learned."

Cognition will be shaped not only by the data and its presentation but also by the experiences that relate to the data: These experiences are external to the subsequent thought process, and have a role in shaping the behavior. The experience is governed by the setting in which it occurs: the social, political and environmental components in which the experience takes place (see figure 2):

"Because each person brings a different set of prior experiences to each new experience, each person’s construction or interpretation of the experience will somehow be different. Learning or constructing meaning, is interactive."

The situated interpretive approach to teaching

- Socio-political environment
- Curriculum
- Prior experiences

Teacher's opinion of the way the concept is grasped by students

Teaching position "location in settings"

Classroom event or phenomenon

Physical setting (classroom)

Student's view and perception of concept taught

Students position "location in settings"

Figure 2
In addition to this prior shaping of cognition, the setting has a post-cognitive effect on behavior. It exerts a governing influence on the actual behavior of people within the space. Structures determine the type and nature of behavior, which can and will take place:

"The situative perspective takes the theory of social and ecological interaction as its basis and builds toward a more comprehensive theory by developing increasingly detailed analyses of information structures in the contents of people's interactions."\(^{46}\)

The situation will define the possible and probable behavior patterns as powerfully as defining the impossible:

"In other words, the actual context is crucial: it dramatically influences the very character of the skills deployed."\(^{47}\)

As a result, it would appear that teaching/learning research cannot fail to take into account the setting or situation of the process. However, this view has only recently gained support in the debate about teaching and psychology. Previously, research was dedicated to quantifying laws of an individual's behavior; the intention was to determine modes of operation, much like those that govern the actions of machines. This deterministic empirical approach in science education research had its background in early philosophy and it's attempts to quantify the mind and it's operation.

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3.4 Explanation of Teaching: Cognition or Place?

Central to an argument about cognition and its role in teaching is the concept that behavior is determined purely by internal processes. To an objective researcher observing the process of teaching, this means a belief in the following logical argument, which Winne (1995), presented as follows:

“1. The teacher thinks
2. The teacher’s behavior reliably depends on that thinking.
3. Someone (teacher, student, observer) describes the teacher’s behavior as teaching.
4. A description of the teacher’s teaching can account for why the teacher’s teaching played out as it did verses manifesting as another pattern of behavior.”

Winne’s argument on the surface appears to be self-evident and logically constructed. However, I contend that his inductive leap in premise (which I read as a conclusion) 4, where he accounts for why the teacher acted in a certain fashion, is not logically consistent from the basis of his first three premises. There is a logical inconsistency in the argument. Based on premise 3, all that can be concluded is that someone would be logically entitled to document and account for the actions of the teacher as teaching, and know that this teaching was to some extent the result of thinking. There is no logical basis for his claim that this description includes reasons for the actions, or why they occurred in the observable fashion that they did.

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In the mental processing model, (figure 1), the concept of place or setting enters the description of cognition only as topics thought of by the teacher. These thoughts will be a combination of the components of the place of teaching and what the teacher is capable of perceiving about the surroundings. This leaves very little room for any form of impact or affect, that may arise during the teaching process that results from the actual setting. If anything, the mental processing model does allow for teachers to think about their actual physical surroundings and these reflections can have an impact on teaching pedagogy. But the theory leaves very little room for socio-political considerations of the teacher and learning environment in space and time.

Under the mental processing characterisation of teaching three main questions appear to arise:

"1. How does the teacher engage in or carry out thinking
2. What thoughts constitute are immediate products, way stations or punctuation’s within dynamic thinking processes?
...
3. Are there relations between teacher’s thinking and the teacher’s behavior? If yes, what are these relations?"^49

This account relies on a separation of thinking and behavior, implying that one causes the other, rather than thinking being a behavior in its own right. One of the characteristics of cognition is that there is no direct access to the process itself or even the immediate products of that process, rather we can only observe the subsequent behaviors or actions and attempt to interpret them.

The major difference between the situated and mental processing models is in the importance and weight assigned to the surroundings of both the initial learning, the cognitive process itself and the eventual action. In a mental processing system, thought and cognition are recursive; an output from a prior phase is the input in the following phase of action or thought. This model does not deny that place does have some role in shaping cognition, but only to the extent that place can shape an input to a future thought process. The place has no external effect on behavior, only as a shaping influence, which has varying impacts dependent on the individuals’ thought patterns.

This position is sharply contrasted by the situated account of teaching and learning. Elemental in an explanation of teaching is an understanding of explanation itself, one perspective of which is a way of understanding what was previously strange and unexplained. This understanding is inadequate if it only describes or quantifies the structures or processes that are involved. As Lave and Wenger put it:

“In our view, learning is not merely situated in practice – as if it were some independently reliable process that just happened to be located somewhere; learning is an integral part of generative social practice in the lived-in world”50

To the mental processing paradigm, the explanation of the cognitive process or structure is all that is required for an explanation of teaching. To the situated account, the processes that must be taken into consideration are not just mental

ones—rather they are the social processes of the people involved in the physical, social, and political setting of the operation. These processes do not operate at a temporal level, which could vaguely affect behavior, but affect symbolic and semiotic things: actions, speech and artifacts.

The structure found in the place of teaching has a physical manifestation; it is not possible to place it within the head as internal individual mental processes. Interpretive research, like most effective teaching is based on a hermeneutic study,

"... the ways in which symbolic forms are interpreted and understood by the individuals who produce and receive them in the course of their everyday lives."\(^5^1\)

Situated theories attempt to place the participants into context at a local level. They explain actions and behavior in terms of the external conditions and frameworks, the place of action in time and space, and the higher-level cognitive processes of thought in an effort to define the semantic characteristics of behavior.

3.5 Constitutive Influence of Place

This concept is central to a complete argument for the causal influence of place on the actions of those within the space. This actual and real influence affects all aspects of classroom behavior. In addition it occurs without the action of any form of internal cognitive process. The features, which exist inherently within the setting, do so in a

previously defined and meaningful way. We humans have created this meaning, a
priori to its existence within the classroom:

"Fifty years of experience have taught us that knowledge does
not result from a mere recording of observations without a
structuring activity on the part of the subject. Nor do any a
priori or innate cognitive structures exist in man; the
functioning of intelligence alone is hereditary and creates
structures only through an organisation of successive actions
performed on objects. Consequently, an epistemology
conforming to the data of psychogenesis could be neither
empiricist nor preformationist, but could consist only of a
constructivism."52

The setting and features of the classroom are previously understood, which results in a
framing effect of the features. They have a dynamic impact on the nature of the
teaching and learning process, in effect constructing the process itself;

"knowledge construction is "rational" in that it proceeds
deliberately according to methodological rules and criteria that
are consciously held within a sociopolitical group.
But--importantly--they stress that these rules and criteria were
constructed by social processes, and thus were influenced by
power relations, partisan interests, and so forth.53

This dynamic shaping of actual behavior by the constitutive influence of the place
does not take place on an actively cognitive level. It cannot be quantified by the
teacher, student or impartial observer. This is because the process does not occur

52 Piaget J. (1980) The psychogenesis of knowledge and its epistemological significance. In M.
within the head, it is an external influence that cannot be measured or determined, as it can change according to the participants or the setting itself.

The mental processing model does not ascribe the same level of impact or consequence to the features that occur within the setting of a classroom. The setting becomes a considered part of the process, which takes place in the mind teachers whenever they teach. Various inputs are processed or monitored by the mind of the teacher, which when taken together and decided upon on the basis of ascribed importance, will dictate the actions of the teacher while teaching. This cognitive process apparently takes place for every occasion when intentional actions take place. In this way, the mental processing model allows for the actual physical setting to be of some importance—but only as a part of the cognitive process undertaken by the teacher.

This argument falters on a number of counts. First, it would be surprising to me if, when asked, a teacher would indicate that the physical surroundings of the class, or the sociopolitical milieu and climate present at the time of teaching had been involved in their cognitive process while teaching. Yet in order to concede some level of importance to the setting, the mental processing model is forced to make it an actual input into every cognitive decision-making process. Contrasting to this approach is the situated account that requires no actual active thought process (cognition) of the surroundings during the action of teaching. Rather, the setting provides a framework, which determines the type and style of teaching, and learning that is undertaken in the class.
The second problem with the mental processing account for the constitutive influence of place is the circularity in the concept of inputs and outputs. It appears that not only is there no way of delineating between inputs and outputs of cognition, but the nature and description of the features of the classroom must also first be understood, in other words be a prior output, before they can be considered as part (inputs) of the cognitive process of teaching. This circularity in the process of description and cognition is a fundamental problem with the deterministic approach to teaching. Even if it were possible to quantify all of the inputs considered in the monitoring process of cognition, and ascribe a relative value of importance to each, so that when all factors were considered, the outcome (behavior exhibited) could be determined and predicted, the observer could never have access to the outcomes of previous cognition or learning which could possibly become inputs for the cognition being described. It appears that it is highly unlikely that behavior can be reduced to a series of binary inputs that would allow for the type of description of teacher behavior sought by the mental processing model.

The third issue with the concept of describable behavior is the problem of observer impartiality. In order to describe the behavior, then work back via a series of questions with the teacher concerned, in an effort to separate the actual cognitive processes undertaken, the researcher cannot help but interpret information and data on the basis of his/her own experience. Different emphasis, questions, and values can affect not only the questions and their style but also the recording of the data and the observations themselves. This research is not a detached clinical study into the affects of new drugs on test animals. Rather it is a descriptive science, a process that cannot be divorced from the previous experience of the researcher.
The final issue is the concept of induction. In order to have any justification for belief in the predictive power of a mental processing model, the researcher must gather data then make the inductive leap from this small amount of information to a universal statement about behavior. The scientific community has long acknowledged induction as extremely problematic, if not downright dangerous. There is no justification for the belief in a system, which claims some form of universal predictive power on the basis of a very limited series of confirmatory observations. In every case, the predictive power is an illusion, based on an assumption.
Chapter 4

The Science Classroom – Viewed in a Social Context

The philosophical debate between the mental processing and situated accounts of learning poses fundamental questions for educators. Not only does it question the traditional methods of teaching and teacher training but also questions the very assumptions of education and the purpose of education. If the reason for education of young people is to induct them into a particular paradigm and way of thinking in order to preserve the status quo then the mental processing model will be the most effective approach. If, however, the purpose of education is to allow learners to exercise judgment and free thought, outside of the norms that pre-exist, then a situated social construction of knowledge approach will prove to be the most effective.

Historically there can be no doubt that the mental processing method has been the dominant paradigm in education. Not surprisingly this has been reflected in the operation of science itself. Philosophers of science such as Kuhn\textsuperscript{54} and Popper\textsuperscript{55} have acknowledged the different ways the conservative, preservative methodology applies to science. In response to his perceived flaws in the operation of science, which appears to resist innovation and holds onto theories which are threatened, Popper proposed a methodology of falsificationism, where existing theories should be actively attacked, as only through their falsification and ruthless discard would new theories develop. Kuhn approached the issue from a different perspective. Rather

\textsuperscript{54} Kuhn T. S. (1962) \textit{The Structure of Scientific Revolutions}, University of Chicago Press, Chicago.

\textsuperscript{55} Popper K. (1968) \textit{The Logic of Scientific Discovery}, Hutchinson, London.
than attack the existing methodology of science he analysed its operation and wrote what I interpret as a cautionary tale which laid out the insular, protective nature of scientific paradigms, resisting change and operating as a collective entity with a common purpose. This theory is perhaps best exemplified in the history of geology, where progress and research into the new theory of continental drift was delayed for 40 years by commitment to an existing paradigm. Here, the power of the existing paradigm to resist alternate theories and continue to propagate its own view via school and university texts and control of academic papers resulted in a long delay in scientific progress. When education fails to take the sociopolitical climate into conscious account in interpreting its agency and purely teaches the rhetoric of the established paradigm, the products of the education system are intellectual cripples, unable to perceive the social implications and its effects on their knowledge.

Science is a dynamic social system; it relies on innovation, freethinking and a perception of causality. The development of new theories and their resultant contribution to the progress of humankind is directly linked to the standard and skills of the new acolytes of science:

"Helen Longino, after citing the influence of Kuhn, Feyerabend, and others, goes on to stress the ways in which science is a communal rather than individual endeavor; scientific knowledge “is constructed... by individuals in interaction with one another in ways that modify their observations, theories and hypotheses, and patterns of reasoning.” (Longino, 1993, p.111)"\textsuperscript{56}

\textsuperscript{56} Phillips, D. C., (1995), op cit., p. 11.
Today's students are tomorrow's leaders; it is not surprising that the conservative process in science and the protection of its knowledge has been reflected in the teaching of science. It is the teaching of science itself that has produced the 'gatekeepers' of our discipline, who today resist an innovative, critical approach to progress:

"We have compelling reasons to believe that there are powerful relationships between the comprehension of a new teacher and the styles of teaching employed."\(^{57}\)

Situated learning, while not the panacea or answer to all of the issues currently confronting science and education, does provide educators with an avenue to engage the inquiring mind through the use of language rather than mere labeling of understanding:

"The teacher also communicates, whether consciously or not, ideas about the ways in which "truth" is determined in a field and a set of attitudes and values that markedly influence student understanding."\(^{58}\)


4.1 Learner Motivation

Motivation and learning are closely linked. Prawat\(^5\) situated learning and a respect for the setting in which the learning process operates as offering a way out of the rationalist dilemma of the mind/body duality. Prawat objects to the rationalist approach to motivation in learners, which advocates that the teaching of learning-skills directly precedes the motivation of the student to learn. This approach, like the mental processing model of education, is strongly dualistic: the system doing the thinking is physically separated from the nature of the information that is being thought about. This type of learning generates a particularly dispassionate and unconnected type of learner. There is no engagement with the knowledge; rather it becomes a means to the ends. Dewey (1890)\(^6\), with his emphasis on the importance of ideas, believes that the power of the idea itself becomes the motivation for further learning. The method of that subsequent learning is of little consequence, and will happen in different forms according to the interests and dispositions of the learner.

In this way, the ideas and thoughts become merged with the objects and subjects themselves. This merging of objects and thoughts as proposed by Dewey and exemplified by Prawat is essential in their fight against the dualism of thought that is a consequence of the mental processing model of education:

"Dewey rejected the origins argument so central to the thinking of traditional rationalist and empiricist philosophers.

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The true test of an idea—the knowledge construct developed by Dewey—is thought to lie in its ability to open up new aspects of the world, in a cognitive-perceptual sense, for the inquirer.\footnote{Prawat, R. S. (1998), op cit., p. 201.}

Dewey and other pragmatists proposed that knowledge is in effect, the same as perception. The perception of an object or experience is identical to the conception of that object or experience. By defining cognition as the same operation as perception, Dewey sought to remove the epistemological difference that had been artificially created by the rationalist approach. The result of this change is to locate the concept of an idea actually within the perceptual environment. To Dewey, ideas became a powerful tool, which could both shape and be shaped by the environment. In this way, ideas are not constrained within the space of the mind but are enabled to go beyond a rigid mind based structure that constrains the data processing model of the mind. Prawat sees this pragmatic solution for the mind/world problem as a model for educational reform, whereby motivation and learning become more accessible to students via a reappraisal of the underlying philosophy of the mind. I propose that this approach is compatible with the situated approach to learning.

4.2 Structures that Frame Teachers’ Teaching in a Classroom.

Within the discipline of science two factors control the content of the curriculum most strongly. These are the prescribed course and the related textbooks, and the a priori experience of teachers and methodology of teacher training. Around the world, the senior science curriculum is very prescriptive in terms of content. This conformist
approach to the actual content of knowledge is—despite my reservations in terms of what it teaches future scientists, probably necessary, so that students across different schools can be compared for University entrance. However, the common curriculum should be designed specifically to introduce students (and their teachers) to the philosophical question of the sociopolitical setting in which science operates. Future leaders of science must be aware of the shortcomings, risks, and external pressures on science. Currently, students are graduating from school with an incomplete knowledge of the nature of science. The science they understand is one purely of theories, some applications, and very little about innovation or divergent thinking. Students are disempowered by the method of assessment, and the type of curriculum prescribed—as it does not afford them the freedom to think for themselves or the perception of the framing aspects of the setting in which they practice their chosen profession.

Teachers teach in a method that is most comfortable and understood by themselves. The teaching that occurs within the classroom will be the sum total of their previous experiences. During teacher training they have reflected on their schooling and identified the aspects they most like. They have studied the curriculum and have some understanding of the methods of assessment. New teachers have attended lectures and seminars on methodology, pedagogy, discipline, and learning styles. These experiences all stay with the new teacher; they become part of the teacher's knowledge base which, when presented with a teaching situation will provide some of the framework that unconsciously determines the teacher's teaching style:
"To advance the aims of organised schooling, materials and structures for teaching and learning are created. These include: curricula with their scopes and sequences; tests and testing materials; institutions with hierarchies, their explicit and implicit systems of rules and roles; professional teachers’ organisations with their functions of negotiation, social change and mutual protection; government agencies from district through the state and federal levels; and general mechanisms of governance and finance. Because teachers necessarily function within a matrix created by these elements, using and being used by them, it stands to reason that the principles, policies, and facts of their functioning comprise a major source for the knowledge base. There is no need to claim that a specific literature undergirds this source, although there is certainly abundant research literature in most of these domains. But if a teacher has to “know the territory” of teaching, then it is the landscape of such materials, institutions, organisations and mechanisms with which he or she must be familiar. They comprise both the tools of the trade and the contextual conditions that will either facilitate or inhibit teaching efforts." 62

The teaching of science is strongly constrained by a concept of place. Science laboratories are quite unlike any other classroom in a school. They are specifically constructed for the activity of science. Other subjects could be taught in a laboratory but teachers are often resistant to doing so, and feel uncomfortable in the alien surroundings. When students enter a science laboratory they do so with a number of preconceived notions of the activities and learning, which they will undertake. Many laboratories are still constructed in a classical rigid structure; this configuration lends itself most easily to a didactic teaching style. Teachers of science rarely let their

students go and discover for themselves, to mix chemicals, test and experiment without structure, the dangers of this form of individual construction of knowledge are too great for many reasons. Rather science laboratories become places of social construction; students are initiated into the ways and methods of school science and school scientists:

"We argue that it is important in science education to appreciate that scientific knowledge is both symbolic in nature and also socially negotiated."\(^{63}\)

This teaching can take place in an atmosphere of discovery and shared experience, but often it becomes a didactic instructional place where students are not empowered to learn, rather they are instructed. Both of these methodologies can be taught under a situated learning paradigm, but only one—the traditional didactic pedagogy—can be applied if the teacher assumes that learning is performed in accordance with the data processing model.

4.3 Constitutive Influences on a Teacher’s Actions

When a teacher enters the classroom there are an inordinate number of factors which could determine the behavior and actions of the teacher. Some of these behaviors will be consciously thought of for example: the best approach to teaching the next idea or concept; how to enhance the learning of all students; how to deal with difficult students and other such thought processes which respond to direct or subjective issues

in teaching. Other behavior patterns displayed will be the result of other factors: the layout of the room; the time of the day; type of class; the atmosphere both within the class and external to the classroom itself—such as the sociopolitical climate of the school—and the teacher’s preconceived ideas on how to teach.

Teachers tailor their approach to different classes and even to different topics in many varied ways; they do so as a result of the constitutive influence of place. The setting of the classroom in space and time situates the type of learning being undertaken. Aside from the philosophical considerations of the social place and role of science, the crux of the issue is that if we are to challenge students and empower them to succeed, we must motivate them to love the idea of learning for the sake of learning. The craft of teaching, then, needs to reflect a more situated cooperative approach than is historically presented in science classrooms. This can only occur if educational philosophers cast off the reductionist program and accept the importance of the setting and situation of learning as a defining influence on the construction of knowledge.

4.4 Nature and Purpose of Science Teaching

What is the nature and purpose of science teaching? This question, although appearing to be easily understood by most teachers, I would suggest that this question is, in actual fact, very poorly understood, either by the teachers themselves or the groups of educational leaders who develop science curricula. There is now a general acceptance and application of a variety of teaching styles and pedagogies, developed from the work of educational researchers such as Piaget (1980). However, these practical pedagogical changes have not received the support of or widespread
adoption by the community of science teachers that perhaps they warranted. The initial promise of cooperative learning as an alternate teaching pedagogy has not been realised, witness the struggle that the STS movement has encountered in this respect. I do not believe that this apparent failure of cooperative, situated learning, intransitive and ideas-based learning that is located in time and space, hence concretely relevant, has been due to deliberate teacher resistance. As educators, good science teachers are moral agents, continually searching for the most effective way to motivate, excite and educate the learners in their care. The failure has been due to more pervasive influences. The climate in which the process of learning takes place implicitly and explicitly affects the type and nature of learning. Currently school education takes place in a climate of outcomes based economic accountability, course curricula have been written and administered in such a fashion as to limit the ability of the teacher to tailor the learning of their students: content is standardised and the role of comparative testing emphasised as the only measure for achievement. Regrettably, teachers have been unintentionally complicit in this process of cultural reproduction in science education, a process that has led to the crippling of teachers’ epistemology. Teachers no longer have a transitive role in shaping young people, rather this has been given up because of the direction of uniform curricula which values certainty rather than problematic nature of scientific knowledge and emphasises similarity, regardless of place.

In order to empower and enable the situated learning process to occur, there needs to be a ‘Gestalt switch’ in outlook for school science education. The social climate in action today, is very different to that which existed 50–100 years ago; despite this, science curriculum remains based on similar principles that existed previously. Fifty
years ago, the majority of the school population did not complete higher school studies, let alone progress to University. Learners required knowledge in the classical sense: theories, and practical experience of natural processes and the scientific theories that explained them. The social climate during this time was such that change was not rapid; education was seen as a way to advance through increasing knowledge and data – the classic mental processing model. Theories of science provided the best method of approaching education; this provided the basis for the growth in socially collective knowledge. Today, society is driven by a radically different set of processes; concepts are replaced by mechanisms or embodied in tools of the information age. The nature of jobs, and the role that change takes within society, have radically altered the important commodity for societal collective knowledge. The ability to make informed decisions, learn new skills, change direction, and to empower oneself in unique and focused areas, and the ability to actively be involved with, and play in, shaping society through human agency have become the central themes of this time.

4.5 Science Education: Embedded in Science, Embedded in Society.

Currently science education does not reflect the changes in the fabric of society, a change that is unique to this time and place. The changing social structures and demands need to be reflected in education if it is to remain relevant and effective. Teachers cannot effect this change in isolation. Despite the best intentions of individual agents within a situated structure such as society and education, change must occur in a general overall fashion where the most powerful factors in any situated system must all reflect the change. It is important to stress the different
influences the various factors have on any system. The physical structure of the classroom will have a shaping effect on the learning within the space, but this will not exert the same causative influence as would the course structure, or educative direction set out by the policy makers within the system. Currently science courses have been written in a traditionally based artificially closed system, despite the fact that science is an open explanatory discipline. The artificially created closure on the nature of science for the purpose of education has enabled science education to focus solely on acquiring theoretical knowledge. This may well have served a purpose during the middle part of the 20th century, where social structures were such that this form of structured, firm basis of knowledge was both required and effective for human agency. However, this is not the case today, when modern social structures enable and dictate very different forms of human agency. A very different approach to education is required so that young people can respond, interact, reproduce and transform these social structures.

The ontological challenge that modern society is increasingly posing for science arises from a number of different yet related quarters. On the one hand there is the now obvious failing of the rationalistic paradigm of science, which has led in turn to an alternate conception of the value and role of science in society. Ogborn64 has linked the loss of the ‘impossible dream’ of science to a “loss of nerve within science education and questioning of the value of teaching science.”65 Simultaneous to this epistemological challenge have been the implications for science education, which have arisen from the work of social philosophers such as Vygotsky (1978), Piaget (1980), Bhaskar (1978, 1983, 1986, 1989, 1993) and Pred (1983). Given the premise

65 Ogborn, J. (1995), op cit., p. 3
that learning is essentially a process of socialisation that has shaping effects both for the individual and the collective, and the understanding of the equilibrium dialectic, where transformative change arises directly from human agency, the role of traditional content driven science education in particular appears to have been fundamentally questioned. The third aspect of this triad of educational ontological challenge has been the debate between the mental processing model for learning and that of situated cognition. These opposing arguments which are at the same time both ethnographic and deeply psychological, has forced educators to consider more fundamental aspects to their teaching than previously would have been the norm. Ranged against these three emerging, fundamental and critical challenges for education within the sciences lies the ever-increasing external control of teaching pedagogy and content. Educational bodies and administrations around the Western world have progressively become more structured and controlling, not necessarily of content itself (for external content direction has always been apparent) but because the standardisation has been in the introduction of an economic paradigm of education one based on common outcomes broadly assessed. Without enforcing total conformity upon teachers, this form of widespread focus on comparative testing through achievement outcomes has greatly restricted teachers by reducing the sanctioned variety in pedagogical approach and entrenching traditional learning pedagogies, by necessity structured around a rationalist, artificially closed, mental processing model of science and science education.

It is perhaps not surprising that all the social issues that have troubled science itself also plague science education today. I would contend, however, that the issues confronted currently by science education are, if anything, dramatically more
important for the future of both science and society. The teaching of science is
directly predicated on the very success and unique status for science that have now
proven to be illusionary. Currently school science education has a two-fold aim to
foster future scientists and to increase the scientific literacy within society. In the
following sections I will discuss how school science education research and practice
might change its aims and approach to best respond to both the rapidly changing
society, and the changing perceptions of science. In order to make these very broad
proposals for fundamental change we must first analyse the three ontological and
epistemological challenges to science I mentioned earlier in great detail, and consider
the place of science in a social context from a critical realist position.

4.6 The Development of Structure, Agency and Place in Science Education

As science education today is an entrenched institution, course structure and
associated content have changed very little over the past fifty years. Small changes
have occurred in terms of the introduction of new technologies, these however, have
amounted to little more than tinkering around the edges. The only response of science
education to changing society and expectations has been to introduce stand-alone
units of technology based activities, usually devoted to application use rather than
process development or active/reactive interaction. Science education is not alone in
this ontologically and epistemologically restrictive structure; it has merely reflected
the same mistaken structure that has been entrenched within science itself during the
same time. This very linear, artificially controlled and closed system-ness exhibited
by science has resulted in a fundamental abdication of the role of science
(consequently science education) in the fashioning of human agency in shaping and
forming society. Bhaskar (1983) proposes a *Transformational Model of Social Activity* (TMSA) to support his views on transcendental realism, through which he attempts to direct the social sciences away from the perverse influence of science itself. There can be no doubt that science has been subjected to some powerful and reasoned criticism during recent times. Many of the traditional fallacies of science have been torn down by philosophers such as Bhaskar (1978, 1986, 1989, 1993), Feyerabend (1995), Ogborn (1995), Archer (1995, 1996) and others.

Essentially, they have attacked the epistemic fallacy whereby knowledge was reduced to characteristics and the similar ontic fallacy that knowledge was reduced to the object. The reductive paradigm allowed science to participate in a speculative illusion, while at the same time philosophy was reduced to a positivist approach whereby the scientific method became the dominant approach. As we have subsequently been shown, when the scales of these fallacies fell from our eyes, not only was the very structure and foundation of science found to be on particularly shaky ground, but scientific theories and progress were justified on the basis of its own success, science being justified by science. Science education has been built out of and justified by, exactly the same process. Where exactly does this leave science education research and practice as we currently conceive of it? The TMSA proposed by Bhaskar certainly provides an excellent repositioning, not only for science teaching itself but consequently science education research. We may find a greater focus more on education as an entrée for this theory of social action in science. If, as it appears, science remains trapped within the artificially created boundaries we have identified, change will be particularly difficult to effect. Science education however, is much more pliable, shaping as it does more impressionable minds, and situated as it inherently is in a shaping transitive role. Education as a field of endeavour is very
much closed to the transformational society/human agency praxis proposed by Bhaskar. In addition, teaching is acknowledged as being a personal moral craft. Given the awareness, resources, climate, and power to act on the development of human agency, teachers—and hence schools—appear to be the ideal starting point for the ‘Kuhnian type’ revolution that is required to transform, not only how science is viewed and views itself, but also the very action of science itself.

While science education remains immersed and steeped in the strongly structuring shadow of science itself, many of the manifestations of science will be repeated in science education via the acquisition and creation of knowledge that result from socialisation of the individual in the milieu of the institution:

“(S)ocial reproduction and individual socialisation, are perpetually spelled out by the intersection of particular individual paths with particular institutional projects occurring at specific temporal and spatial locations.”

Since science education occurs within the actual process of the institution of science, and given that science education is standardised and universal in delivery, content and assessment, this influence becomes all the more pervasive:

“(I)t is to be understood that dominant institutional projects greatly affect the similarity of daily paths, and thereby the similarity of internal experience and sense-of-place, because their understanding of explicit or implicit rules require that participating individuals expend their labour power or in some way engage themselves in a

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given manner, at a time and place, rather than doing something else, during the same time period. (Participation in dominant institutional projects is synonymous with the reproduction of social structural relationships since it involves the placement of certain individuals and groups of individuals in a subservient or dependent and conflict-laden relationship with those other power-wielding individuals and groups who define the projects in question and who either own, or have jurisdiction over whatever material... resources are necessary...)

If human actions, learning and behaviour are continuously shaped and 'scaffolded' by the environment, milieu and situation as it proposed by situated theorists, and this shaping is time/place dependent, how can the independent existence of individuals be realised (people are different in many and varied ways, society is far from homogeneous). Bhaskar proposes that social structures 'enable or constrain' the action of human agency, which in turn causes a reproduction or transformation of the immediate social structure. Situated theorists such as Kirshner and Whitson see the social environment as providing tools that are used and adapted for use by individual learners within the situated context. These tools are either linguistic or actual materials; as a result knowledge becomes enmeshed in the context of the situation. Greene develops a theoretical framework to explain learning, his focus being on increasing the learners' participation in social practice. This improvement can be understood, as the learner becomes more attuned to the constraints or enables of activity within the social context—in this way the learner becomes a more successful participant in society. All of these slightly different approaches to the same issue

account for both the apparent broad picture, of the homogeneous nature of society and the diversity of individual differences within this context. However, unlike the pixels on a television screen, which exhibit individual differences yet when taken as a whole provide a coherent picture, all individuals exhibit to some extent the very nature of society as a whole. Analysis of individuals within a social system or social structure can provide a very good guide for the nature of society itself. In my opinion, this mirroring of society as a whole in the actions, beliefs and knowledge of the individual provides the compelling evidence for transfer (from a situational perspective) or of transformation (enablement and reproduction) in the transcendental realist position of Bhaskar. This recursive character of human agency and society provides the key to understanding the learning process, where knowledge becomes belief and society is a manifestation of human social activity. "Thus (a) social being is to be conceived, whatever else it also is, as bodily being; social structures are to be earthed in space and situated in time; and space-time is to be seen/scene a flow."\(^7\)

For science education to be successful, and future orientated, and it must respond to the needs of individuals, equipping them to successfully interact with, and participate in society. At the same time science education should be empowering and directing society through collective reproduction and transformation towards a more open, reflective, self-aware and critically realist structure.

\(^7\) Bhaskar, R. (1989), op cit., p.93, (emphasis in text).
4.7 Reality in Science Education

It was proposed in Chapter 1 that it may be useful to approach understandings of society in a way which parallels the development of science. In this, general society and social structures arise directly from the many sub-sets of social structures which are contained within it. These sub-sets themselves are often the manifestation of smaller structures, and so on until you reach individual human agents. This complex, ever changing hierarchical structure gives rise to the collective knowledge, actions, and nature of society. It is very important to realise that in some small or large way, each sub-set structure is enabling/constraining, reproducing/transforming agency while simultaneously being enabled/constrained, reproduced/transformed.

All of these factors, effects, and structures can be thought of as the situation in which society exists.

Since the industrial revolution the place and impact on overall society exercised by the social structure of science has been dramatic. Some aspects of this influence on society have been warranted: in terms of health, well-being, communication, and other individually empowering results from scientific endeavour. However, science has caused some negative social effects, quite apart from its negative impact in actual physical terms. Science has changed the very nature of society itself by a series of untrue premises and without adequate justification. Whether all of the blame should be laid at the feet of science for this fallacy is debatable, given the cascading effect that will result from social structure reproduction and the intermeshing of an incredibly complex hierarchy of structures within society. Whatever the cause,
science must take the blame for knowingly participating in the myth or ‘cult of personality’ that it became. Science became embedded in a rationalist paradigm. In doing so scientific knowledge and beliefs became elevated by society as a whole to a level they were never intended to reach. Ogborn\textsuperscript{71} in referring to the work of Michael Oakeshott writes of some of the features that characterise that rationalist paradigm:

“knowledge which cannot be formulated in explicit rules is not knowledge; there is a common power of ‘reason’, independent of knowledge and experience; rationality consists in having pre-specified criteria of rightness; technical rule-based knowledge begins, continues and end in certainty.”

\textsuperscript{71}Ogborn, J. (1995), op cit., p.4
Chapter 5
Agency, Structure and Purpose

5.1 Social Structures and Reification

The community of science teachers is a largely homogeneous group of like-minded, similarly educated individuals, situated in a context specific time and place. Science teachers possess a similar 'knowledge base', a milieu of belief, practice, understanding, ideas and myths. This commonly shared, individually constructed knowledge that constitutes science teachers' and their own 'society', when combined with the extra-individual structures represented by a socially constructed wider society, constrains the actions and nature of internal interactions. Bhaskar and Giddens provide explanations for these social structures that are simultaneously enabling and constraining of the actions of the members of the society. Social structures are external to the individual, constantly interacted with, and recreated by, individuals in their conversations within the structure. These structures are actual entities that exist external to the individuals within them, as the structure that comprises resources and rules. The structure both predates the individual and also provides the opportunities for individual action.

Thus science teachers are members of two powerful and influential social structures. First is the wider society, the one into which they were born – the culture in which they live. The second structure exists necessarily within and as a part of the first. It is, however, constructed of a different set of social functions: the traditions and
structures of the scientific paradigm. Bhaskar identifies this social transparency of the indicative activity of science teachers:

"Society stands to individuals, as something they never make, but that exists only in virtue of their activity."72

Science education, as Bhaskar and Giddens see it, is reproduced as an unintended outcome of teachers' action. Science education is essentially a discourse; it is in reality, a set of scientific conversations. To Harré (1997), discursive action is the basic social activity and causal process. In the Transformational Model of Human Action, Bhaskar proposes an emphasis on the transformational aspect of action rather than reproduction. This is achieved via an exploration of the notion of socio-structural reproduction. This model requires, as a fundamental starting point, the rejection of a Cartesian mind/body structure/agency dualism. Dualism, implies that one part can exist independent of the other, thus creating a concreteness and solidity that seems at odds to the dynamic equilibrium that appears to exist between society and individuals, simultaneously shaping and being shaped, constraining and enabling. Science teachers are the outcome of the educational process of Science itself; this process which abstracts society develops a community of individuals, all of whom have "particular values, motivation, habits, capacities and experiences (the acknowledged and unacknowledged conditions of action)."73 This socialisation will determine the possible and probable actions open to any individual, as well as the nature of inter-personal interaction.

In this way, science and science teaching reproduces itself in a particularly entrenched and institutionalised individualism. Science is perhaps ironically more susceptible to reproduction, yet due to its very nature, more open to transformation. Individual science teachers have been inducted into the discourse of science education from within, and through, the pre-existing social forms and structures of the scientific society. In this causal realist view the continued existence of this society is reliant on the actions of individuals created by the society, reproducing and transforming the structural norms and recreating and reforming the structures.

5.2 Semioses: Classroom Language as Sign Structures.

Society shapes the structures that are reproduced, reshaped and sometimes transformed by individuals within the society and learning is a social activity participated in by individuals, influenced by time and place, it is necessary to analyse the underlying structures and fundamentals of human interaction and knowledge in order to understand and transform the workings of the system. Harré, who like Bhaskar, takes a realist view of scientific theories, offers one explanation of the social structure/agency interaction. In the social sciences he makes the argument that there is a peculiarly intimate connection between scientific theorising and other human practices and projects.

Harré presents this type of analysis in his examination of grammar and context within language:

"A major insight of discursive psychology, drawn in part from Vygotsky, Luria and Leontiev, is that diverse grammatical 'dye-stuffs' not only reveal what is there but in the symbiotic processes of human development, transform, within the constraints of human ethology, the infant organism."\textsuperscript{75}

In essence, different grammatical dyes expose different underlying structures. Science teaching is an activity that takes place within the context of the human sciences yet represents the physical sciences. Harré does not see realism in the two areas as being the same. In the human sciences, realism is represented by discursive patterns within a community.

Structures, or as Harré calls them, enabling conditions, do not exist independently of the discursive activity to which they refer. Harré uses the metaphor of sport to demonstrate the essential link between skilled performance, or interaction, and the socially maintained rules and structures of the game. In a similar way to the Wittgensteinian language game (Wittgenstein, 1922), this conjoined aspect of structure and agency provides the interface at which the two meet. Structures will not exist independent of agency – just as agency will not arise independent of structure. Discursive practices in classrooms are social entities that constitute the dynamic relationship between agency and structure and illustrate the positioning of the participants:

"Every psychological process or phenomenon is a skilled performance by a person or persons. A performance is skilled if it is intentional, that is directed to some end and is subject to assessments of right and wrong, that is, is normatively\textsuperscript{76}"

\textsuperscript{75}Harré (1997), op. cit., p. 174.
constrained. A useful model for the interpersonal flow of skilled action is conversation."\textsuperscript{76}

In order to demonstrate skilled performance, some condition or environment in which that skill is relevant needs to be available:

"We could say such environmental conditions afford each its own range of possible actions. Notice that some of these conditions are material and some social, that is discursive."\textsuperscript{77}

The semioses we employ in our classroom discourse are representations tuned to individual learning of the nature of science. Because it did not attend to internal representations and did not focus on the dynamic of what was entailed in the students' minds, the STS movement gave a less than adequate treatment of semioses in science teaching.

5.3 Agency

Where lies the epistemological authority of teachers' belief that their students have learnt science in the STS framework? Roberts\textsuperscript{78}, sees it in communities of science teachers sharing a dialogical view of teaching that embraces a realist conception of science. He proposes a social constructionist configuration of a 'trialogue' between scientific domain/teacher/student that attends to both individual learning and social learning in the classroom setting. Giddens would say that epistemological authority

\textsuperscript{76} Harré, R. (1997), op cit., p. 175.
\textsuperscript{77} Harré, R. ibid.
\textsuperscript{78} Roberts (1994), op cit., p.423
must reside in a 'discursive consciousness' of their agency. Agents act intentionally with a specific state of mind that is a causal factor in bringing about the action (Bhaskar 1989). Harré effectively asks what makes scientific concepts meaningful or determinate? He sees this in terms of a mutually determined triad of positioning / social allocutionary forces / story lines. These actions are carried out by knowledgeable agents; they are skilled performances taking place within the context of a series of related events and conditions, and intelligible only within this context. In addition agents are able to describe their actions, reasons and decision factors through discourse. The issue then becomes one of intentionality in terms of positive transformation of social structures by knowledgeable agents rather than unintentional reproduction:

"Society is both the ever-present condition (material cause) and the continually reproduced outcome of human agency. And praxis is both ... conscious production, and (normally unconscious) reproduction of the conditions of production, that is society."80

Both Bhaskar and Giddens advocate a change or transformation in the existing structures, this they perceive has its best avenue through the human sciences. The criticism and explanation of false beliefs provides a transformative or emancipatory potential for agents. Both see science as providing the opportunities for bringing about social change. Although most of their work is about the unintended reproduction of rules and resources which are their social structures, through exemplification of the negative, they provide a model or method by which intentional

80 Bhaskar, (1989), op cit., p.35. 
transformation might take place. In their view rules exist and are created at the interface between structures and agency. Institutions like science curriculum embody and embed dynamic relations between structures and agency. Despite this, it is hard to comprehend what knowledge Bhaskar and Giddens see as producing intentional transformational change.
Chapter 6

Causal Realism of Science.

Bhaskar (1978, 1983) presents a comprehensive explanation of social interaction through structure and agency in an attempt to develop a unified theory of the social sciences. The causal realist account of a transformational model of science education is based on a series of principal premises and understandings of society:

(i) Social life and interaction is a natural and necessary result of existence, impossible without and causally linked.

(ii) Society manifests itself and is shaped solely as a result of the intentional agency of humans within the society, without agency there would be no society. Social transformation is the logical outcome of human activity and interaction with structures or materials (both physical and intransitive structures such as meanings or expressions). This transformation will transform the very given structures and materials that determined the activity initially (… media, resources, rites, etc.). Transformations are always situated activities; as such they are time/space dependent and are not limited to physical products…

(iii) Society and agency are irreducibly connected, one cannot exist without the other, and both exist prior to and as a result of the other. This leads to a concept where social structures enable or constrain agency and agency transforms or reproduces social structures.
Structure and agency cannot exist as an artificially closed system; society must by definition always be open (to change) and evolving (being transformed). Closed systems are a tacit condition of empirical realism, this is the epistemological limit of science.

6.1 The Implications of Causal Realism for Science Teaching.

I understand Bhaskar's definition of society to be rather flexible; societies can exist in various forms. Multiple societies all exist, some independent of each other, others intersecting, with still others wholly a part of a larger society. In this way, it can be seen that certain societies such as the society of science teachers, will be enabled and constrained not just by agency and structure within its own society (science teaching) but importantly enabled or constrained by the social structures and agency from other societies, for example: the society of science, and the wider society in which it exists.

When we conceive the existence of society in this fashion, a series of interlocking and connected subgroups of a whole, informed by a transcendental realist understanding of society as the manifestation of agency and structure, we can come to a number of important conclusions.

6.1.1 Situated learning

Situated cognition places the learner firmly in a social environment, both from a perspective of the actual process, a socially determinate language focused activity, laden with semioses that is simultaneously interpreted and reinterpreted while being understood by learner and teacher from their own purpose. This social interaction
must inherently be time/place dependent. This essential as social interaction by intentional agents is inherently a time/space dependent activity. We can see that if society is both the outcome and cause of intentional action, a society must exist within a classroom. Teacher and students become agents, enabled and constrained, transforming and reproducing that society. This classroom society is informed and dependent on shared structures, actions, understandings and structures that exist both as a direct result of the existence of the classroom society and independent of its existence. In this way learning becomes a social interaction defined by the agents within the process and by structures inherent in the milieu of social interaction, agency and structure, in which the classroom exists, specific in time and space.

Situated learning is both the outcome and cause of society, just as society is the outcome and cause of human interaction. Learning is always an open, ongoing process; it is not artificially closed, just as society is also an open evolving entity. Providing intentional agency exists, structures will exist, and so too, society will exist. Science education must be seen as an inherently social process, the outcome of a linguistically based social interaction between agents and structures, that occurs within and a direct result of other social activities, all of which serve to structure, position, and influence the nature of the structures that exist within the sub-set society of science education. These external social structures that result from human agency have a causative influence on the nature of the agency that is enabled within science education. Science teaching is constrained and enabled, transformed and reproduced by social interactions that are both simultaneously internal and external to the actual process of science education. As such, science teaching is situated, both internally and externally, within a time/space context and socially determinate.
6.1.2 Enablement/constraint in science education

As a sub-set of science, that is itself a sub-set of the general wider society and intersected by other societies such as the wider sphere of education, science education is enabled and constrained prior to any agency occurring internally. These external structures that pre-exist in any social setting are the outcome of prior agency and structure. The continuous nature of society as the product of continuous transformation or recreation by intentional agents participating in the society ensures that any created sub-set society will be initially framed by external structures. These will be socially constructed, the outcome of previous interactions by all of the participants in the sub-set. As the interactions between intentional agents within the sub-set society develops, 'internal' structures will develop and be transformed/reproduced. This results in the creation of a society that is both internally and externally structured containing intentional agents who interact both within the society (internally) and outside in the wider society (externally).

Science teaching is continuously shaped and determined not just by internal interactions but also importantly by external socially illocutionary forces as well. The recursive nature of this model is evident in the causative influence over the interaction between agents within science education that exists as a result of the interaction between agency and structures external to the actual process. The society itself is a social product. Science teaching is influenced strongly by the enabling and constraining conditions that exist, not only within the society of science education but most importantly exist independent of the existence of science education itself.
6.1.3 Enablement/constraint of wider societies by science teaching

Human agency constantly transforms and reproduces the social structure, this social structure simultaneously enables or constrains human agency. This feedback, inter-relational aspect of society is inherent in the very definition and existence of society. If we take this explanation for society and social interaction to be correct, then it must be extendable to the concept of societies within societies, the sub-set groups and associations that have societal characteristics and exist within the existence of the wider society. Just as the sub-set society of science education is enabled and constrained by the existence of the wider society in which it operates, so too must science education have enabling and constraining effects on wider social structures. Science education will directly affect the scientific literacy, the knowledge base, and the capacity of intentional agents to interact with other agents and structures within society. Society exists as a result of the substantive productions of agents; science education will have a major impact on the nature, type and method of these productions.

In order to comprehend the nature of this interaction between societies, I propose that we consider associations of individual agents as intentional agents interacting with structures that arise both internally (within the agent, or society) and externally (the result of the interaction and interface between different society agents). In this way we can see that there are very complex interactions between related and overlapping
societies that are necessarily recursive. All societies will intentionally interact with each other as agents, and with structures that exist internally and externally. Science teaching will have an enabling and constraining effect on the wider society just as the wider society has an enabling and constraining effect on science education. There is no closed system; social interaction ensures that a continuous two-way process will exist. The nature of science education and the social interactions that occur within it will determine the nature of agency capable of being exercised within any given society, it will in effect enable and constrain agency by creating social structures.

6.1.4 Transformation/reproduction in science teaching

The purpose of the analysis of science teaching that we have made in this section has been to understand the interaction between the practice of science education and the operation of the wider society. Science teaching itself, as a social process, entails the same explanations of agency and structure as any society. We can consider this to be the internal social interaction that will contribute to the nature of, and manifestation of, science teaching. However, as a component of other social structures, and indeed a sub-set of both science in general and the wider society, science education as a whole can be transformed or reproduced by praxis (motivated production) from external events. Given the shared understanding and similarly situated and framed cognition of the society of science teachers (that results in a similarly held, situated cognition of science by the learners), science education as a society can be seen as an agent in itself. This intentional agent will be interacting with other agents (both individual and collective societies) and structures. This interaction is transcendentally necessary, as it is a condition of the existence of society.
Agents external to science education will have causative influence over the structures that are manifest within the society of science education. These structures in turn will frame and shape the nature of social interaction within the activity of science education. This will occur as a result of the enabling/constraining social structures within science teaching consequent upon the intentional and motivated action of agency through transformation/reproduction. Science education can be transformed by external action just as it can be reproduced, or reified. The result of this socially motivated agency by social forces external to science education can be emancipatory, re-orientating and re-structuring the nature of the social interaction that is science education.

6.1.5 Transformation/reproduction of wider societies by science teaching

Essential to the concept of causal realism is the two-way nature of societal interaction. Science education is not isolated, it operates and exists as a part of a wider system of social interactions and structures, intentional agents interact with each other and with structures. If human agency can transform or reproduce social structure, so too must sub-sets of defined social interaction be able to transform or reproduce social structures. In fact it can be seen that this would result in a type of social ‘biomagnification’. The transformative/reproductive effect of agency will be enhanced when large numbers of individuals all enact their agency in a similar way. Societal sub-sets of this type are particularly powerful within a society as their praxis is by nature larger. This magnification effect of similar intentionality that results when shared agency is enacted is a very powerful transformative/reproductive process.
Science teaching has the potential to be a powerful force within society to transform both the type of structures and nature of the agency that will result in the society and in the social rhetoric of political leaders. Indeed, this is the public expectation, even hope, that science education/teachers be agents of social transformation/adjustment. Why has science education not transformed schooling/education in the same way that science has transformed society? \(^{81}\)

\(^{81}\) A short answer to this question posed is that science teaching has another social function—the reproduction of an expanded technical class, outside concepts of liberal education. A longer answer is it is embedded in the subversive nature of the discoveries of science.
Chapter 7

The Animation of the Transformational Model of Social Action

Not only is a structure for transformational social action needed, but we will also need a method of identifying structures that are susceptible to change. Without a conception such as this, transformation appears to be condemned to be nothing more than unintentional consequences of knowledgeable agents interacting with society. Some realists such as Roberts\(^8^2\) argue that deliberate social reconstruction is *logically* impossible. Roberts bases this contention on the closed feedback loop that must inherently exist between any social structure and the agents within it. In the first place, any radical contradiction of the structure would mean nothing to the members of the society as this would lead to a loss of a sense of identity. Secondly, during the process of structural change a similar change must occur in the agents' relations, both with the structures and each other; this will result in a changing justification of the change that may well negate the process itself.

According to Giddens\(^8^3\), social change occurs in four main ways: system reproduction, system contradiction, reflexive appropriation and resource access.

Despite these suggested social change operators, problems still abound in terms of the translation of deliberate transformation. How can we change social structures? One thing is certain, that in order to transform structures we must first identify them and the manifestations that they take, their role in society and usual method of reproduction in semioses.

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\(^8^3\) Giddens (1990), op cit., p. 304.
This Marxist approach would be similar to Giddens reflexive appropriation; awareness of system reproduction and contradiction processes then an attempt to control them. In this way, reform can be aligned with structure to give the greatest chance of transformation. This approach stresses the understanding of structures as the key in successful social transformation.

Science is a very effective transformative discourse embedded and embodied in agency and structures. The move from universal conceptions of the nature of science to an appreciation of peculiarities of its practice for the purpose of curriculum design in science education is desirable on several fronts, identified in this thesis. It is possible to suggest a research agenda for understanding science teaching within a framework derived from Bhaskars' TMSA, the work of Peirce and Bakhtin's
dialogical theory (see also Fawns, R. Arkoudis, S. and Healy, G. Signs, Social Ontology and Critical Realism in Science Education [In press]), that synthesises some social ontological and phenomenological representations of learning and action.

Since the TMSA, as proposed by Bhaskar, is predominately a sociological critique that proposes to provide a framework for a realist understanding of society that can be utilised by agents—essentially to comprehend social interaction whereby informing their ongoing agency and shaping the nature of their interactions with social constructs—we need to look at subsequent attempts to animate this socio-realist stance. Archer, (1995, 1996) proposes a morphogenetic approach to social interaction, with a specific interest in the interface between culture and agency.

Although her emphasis on culture and not structure is central to her position, she firmly places her morphogenetic approach within the boundaries of reconciling the various positions taken in regard to structure and agency. She adopts a Bhaskarian stance in her justification of the triumvirate nature of social interactional interfaces; Cultural (Structural) Conditioning → Cultural (Social) interaction → Cultural (Structural) Elaboration. What Archer terms 'the Morphogenetic approach' provides the link between social ontology and practical theory. As a general foundation to her program Archer sights the need for agents to deal with societies' specific characteristics:

"Firstly, that it is inseparable from its human components because the very existence of society depends in some way upon our activities. Secondly, that society is characteristically transformable; it has no immutable or preferred state. It is nothing but itself, and what precisely it is like at any time depends upon human doings and their consequences. Thirdly, however, neither are we immutable as social agents, for what we are and what we do as social beings are also affected by the society in which we live and by our very efforts to transform it." \(^{86}\)

This fundamental statement of society, one that contains agency, structure and interaction, provides a strong stance to reject the two opposing social theories that pre-existed Bhaskar's work. Each had the effect of rendering one of either structure or agency to be epiphenomena of the other. Archer labels these two positions as being


‘upwards conflation’ and ‘downwards conflation’. The social theories that developed during this period and have been labeled by Archer in this way were the result of the nature of the methodological stance adopted by the relevant theorist. This methodological position naturally had a structuring and framing effect on the social theorising that resulted. This is similar in the interaction that, under a realist view of social action, will be held by the type and nature of social ontology adopted in terms of the methodology that would result. In this way, the methodological and ontological fallacies that existed in the nineteenth-century debate became the same fallacies on which the twentieth-century theories of Holism and Individualism were based. The work of Bhaskar must be seen as a social theory addressing the fallacies inherent in both of these social theories and charting a new direction, one based on social realism.

It is from this background of personal and sociological positioning that Archer makes her contribution to the animation of the TMSA. In doing so she develops a methodological program for understanding the interactions between agents and the pre-existing, post-created culture of society. Agents interact directly with socially constructed structures (cultures); this interaction is constrained and enabled by the nature of these structures (the culture). In doing so agents shape the future nature and appearance of the structures (culture). This reshaping of reproduction/ transformation is not deliberative, as the form of the future (structures or culture) cannot be known in advance. Archer quotes Markovic to support this point “past and future are living in the present. Whatever human beings do in the present is decisively influenced by the

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past and by the future ... the future is not something that will come later, independent of our will. There are several possible futures and one of them has to be made.\textsuperscript{88}

7.1 Morphogenesis

Morphogenesis is the name used by Archer to describe the complex interactions that combine to produce a change in a social systems' manifested form, structure or state, the product of which is called 'Elaboration'. Social action remains a continuous process, an essential condition of society, but Archer defines morphogenesis as the interactions that produce changes in future interactions on the basis of the elaborated consequences of the prior (original) interaction. By proposing the three-part cycle, time becomes a central aspect of socio-cultural change. According to the morphogenetic approach, culture and agency are subject to different time periods of operation. In the same way that Bhaskar inherently introduces time to the TMSA and critical realist explanations of society, Archer’s morphogenetic program is based on the propositions that “the Cultural System logically predates the Socio-Cultural action(s) which transform it; and that Cultural Elaboration logically post-dates such interaction.”\textsuperscript{89}

Archer has identified that what is lacking in Bhaskar’s work is a dynamic view of how ontological levels can be brought into relationship.

As bodies, and as minds, people are ongoing events, and are products in a process.

Moreover, one of the unusual features of social structures is that they exist only in

\begin{footnotesize}
\textsuperscript{88} Markovic M. From Affluence to Praxis. Michigan University Press, Michigan, p. 10-11 (emphasis in text).

\textsuperscript{89} Archer, M. (1996), op cit., preface, p. 25
\end{footnotesize}
virtue of agents’ activities. People produce the social conditions of their own existence; social conditions are emergent from humans biological capacities. If, for example, we have no ability to communicate, society wouldn’t exist at all. But the ontological significance is that people (genetically) create a new structure, a new society, which is a structure of relationships conditioning the possible actions that people may take. In that sense, social structures as possibilities depend on people as actualities. We may interpret Archer’s analysis (1995) as a three-tiered social ontology of structures, agents and culture that corresponds to the general ontology – semioses, actuality and possibility. This arrangement accords to concepts and other signs a clear place in the theory of social dynamics, TMSA or morphogenesis. If we map Archer’s analysis of morphogenetic cycles on to these ontological strata, one sees an emerging pattern in which ‘movement’ from one domain to another or their ‘intersection’ is involved. For example Archer⁹⁰ depicts the morphogenesis of structure through the diagrams on the next page. Considered ontologically, the emergence of new structural configurations appears as those shown in figure 3a. In this diagram I rename the ‘cultural’ domain as ‘discourses’ for reasons to be explained later.

This process is time dependent, the morphogenesis of culture in figure 4 and the emergence of cultural change in figure 4a can be graphed similarly. Ontologically the emergence of structural and cultural transformations must pass through agents because only agents can shape either Archer’s⁹¹ diagram of morphogenesis of agency (fig 5) shows the ontological movement to be different, since agents act on the basis of their structural and cultural conditions and resources; changes in group

configurations may have discursive and, or structural ramifications. While such analysis may serve for understanding the broad outline of emergence – in society, they will not suffice. When we examine the ontology of specific learning in science teaching, technological production cannot occur without semiotic activity such as communication and, for that matter, imagining a product and ways to produce it. The knowledge taught in the science classroom re-enters the structural domain in the sense of contributing to the material conditions (e.g. economic capital) for the next cycle of production; but it is also part of the cultural sphere, even when it is not explicitly semiotic in content by being a status marker or artifact (cultural capital). Since choices of food, clothing and entertainment are as much indexes of social position as is wealth, scientific knowledge is a marker of social status, as it has a powerful influence on an individual’s choice of employment; as such, school science has a critical role in either reproducing existing social stratification or transforming it.
Structural conditioning
\[ T_1 \]
\[
\text{social interaction} \quad T_2 \quad T_3
\]

Structural (elaboration)
\[ T_4 \]
Morphogenesis of structure

Figure 3
Emergence of structural change

Cultural conditioning
\[ T_1 \]
\[
\text{socio-cultural interaction} \quad T_2 \quad T_3
\]

Cultural elaboration
\[ T_4 \]

Figure 4
Morphogenesis of culture

Figure 4a
Emergence of cultural change

Socio-cultural Conditioning of groups
\[ T_1 \]
\[
\text{Group interaction} \quad T_2 \quad T_3
\]

Group elaboration
\[ T_4 \]

Figure 5
Morphogenesis of agency

Figure 5a
Emergence of agential change

Discourses

Agents

Structures
7.2 Ideal Teaching Model

Roberts (1993, 1994) points to an “ideal” model of teaching that connects classroom discourses in a Peircian semiotic triangle. This “trialogue” model (figure 7) invests epistemic authority with the teaching community through a theory of social action that is required to underpin an STS agenda. The role of the agent, teacher or student is central to the critical realist position that emphases construction and signification. The students participate in or ‘observe’ events within the domain, bringing with them personal, pre-constructed explanations or representations of the phenomenon or events. These pre-constructed concepts are embodied in the students’ level of understanding. During the interaction the students compare and consider the teachers explanations of justified knowledge with their own, reconstructing, justifying and re-representing their understandings.

Essential to this trialogue is the justification – representation and explanation (R/E) that the teacher employs, as it necessarily must be informed and justified by the domain, while at the same time actively feeding back to the students’ differences that may exist between their own and the student’s justified social understanding and the embodied, not necessarily justified, understandings of the students. For practical reasons science teaching cannot proceed in this fashion in each lesson or perhaps many lessons. However, it should be performed often enough for the students and teacher to be familiar and confident in participating in it, to know that the teacher would prefer to be using this model and why, and to know how to use the opportunity when the time permitted.
The more common Impositional Model

The Ideal Triologue Model
The STS movement did not have a concept for the epistemic authority of teachers' beliefs or of how these beliefs are justified. The influence of the domain in the shaping and justification of understandings and beliefs was not considered by the STS movement. There was a focus on the teacher/student interaction and science teaching was reduced to being only concerned with this interaction. By failing to deal with the issues of teachers' epistemic authority, both in terms of development and establishment through the domain, teachers were left in an epistemic vacuum. Just as the STS movement lacked any transformational model of social action, STS justified the learning of their students solely on the basis of the interaction itself, devoid of any reference to the domain. It did not promote a role for science teacher communities in establishing beliefs about students' learning. The epistemic authority lies in the authority of the teachers' experiences, their representations and, or, explanations of the domain. The neglect of the epistemic authority of teachers' beliefs weakened the STS position as it marginalized its relevance. We can see that the notion of teacher agency is embodied by the notion of epistemic authority of teachers' beliefs. As such, the agency of teachers becomes central to any re-conception of science teaching, something that did not occur within the STS movement.
Chapter 8

Causal Realism

The term Causal Realism describes the combined positions of the logically twinned theory of Transcendental Realism (Bhaskar 1975, 1978) and Critical Naturalism (Bhaskar 1979, 1989, 1998). The first was essentially a theory of science and the second, of social science. Together they form the substance of a sociological theory that stands against the (Humean) positivist conception of science that endeavored to explain the development of science through a monistic, deductive process of coherent theory. It emphasised both the epistemological and geo-historical-social dimensions of science (the transitive dimension) as a necessary precondition of the reproduction/transformation of scientific knowledge. Finally, it claims to combine and reconcile the three areas of ontological realism, epistemological relativism and judgmental rationality. This was achieved through an understanding of the ontological depth that exists in the inherently open-ended system that is society. This ontological depth arises from the intransitivity, transfactuality and stratification of society. Intransitivity exists as a result of the fact that science is a social product yet it operates on mechanisms that exist a priori of society. Failure to acknowledge this leads positivists to the epistemological fallacy. Put another way, the domain of the real is distinct from, and greater than, the domain of the empirical. Unlike science, social systems are inherently open systems: laws must be understood to be transfactual, rather than actual or empirical as they operate independently of the conditions for their identification. Failure to make this distinction leads to the fallacy
of actualism that collapses reality; the domain of the real is always distinct and greater than the domain of the actual. Stratification exists inherently in nature; science, as a manifestation of nature must also exhibit stratification in all aspects. Social systems are the manifestations of very complex interactions and relations; as such they are unique. This multiplicity grounds a plurality in the science that would study them. This stratification of nature and society provides ontological depth, the limits of which can be derived from the TMSA and expressed by Bhaskar in terms of: concept-dependence, activity-dependence and space-time specificity of social structures. A relational limit arises from the causal interdependence between social science and the TMSA’s subject of study, in this case science education. Finally, the epistemological limit provides for explanatory criteria for theory assessment based on the condition that social systems are intrinsically open. It can be seen that the Causal Realist position is that society is a pre-existing and necessary condition for agency, while simultaneously existing and pre-existing in virtue of agency:

"The picture that emerges from critical realism, then, is one in which society is portrayed as a nexus of (in many cases internally related) social positions, each of which is accompanied by a corresponding set of rights and obligations and is occupied by an individual socio-economic actor."\textsuperscript{92}

8.1 Antecedent Structures

The enablement /constraint that is experienced by agents by virtue of the pre-existing structures with which they interface, exerts a causal influence on their social activity

at that particular moment. These structures can change over time, hence the nature and type of causal influence that they exert will also change, leading to different interactions and interfaces with agents. Most important to this conception of social interaction is the fundamental fact that the social structures that manifest themselves at any given moment are the products of prior interactions between agents and structures that by implication also exist prior to the present. Therefore, for Bhaskar and Archer, agent interaction and structural existence “constitute an objective reality that is ontologically irreducible to behaviour in the present”\textsuperscript{93}.

Any course of action undertaken or endeavouring to be undertaken by any agent at any given time is predicated on antecedent structures that were socially constructed by an ongoing process of interaction and exist prior to the present action or course of action. These structures and artifacts take the form of materials or cultural resources, such as economic power, cultural status, access to communication or any other body politic, social potentiality or actual object. These socially constructed and dependent artifacts are inherently stratified within nature and hence society; they are not evenly distributed. It can be seen that this modality of stratification must also exist prior to any specific interaction of an agent. Agents within any social system will experience different interactions with structures in virtue of their stratificationary position determining their interface potential. Any interaction by agents within society (that is inherently transfactual and stratified) will be directly shaped and influenced by the distribution of artifacts and the nature of structures that have been historically bequeathed to the present agent by the interactions of past agents.

\textsuperscript{93} Lewis, P. ibid., p. 259.
Present interactions unknowingly create the artifacts and structures that will post-date the present; in other words, the future is blindly created by the combination of present interactions of agents on present incarnations of structures and artifacts which were themselves created by past interactions.

Bhaskar states the fundamental question, which motivates the critical realist analysis of society, as follows: "What properties do societies possess that might make them possible objects of knowledge for us?" I have tried to answer this question in two stages, first of all addressing the ontological issue of what properties society possess (this is roughly where Solomon and the STS writers took us) before then going on to consider the epistemological question of whether those properties make societies possible objects of knowledge for us. At the heart of the critical realist analysis of the ontology of the socio-economic world lays the critical realist account of the relationship between social structure and human agency. People constantly draw on social structures in order to act and in acting they either reproduce or transform those structures. This relationship between structure and agency, as we have seen highlighted by Archer, has a temporal dimension. Every human agent is born into a world of antecedent social structures, they learn a language, face a culture and mode of economic organization that is not of their making - there is an "ontological hiatus". Social structure pre-exists and is therefore ontologically irreducible to the current exercise of human agency. It is in virtue of its being emergent (irreducible to people and the practices in which they engage) and causally efficacious in shaping people's actions that, critical realists maintain, social structure may be regarded not as a mere theoretical construct but as real.

Bhaskar, (1989), op cit., p.25
But there is an issue here in the downplaying the problematic reified nature of the Bhaskar and Giddens position on the interaction between structure and agency. We must avoid at the outset the reification of an abstract term - causal power applied to social structures. For Harré and Varela (1996), the attribution of causal efficacy to social structures involves detaching causal powers from powerful particulars of the social world, namely human actors. In their theory of causal power they see social structure as immanent in (and so ontologically reducible to) people and their practices (Harré and Varela, 1996, p. 313, 315, Harré 1997). From this perspective the social world is the joint product of people's discursive practices. Such an account suggests that macro-social concepts like "class" are best thought of as taxonomic categories, which are used to classify and label different types of people and practices. The referents of such a concept are not objective social structures but people's discursive practices. A science teacher's actions from this perspective are facilitated and constrained, not by pre-existing social structure as such, but by the willingness of his or her interlocutors to take up that person's meanings in their conversations (Harré, 1997, pp. 181-2) and are understandable in terms of their relative location in the local moral order in these conversations. Harré's positioning theory is a dynamic alternative to role theory in attempts to understand the dynamics of social episodes. Science and scientists are agents in most major social episodes. The STS agenda can be seen as an attempt to reposition science educators and their students in conversations about science, technology and social development. It is in the occupancy of discursive positions by particular individuals in different institutional locations - and more specifically the rights and obligations that accompany these positions - that lies at the heart of the interaction between structure and agency.
Causal realism can concede as outlined in the introduction to this thesis that pre-existing social structures are not efficient causes and hence not powerful particulars, and still maintain that social structures are causally efficacious. The distribution of interests and resources bequeathed historically within schools to the current generation of teachers may exert an important influence in the social affairs of science education and science. Causal realism does not deterministically reduce human agency to an expression of pre-existing social structure. The vantage point provided by causal realism moreover reveals that the conversational analogy in terms of which Harré frames his account of the social world has serious shortcomings. Perhaps most significantly, the conversational analogy entails a severely restricted metaphysics, which may exclude in particular the category of historically given social structures and artifacts, which have shaped science. Attempts to explain in science classes why a person or group responded in the way they did to a particular narrative about cloning for example might well profit from considering the pattern of vested interests embodied in antecedent social structure.

8.2 Causal Realism and the Teaching/Learning Interface

Causal realism can inform the teaching/learning setting so as to provide an insight into the nature of this important social interaction. Social structures provide the framing that is constituted by a set of positions that are associated with particular rights and responsibilities into which agents are placed. In effect, agents are endowed with particular artifacts, potentialities and social positions. It is these structures that have shaped the present positioning of the agent. This positioning encompasses the
behaviour, knowledge, skills, outlook, socio-political view, economic wealth and ethical system of particular individuals. In addition, the actual structures of the specific social strata in which the individual exists will have a causal effect on potential and realised behaviour in any specific interaction:

“We are looking for a way of conceptualising structure that recognises its reality, i.e. its causal powers, yet also recognises that these operate via human action, i.e. by presenting agents with reasons – sometimes ‘overwhelming’ reasons – for acting in certain ways. ‘Society’ provides the conditions for acting, but does not itself act.”

This is the essence of the interaction of structure and agency. Within the social practice of teaching, students and teachers interact at the interface of a classroom. Many structures abound in this interface, those of the classroom, the teacher and the student(s) both individually and collectively. This social interaction will be highly relational in nature, specific in terms of space, time, and the particular set of agents participating in the interaction. This relational nature of social structure exists in a hierarchy of external relations and internal relations without and within the interaction interface, shaping and defining the very nature of the interaction itself. This is not to present a deterministic view of social interaction, far from it, but rather to place social interaction into the context of the action itself by providing an initial distribution and manifestation of the artifacts inherent in any interface of structure and agency. Individuals within the social system constantly interact with structures and draw on artifacts in order to reproduce or transform the structures with which they interact.

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This interaction can be understood and interpreted under the TMSA model proposed by Bhaskar.

Agents are knowledgeable beings, and social practices their skilled accomplishments Bhaskar\(^{96}\). These practices can take the form of unconscious action; agents are aware of the range of possible actions, responses or stances that are open to them by virtue of their position in society and their prior experiences with social interaction. Alternatively, they could be deliberative conscious actions, the result of a balanced informed comprehension of the structures that enable and constrain their current course of action. Structural reproduction is an unintended consequence of agency when the agent acts within the existing guidelines or structures. By acting within the social structures, they are following the rules that constitute whatever activity they practice, reproducing the system of structures. This reproduction will take place as a symptom of their actions that is the result of their own understood purpose. The interaction of agents with structures, and the existence of each other as a recursive outcome of the other, leads to a duality of character or structure. Giddens\(^{97}\) understands this to mean that "(t)he rules and resources drawn upon in the production and reproduction of social action are at the same time the means of system reproduction."

Bhaskar introduces the notions of conditions, outcomes, production and reproduction to explain the existence of society:

"(B)oth society and human praxis must possess a dual character. Society is both the ever-present condition (material cause) and the

\(^{96}\) Bhaskar, R. (1989), op.cit., p. 36
continually reproduced outcome of human agency. And praxis is both … conscious production, and (normally unconscious) reproduction of the conditions of production, that is society.”

Social scientific knowledge can offer the justification for social change and transformation; it also provides the cognitive resources for this change. It is another matter whether or not an intentional social structural change (transformation) is possible.

8.3 Causal Realism: The middle way.

A causal realist position can be seen as being the mid-way point between a naïve realist position and the extreme constructionist view of knowledge development. In the naïve realist position, a direct, one-to-one correlation is assumed to exist between the nature of content and the actual “world” of the mind. By contrast the extreme social constructionist position holds that all knowledge is constructed in social interactions with no connection to any reality external to the specific, momentary interaction. The differences between these two ends of the spectrum in the debate about knowledge have been characterised by the more widespread and easily accessed debate between data processing and situated learning. Causal realism attempts to reconcile the two extreme stances by acknowledging that in reality, both have a place in explanations about learning.

Causal realism requires an intermediary between the real world and the knower, a construction that importantly is founded in reality. The role of construction and signification are of great importance in this process; however it is the role of the agent

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that in a causal realist position assumes the central and pivotal aspect. Science education reform has traditionally been poor at explaining the social ontological dimension of learning. Teachers have been left without an understanding of their role in the classroom, their agency. Traditional science education has espoused a genetic model for knowledge development, one that has neglected the domain and its causative role in shaping experiences. The three-way dialogical representation of learning that was proposed by Roberts (1993, 1994), as shown in figure 7 is invested with an epistemological authority by the theory of social action that is developed under a critical realist position.

8.4 The Stratification of Ontological Domains.

The concept of ontological stratification, as indicated earlier is fundamental to causal realism. Bhaskar perceives reality as being stratified into three ontological domains: the real, the actual and the subjective. The real domain contains real entities that possess various causal powers, structures that affect and are affected by other entities. The structures or mechanisms can take the form of physical ones like chemical or atomic structures, biological ones such as ecological systems, or social structures such as social relationships or modes of production. The relative power, effect or influence of these structures can vary according to a myriad of potentialities and inter-relations. These interactions occupy the domain of the actual, where causal forces interact to produce events. Those events that are the result of experiences or concepts belong in the third domain, the subjective. This subjective domain can be reinterpreted as a semiotic domain that emphasises sign-processes, continual activity and productive practice.
What distinguishes the ontological domains in causal realism is the concept of emergence. Bhaskar\(^{99}\) defines emergence as a "relationship between two terms such that one term diachronically or perhaps synchronically arises out of the other, but is capable of reacting back on the first and is in any event causally and taxonomically irreducible to it." The actual is emergent from the possible; actualities not only are governed by underlying structures and generative mechanisms, but may also act on them, altering them or even creating new ones. This concept of emergence underscores the fact that signs and actualities are both real (causally efficacious), but not all of the real and that signs (concepts and experiences) only represent some actualities. It can be seen that the TMSA provides a model for understanding the nature of interactions in the domain of the real. Social structures in this domain are dependent on an agent's activities and concepts while being only relatively enduring. Importantly, neither structures nor agents can be reduced to the other. As a result, agents act on the basis of given structural conditions, and these actions reproduce or transform structures.

8.5 The Ontological and Phenomenological Dimensions of Social Activity.

The three social ontological domains – discourse, agency, and structure – appear in some form within each dimension of social practice, because the domains only exist through human agency. Since the phenomenological dimensions are related to the ontological domains, they have emergent properties and a degree of autonomy. Taken

together, the social levels and their phenomenological dimensions can be represented as the grid in Table 1.

The vertical axis shows the three levels of social ontology and in parentheses indicate the general ontological domain to which they are most connected. The horizontal axis presents the phenomenological dimensions of practice with parentheses showing modes of operation. The grid attempts to indicate the social elements that exist. However, due to the overlapping and mixed character of all social interactions and practices, it is difficult to delineate accurately between certain social features. It may be that alternate divisions to these practices could be proposed, however, in this thesis the aim of the grid is to exemplify and attempt to reveal social ontology and phenomology rather than examine the minute of social practice. Starting in the lower left cell and working counter-clockwise, we find the material structures of society (forces of production and human bodies), including economic structure, the framework of communication and possibly family structures. Out of these material processes emerge social relations and forms of power such as domination, subordination, exploitation. From both the material and sociological dynamics emerge meanings in the form of basic concepts and images, which are principally iconic. The 'scientific disciplines', 'teacher' and 'learner' are icons of intellectual and social exchange in science education, the powers of which are not identical to their uses in capitalism that generate icons of commodity exchange as the basic social relations. Conversely, our understanding of underlying structures such as the scientific domain depends on our ability to generate iconic models of them. Image schema and basic categories conjoin to form meaning structures that act as generative principles for higher-level forms of meaning. These image schemata provide the
basis for images of ‘self’ and ‘other’ that constitute ideas of social identity and effect social identifications. They also organise transportable discursive and performance strategies or norms of behaviour. Science identity-imagery and meaning-strategies are distinguished according to agents’ social positions; they are indexes of agents’ locations in society (Harré and Van Langenhove, 1991).

Continuing counter clockwise from the upper right cell, identity-imagery and meaning strategies provide the most immediate social bases for the explicit articulation of discourses in science education in such forms as theories, ideologies and lessons as cultural products. Such articulations depend on Peircian symbols and have symbolic effects (among them, their potential claim to generality or universality). They also supply justifications and/or rationalisations (whether real or pretended) for agents’ actions, which take the form of intended meanings (see next cell to the left). Psychological dynamics are a significant part of intentionality, but these too are socially conditioned and social in form, as indicated by thought’s character as inner speech. Like agents and structures, discourses are connected to a specific form of power to choose, including the choice of how to interpret and express things once again conditioned by social position. Expressions take material form (upper left cell); but Peirce argues that the semiotic process may ultimately generate habits, habit changes and habitus within agents. This is part of the organisation and institutionalisation of agents. Thus the individual body of the science educator as a mode of agency has structural and semiotic effects incorporated within it; it is established as a political body. It also resides in the body politic – agency depends upon and accumulates the ability to act by means of collectives, such as the subject department, the school or university, the professional organisation.
<table>
<thead>
<tr>
<th>Ontological levels of society</th>
<th>Discourses (Semioses)</th>
<th>Agents (Actuality)</th>
<th>Structures (Possibilities)</th>
</tr>
</thead>
</table>

Table 1: The ontological and phenomenological dimensions of social activity.
The research hypothesis forming the basis for the division in Table 1 is the conjecture that each ontological level, social structure, agent, discourses, has an existence *sui generis* which can be related to but cannot be collapsed to the 3 phenomenological representations, material, social and hermeneutic. One first piece of evidence for this conjecture is simply that science education is already focused around and concentrated upon disparate levels, indicating that they are indeed regarded and treated as involving relatively autonomous, non-reducible objects. Level-autonomy thus resides in non-reductive causal mechanisms of particular interest at each specific level.

According to causal realism, the fundamental task of science education theory development is to identify the mechanisms specific for each level, and to identify the mechanisms that bind the levels together. While the former explain the autonomy of the levels, the latter explain how agency and structure influence each other in particular discursive setting. A level-ontology coupled with a causal approach probably constitutes one of several possible first steps towards the epistemological break that is necessary if science education wants to leave its present phase of Naturphilosophie and become the genuinely explanatory science as the STS proponents seek.

8.6 Transformation of Embodied Social Activity

Transformation in such modes of embodied agency can transform the material structures with which we began. At the centre of this account of social action is embodied intentional activity (both individual and group), which provides the motive
force behind social processes. The cycle that has been described for the purpose of animating the grid is only one pattern through which these processes work, as there are many different ways for the elements to interact. But by distinguishing between the ontological and phenomenological dimensions of social activity the issue of societies concept-dependence can be brought into sharper relief. The operation of society depends on concepts but is not exhausted by them, particularly at an agential level, which is more volatile. Discourses are critical for establishing identities and alliances, differences and oppositions. To this degree, post-structural critiques of science education rightly emphasise the significance of discursive articulation and the political valence of struggles over meaning. Yet there would be no point to these struggles were it not that the processes of forming and maintaining alliances, oppositions and organisational arrangements which often consume limited resources, dedicated to the future use of others, can seldom readily be undone and ultimately reproduce or transform the fundamental structures of society, including structures of power.

Causal realism in science education can fill many gaps, supporting and empowering understanding and change. It can support an understanding of signs and semioses that grasps both the intransitive (inner world) dimension of knowledge and the semiotic nature of our mental access to it in the transitive (outer world) dimension. It can provide an understanding for the place of learner, teacher and domain in a triad of discourse, providing a model for the epistemic authority of teachers. Thus informing science education reform through an appreciation for purpose and the nature of agency.
Chapter 9

STS and Science Education Viewed Through a Causal Realist Lens

When he proposed the TMSA, Bhaskar provided a framework that could be used to inform sociological analysis, change and redirection. This framework can also be seen as a tool that allows social interaction, agency and structure to be revealed and analysed within any situated social system. However, in generating and providing the framework or tool, Bhaskar did not provide examples or instructions for its application. Bhaskar’s theory is a global pronouncement that is designed to be applied wherever social illocutionary forces act. I do not believe that Bhaskar’s intent when he wrote the theory was actually to provide a tool, rather he was endeavouring to provide a critique of social reproduction and exemplify the role of agency within continuously recreated and reproduced social structures. All of this he achieved. However, I contend that it is when the TMSA is viewed as a framework, or tool with which social illocutionary forces can be brought into relief within the context of social structures and human agency that we will find its greatest value. The TMSA is not a quantitative device, rather it is a form of lens that can simultaneously reveal structure, interaction, and agency within a social structure while providing a guide, or framework to understand the nature of intentional social change as opposed to unintentional social reproduction. When viewed in this light, the TMSA becomes essential prerequisite knowledge for any attempt to reform or transform a social system.
Within the social system of science teaching, curriculum reforms must have at their core a vision for teacher agency and acknowledgement of structuration within the socially determinate system. The challenge to teaching/learning reform is to examine the artifacts that exist by virtue of the undertaking itself, both in the culture and classroom layouts and to understand the social nature of teaching and learning in which intentional agents interact with other agents and structures, constantly refining and recreating the nature of their social interaction. The synergy between human agency and the agency of artifacts determines the nature of the structures that are manipulated and interacted with by agents. Archer\textsuperscript{100} applies the theory of morphogenesis to the three realms of structure agency and culture. Her perception of culture is one where it does not simply reside ‘inside the head’, rather it exists in the artifacts of the social system, the traditions, accumulated history, objects and repertoire that combine to make up a coherent system. Artifacts exist independent of the agents who interact with them. The artifacts of science education possess a unique set of emergent characteristics that make them specific to the social system of science education. They have been subjected to a continuous process of conditioning, social interaction and elaboration that has shaped and structured their manifestation. The process of interaction inherent within any social setting must be understood and provided specific attention by any curriculum initiative wishing to change the nature of any of the components within the system:

\textit{"For example the small-scale interactions between teachers and pupils do not just happen within educational systems ... Both pupils and teachers, for instance, bring in with them different degrees of bargaining power (cultural capital as expertise) that is resources with} \textsuperscript{100} Archer, M. (1995), op cit., pp. 12-16
which they were endowed in wider society by virtue of family class, gender and ethnicity. Equally, the definition of instruction which they literally encounter in schools is not one which can freely be negotiated in situ but is determined outside the classroom, and, at least partially, outside the education system altogether.”

It would be reasonable to assume that curriculum reform within teaching and learning is designed to modify or change to some extent all of the system components: agency, artifacts and structures. Given this transformational brief that we acknowledge exists in any teaching or learning reform, any initiative would be incomplete and flawed if it did not fundamentally understand social interaction and social reproduction in addition to specifically addressing a vision for teacher agency within the ontological status of social interactions. Traditionally, revolutionary curriculum reform has failed to deliver the social transformation that it promised, quite the opposite; it now appears possible that these ‘reforms’ actually reified the a priori structures and artifacts and failed to change the nature of human agency within science teaching:

“The greater the time-space distanciation of social system – the more their institutions bite into time and space – the more resistant they are to manipulation and change.”

Traditional science pedagogy and scientific structures have a large time-space distanciation, they are grounded on a system that has developed over hundreds of years and which has constructed on a series of fallacies. These fallacies have become entrenched within the social structures and the knowledge of the agents. As such, the

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structures that we see existing in science teaching are very resistant to manipulation and change:

“The role of the human sciences is via the criticism of false beliefs and the explanation of why they are held, which, since truth is good, constitutes a reason for transforming structures which generate false beliefs.”

I contend that the failure of reform movements can be attributed to the fundamental socio-psychological understandings inherent in the reform and a lack of understanding of the need to address teacher agency within a socially reproducing system (on a fundamental level). This vision for teacher agency and structuration needs to be both in terms of the specific curriculum reform itself and on a wider scale, of the profession of science teaching itself.

9.1 Educational reform

Educational reform can arise from a wide range of different sources; dissatisfactions with existing curriculum, aspirations for a new way, institutional directive, or slow evolutionary change driven by a changing society. Many of these do no more than reproduce the existing paradigm in a slightly new fashion.

Although most of these so-called reforms can be said to have been intentional, the fact that they have resulted in nothing more than a reformulation or reproduction of what had preceded them devalues their role as reform agents. Not only should we judge the transformational power of individuals' agency, in terms of some form of hierarchical

103 Bhaskar, R. (1986), op cit., p. 63
view of value, we should apply the same criteria to a broader scope of institutional change. In this way, we come by a notion of reform that can be judged by its transformational impact on the pre-existing structures.

Over the past 15 years the process of science teaching has changed somewhat, particularly in the area of situated learning. As I have suggested earlier, this pedagogy has become widely accepted as an important aspect of classroom teaching and learning. Many teachers have a good understanding of, and are familiar, at least in part, with the deep-rooted argument which can be traced back beyond the General Science debates of the 1930s and 1940s. The STS movement as outlined in Solomon’s book (1993) has specifically adopted a situated learning stance both for classroom teaching and for teacher professional development. The simultaneous move towards cooperative classroom learning served to further expose teachers to a more social stance concerning their classroom. These pedagogical changes have now become adopted into normal teacher practice, they are not used exclusively but do appear in different contexts. What has not changed throughout this process has been an understanding of fundamental socio-psychological factors involved within any social system, in this case, specifically the social order of science teaching in schools.

9.2 Educational Reform Oversights

The shared social representation of science teaching held by teachers is one that is not easily changed or challenged. STS reforms attempted this transformation but this has occurred without a reappraisal of teacher agency and structuration within a social setting that simultaneously enables and constrains the agency of the agents that they
themselves created. This has led to embodied views of the social nature, purpose and setting of science teaching, without a firm grasp of teachers’ agency and structuration. There is no valid context for discussions such as these in schools nor were they fostered or encouraged by the STS reforms. The whole edifice of science teaching in the STS proposal has been built without institutional foundations or a social theory of science education. This has resulted in an unsatisfying mixture of traditional teaching and learning styles juxtaposed alongside more socially orientated settings set against a background of supposed social ends and means that appear to defy analysis, response and achievement. In the confusion and disenchantment that has resulted, a wide Cartesian distinction persists. Full of certainty and theory, a disembodied science teaching has been seen as a ‘safe haven’ for teachers. The difficult and challenging questions raised by STS about rules and resources by which science teaching is structured and the shift towards a social reconstruction of science pedagogy in the absence of an understanding of the socio-psychological nature of science teaching (social interaction, social transformation, structuration and agency) have been avoided.

The redress of this lack of understanding and vision of teacher agency lies squarely in the domain of research in curriculum reform and teacher professional development. We would not expect teachers themselves, unprompted or in isolation, to transform both their fundamental understandings of the nature and purpose of their activity, in effect to transform their agency and simultaneously transform the nature of social structures that exist independently of any individual in the domain of the society. Under the TMSA this would not be possible as the nature of teacher agency is determined (enabled/constrained) by the nature of the structures and artifacts with
which they interact and that have been created by collaborative social interactions of many agents within the society of science.

9.3 STS as an Educational Reform Movement

As we have seen, the STS movement had complex foundations and origins. It constituted a new approach to the concept of science education. The concern over limited scope and reach of the existing traditional science structure, combined with, on the one hand, the growing reliance of society on science and on the other hand with the impression that only a small fraction of society was scientifically literate. From an economic, political and social perspective science was a contentious matter. STS offered a type of relevance to everyday experience and life that previous curricula did not; it offered a new construction of the structures of school science education.

As a reform movement the STS curriculum as institution was aided by many of the relevant social concerns that abounded during the time of its inception. There was widespread concern over environmental issues, and the power of science and scientists. It would appear that at least in this respect, STS was a reform that was manifestly aligned with its time. Students were to learn science with an understanding of social issues and impacts, engaging in and solving real world problems. STS sought to embody a concept of science that was empowering and open for all, regardless of culture, status or socio-economic power. It was intentional, well articulated, and well supported with literature and resources; it also encouraged discourse and valued agency. STS set out to transform science teaching and learning as process, and it did so through proposals of social action. In short, STS should have
provided a realist framework for such social action by teachers in their classrooms. This could have been based on Bhaskar's *Transformational Model of Social Action*.

Solomon does not address the "constructivist impasse" as she sees it between real science and "the need to let loose the children's creativity" (p300) in terms of the social agential role of the teacher. She addresses it in terms of truth against Rawls' modern social justice and Rorty's "final victory". Solomon associates Harré with teaching towards "the confirmation of selfhood" (p303) through making analogical links between new and previous learned representations, than an understanding of his realist social positioning in issue-based case studies materials used to teach about decision making scenarios in science, technology and science curricula. Science teaching is not perceived in the context of any transformational model of social action. The stratified ontological dimensions of her social model of teaching are not developed. I have tried to develop a realist model of the social behavior with teachers in mind. I have argued for the need to go back to reality.

9.4 The Failure of STS.

There can be many different explanations of why STS has founded. One view is that it was a victim of the conflict between the hermeneutic of mind/body. The language and semiotic devices employed by the STS movement failed to span the divide between either the discursive practices of teachers, or the practical and physical patterns of interaction in the situated landscape of the school. The STS movement, as exemplified in Solomon's writing, attempted transformation in the nature of social interaction within science teaching, but founded because it
focused on the results, the outcomes of the reform – a new system of viewing the relationships inherent between society, science and technology. It did not address the teachers' understandings of their social behaviour individually or collectively in the social transformation. Teacher agency and social structuration were not considered to be important to the curriculum reform proposed by the STS movement. I argue, however, that these understandings are actually fundamental in any social transformation within science teaching. In the absence of a renewed understanding and vision for, and of, teacher agency, without an appreciation of the role of socially constructed, constantly refined structures, curriculum and pedagogical transformations are impossible. In order for any intentional transformation in a social system to occur, the transformation would need to be predicated on an understanding of the existing conditions that enable and constrain agency, as it would be only then that the proposed transformation could be aligned with the social structures and transform them through a process of reflexive appropriation, or perhaps by some other transformational model.

A pragmatic view of this failure would be one where the notion of representation has been missed. This would arise on two levels; first the level of the Wittgensteinian language metaphor. Since practices cannot be separated from the mix of speech and action, practices must be seen as reverting to a variable emphasis on plans, instructions both inter- and intra-personal and the nature of the catalogues that are easily accessed. Development and transformation are somehow entailed in a conception of discursive process. The second aspect to the failure of representation is closely linked to the first but different enough to be considered separately. STS made assumptions that fundamental purposes would be self-evident and commonly held,
fundamental to the belief systems of all science teachers. However, I would contend that this is in fact not the case. Science teachers certainly do possess an understanding of purpose but this purpose is from solely their own perspective. The perspective of purpose that is necessary for the successful implementation of STS is that of the learners. Science teachers do not perceive science education from the purposes of the learners; this inability arises not from a moral abrogation but from the mind/body praxis. Teachers cannot ‘hear’ the views of their students because of an inability to listen or engage with learners; to do so would require an understanding of learning as being purposeful from the perspective of learners.

Science education is not seen as representing emergent knowledge; rather it represents fully formed conclusions, conclusions that all too often can't be imported into the ‘real world’. Alarm is often expressed by the inability of learners to transfer their class-based knowledge to real world situations. I am quick to stress here that this particular failing of STS is not concerned with the cognitive notion of transfer, rather it resulted from a confusion of social and individual purposes in education through science. It failed to examine the interface of structure and agency. It failed to frame a realist view of science in classroom dialogue that arose from a failure of purpose and a poor grasp of the real conditions of teachers and learning in schools.

The theory seeks to offer a TMSA for understanding the behavior of science teachers as social agents for a revitalized STS platform. A central question addressed within the realist framework is how are we to understand that the logic of causal powers underwrites conversational realism in the science staff room in schools and society where the objects of knowledge are various representations (Markova, 1996; Varela,
Thomson and Rosch, 1991) of science and technology in society. The answer I propose in a model of causal realism for science education resides in the relationship between self-mobilization - the very process of agency - and causal powers. Since the process of the exercise of human agency is social, to locate the agentic act 'inside' the individual is not only to lose bringing about joint acts with others, but it is also to lose the essential joint character of social reality. Self-mobilization is a social act; a mutual process of consideration whereby persons consider how the other person will, can or could act in response to their own act in order to direct themselves to act is such a way that a joint or social act is accomplished. Hence the everyday display of powers belongs to the person and not to the organism because their enactment can only be accomplished socially not individually, and in addition 'person' is a social category. Causal powers theory underwrites conversational realism and the concept of positioning as understood within the discursive framework of an STS classroom.

STS conceived knowledge as being object representations; as a result it was thought to fit best into a coordinated approach to curriculum, where traditional constructs were coordinated with STS themes in an attempt to make the activity more meaningful and authentic. However, this notion is to trivialise the language of learning as it leads to a position where anyone with authenticity can authenticate and experience or action. A causal realist position requires a new conception of the use of language – a switch in orientation to language so that it can be seen as interpretive in a purposeful and powerful discourse: of signs, images, representations, and experience of how people might understand things, a methodology by which life might be lived and are revealed doing it in school time! Science teaching should not set out to be inactive, something that fulfils a purpose devised by those delivering
rather than receiving the process. Rather it must be seen as the result of our social interactions and as such be deeply imbedded in social discourse and actions. The purpose of science education should by rights emerge from the learners' aspect, not only fulfilling their needs but also accessible in the classroom discourse. The agency of science education should be more explicitly understood as a *Transformational Model of Social Action*. 
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