LEARNING PERSPECTIVES: IMPLICATIONS FOR PEDAGOGY IN SCIENCE EDUCATION

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ABSTRACT *How we understand learning has implications for the learning outcomes we value and how we seek to achieve them particularly when we want to do something about learning. In this paper I outline, albeit briefly, the implications for the relations between teaching and learning, for teacher roles and responsibilities, and for the goals of education and curriculum-making of the cognitive-constructivist and situated-social views of learning. The proposal here is not that either of the views is right or better but rather that each foregrounds different aspects of the teaching-learning process and supports particular ways of acting and interacting and hence learning and teaching.*

> A perspective is not a recipe; it doesn't tell you just what to do. Rather, it acts as a guide about what to pay attention to, what difficulties to expect and how to approach problems. (Wenger, 1998, p. 9)

Learning is not something that is tied to a particular time, place or group of people nor is it necessarily dependent on instruction (Wells & Claxton, 2002; Wenger, 1998). Nevertheless, schools are responsible to society for bringing about learning. They are places where teachers are increasingly being held accountable for the learning of individual students in relation to what is prescribed in national curriculum documents (Crooks, 2003). This assumes there is a direct and unproblematic relationship between teaching and learning and that what is and should be learned is uncontested. Whether this might be so depends on how learning is viewed.

How we understand learning has implications for the outcomes we value and how we seek to achieve them particularly when we want to do something about learning – as individuals, as communities, and as organisations (Driver, Asoko, Leach, Mortimer & Scott, 1994; Wenger, 1998). Views of learning have the potential to serve as frameworks for analysing pedagogy and for creating further possibilities. This paper sets out two broad views of learning to discuss what insights these offer as a means for conceptualising pedagogy, with particular reference to science education. Questions are raised with respect to the appropriate unit of analysis and implications for how teaching might be enhanced.

VIEWS OF LEARNING: IMPLICATIONS FOR TEACHING

For the purposes of this paper, two broad views of learning are distinguished: a cognitive constructivist view and a situated-social view (Greeno, 1997; Kirshner & Whitson, 1997). A cognitive view of learning postulates that knowledge is a mental representation that is actively build up by the learner as part of the process of making sense of their world (Driver, 1989; Osborne & Freyberg, 1985). This view is generally consonant with educational goals of increased knowledge and skills. Learner prior knowledge and experience are considered to both enable and

constrain individual meaning making. Learning is seen as an active, rational, individual and somewhat idiosyncratic process (Salomon & Perkins, 1998) for which the learners themselves have the major responsibility. Learning and teaching are not viewed as directly linked.

What social views of learning bring to the fore is that any study of learning involves the situated social system as a unit of analysis (Greeno, 1997; Lave & Wenger, 1991). Building on Vygotsky's work, some writers with a social view of learning construe it as an individual process mediated by tools and social interaction; others propose that both learning and what is learned are situated by virtue of being distributed over people, places and things and the changing relations between them (Salomon & Perkins, 1998). In this latter sociocultural view the practices in which people participate constitute what they learn (Wenger, 1998). Knowledge is a matter of competence with respect to those activities valued by the social group of which one is a part. Learning involves the transformation of participation and formation of identity through a process in which the individual and the collective shape each other and experience life and the world as meaningful. In this view, learning is about becoming as well as knowing and identity develops both through individual agency and through social practice. Seen this way, teaching and learning are not directly linked or even mirror images. The teacher and the setting are integral with the learning that takes place. The goals for education encompass successful and increasingly complex participation in socially organised activity and the growth of students' identities as learners (Greeno, 1997).

From a cognitive constructivist perspective, in science education at least, the recommendation is that teachers serve as conceptual change agents who also foster student metacognitive awareness (Hewson, Beeth & Thorley, 1998). To this end, their role is to provide activities to shift student thinking towards that of the target discipline. Activities that generate cognitive conflict and/or development including the use of mental models and analogies are seen as useful in this regard (Gilbert & Boulter, 2000). Just as importantly, teachers need to monitor and respond to the sense students actually make through formative assessment (Bell & Cowie, 2001). The implication here is that teachers require extensive knowledge of the content to be taught, of the likely progression of student ideas, of ways for finding out about student ideas and of strategies for moving student ideas forward. Teaching is also a learning process – teachers learn about their students, the subject and the impact of the activities they are using.

The work of the early Learning In Science Projects (Osborne & Freyberg, 1985) provides examples of the cognitive constructivist approach. In a unit of work on electric current, for instance, the students' first task is to wire up a bulb and a battery so that the light glows. From this the teacher is able to see whether the students consider one or two wires are needed and hence to gain an insight into how students think about electric current. Students next explore a range of circuits and investigate how to produce a string of 'Christmas lights' where one bulb blowing does not lead to all the lights going out. The students then select one of four research-based models as the best explanation for what they have observed. Class debate follows and the unit culminates with the teacher providing a practical demonstration of the scientific explanation. The work of Taylor (2000) provides another more recent example of the cognitive constructivist approach. Taylor developed and trialled a unit using a model-building approach designed to teach astronomy to New Zealand year 7 and 8 students. His intervention comprised 11 lessons that focused first on mental and actual models and their

limitations and moved on to examine scientists' mental models for the solar system. Students then constructed an actual model (called an orrery). Students were encouraged to utilise the scientists' mental models to solve problems, some of which were novel to them. The class debated the solutions proposed by different groups to help further consolidate the scientists' mental models. As can be seen from these units, the teacher played an active role in taking account of student thinking to shift it towards the scientific view (Bell & Gilbert, 1996).

Viewed from a sociocultural perspective, possible roles for the classroom teacher are mentor of students as apprentices through the zone of proximal development and someone who works with students to develop and sustain classrooms as learning communities. In this case the practices that teacher-selected tasks afford are centre stage (Cobb, 2002). Any teaching activities need to engage students with teachers in practices consonant with the discipline under study and contribute to positive student identities and identifications with learning and the subject of study in both the short and long term. The aim is for students to become "owners ... acquirers, users and extenders" of knowledge in a particular domain (Brown et al., 1993, p. 190). The collective learning trajectory is considered to be shaped by both the teacher and student interests, knowledge and skills and the resources available in the setting.

The sociocultural perspective poses a number of challenges for teachers not the least being that, as Lave and Wenger (1991) point out, in school there is often "no cultural identity encompassing the activity in which newcomers participate and no field of mature practice for what is being learned" (p. 112). A danger then is that children will simply learn 'school' or how to be a student. The alternative, that teachers aim to develop the class as a "community of scholars", implies that teachers themselves need to be intentional, self-motivated individual and collaborative learners with their students (Brown et al., 1993, p. 190). The challenge for them is to maintain their integrity with respect to their responsibilities to their students and to the members of the discipline of study and society as a whole with regard to moving student views towards those currently viewed as viable. Put another way, teachers need to manage the interaction of the planned and the emergent curriculum so that teaching and learning interact to "become structuring resources for each other in a way that maximises the negotiation of meaning" (Wenger, 1998, p.14).

A sociocultural perspective is consonant with current recommendations in science education that teachers need to support social interactions that promote the development of scientific reasoning (Dushl & Hamilton, 1998) and is, therefore, consistent with suggestions that teachers provide opportunities for students to talk, read and write using the language of science (Lemke, 1990) and to learn through argumentation (Driver & Newton, 1997). This perspective recognises that students not only learn science but also learn about science and so this approach lends import to current recommendations for an explicit focus on the nature of science (Driver et al., 1996), particularly in terms of how scientific ideas are investigated, debated and validated (Hipkins, Stockwell, Bolstad & Baker, 2002).

This perspective is consistent with current calls for more inclusive and socially relevant teaching of 'science for all' and the associated concern with scientific literacy (Laugksch, 2000). The use of stories, including the stories of science, is recommended as a teaching approach (Millar & Osborne, 1998) that promotes student understanding of both science content and the nature of science. Scientists are construed as real people with real motivations, interests and feelings

and so science knowledge development is represented as a human, creative endeavour. Barker (2002) provides three stories about New Zealand scientists with the potential to meet these goals. These include a story about *Andreas Reischeck – The Collector* and another about *Joan Wiffen, Dinosaur Woman* which have links to the Living World, and Planet Earth and Beyond strands and also illustrate the ethical and non-authoritarian nature of science. Similarly, Boniface (2002) provides ideas for a range of *stories for chemistry* and McKinley (1997) suggests traditional Maori legends have this potential. Others have found that traditional children's stories can serve similar purposes. For instance, Grugeon and Gardner (2000) used *Goldilocks and the Three Bears* as a context to explore heat transfer during cooling with primary school students. (In the scientific sense, Mother Bear's porridge should be 'just right' and the smaller bowl of Baby Bear's porridge should be the coolest.)

VIEWS OF LEARNING – A FRAMEWORK FOR UNDERSTANDING RESEARCH ON TEACHING

Looking across the two views of learning it is clear that they reflect a widening unit of analysis for learning and what is learned, along with increasing complexity in the means by which might be supported and directed. Interestingly, a shift similar to that outlined above is evident in research on teaching. Concern with teacher knowledges (Shulman, 1987), particularly pedagogical content knowledge, arose in the mid 1980s – a time of intense interest in student alternative concepts in science education. At the same time, a view of teaching as a rational individual activity found support in a concern with teacher reflection in and on action (Schon, 1983) alongside research on student metacognition (Baird & Northfield, 1992). The ability to reflect on action was, and still is, considered crucial to transforming complex knowledge into action and the development of further knowledge based on practice (Darling-Hammond, Wise & Klein, 1999). This said, debates about the existence of a body of knowledge for teaching and the nature of such knowledge are ongoing.

Investigations into the knowledge needed for teaching, particularly those conducted through classroom-based research that also take into account teacher perspectives, have illuminated the complexity of the knowledges teachers bring into play at the moment of teaching. Teachers use an integrated amalgam of understandings about students, the subject and pedagogy that is both subject to change, context specific and linked with personal experience, inside and outside the classroom (Hiebert, Gallimore & Stigler, 2002; Shulman, 1992). There is a body of evidence that teacher beliefs and views about students, teaching and the subject of study influence practice (Bell & Gilbert, 1996) with some referring to these as a 'hidden curriculum' (Uhrmacher, 1997). With this research has come the realisation that teaching is a complex practice that cannot be dichotomised into knowledge and action (Boaler, 2003). Rather, as Shulman proposed recently, teacher knowledge is "part of a complex set of interactions, involving action, and analysis and affect" (Shulman, 2003, cited in Boaler, 2003, p. 1-2). This contention has support at the level of effective classroom practice from the work of Jones and Moreland (this issue). They found that a dual focus on teacher pedagogical content knowledge and teachers' formative interactions in the classroom led to enhanced student learning.

Support for a wider unit of analysis for pedagogy also comes from the work of Connelly and Clandinin (1999). They found that although an initial focus on

teacher knowledge through notions of personal practical knowledge and professional knowledge landscapes resonated with teachers, it did not address teacher concerns completely. Careful attention to these concerns indicated teachers were "more concerned to ask questions of who they are than of what they know" (Connelly & Clandinin, 1999, p. 3). This led Connelly and Clandinin to a focus on how knowledge, context and identity are related and to explore links between teacher identity and curriculum making, the ways in which teacher identities are composed, sustained and changed, and the links between context (including space and time) and teacher identity.

Research on teacher careers and professional development supports the importance of the temporal dimension in any unit of analysis (Huberman & Grounauer, 1993); this is a feature of situated-social views of learning. Teachers in Bell and Cowie's (2001) research indicated that a focus on a particular idea could be sustained, albeit intermittently, over the duration of a five week unit and that, whereas their focus at the beginning of the year was on getting know their students, by the end of the year mutual teacher–student confidence supported greater risk taking by teachers and students in the pursuit of understanding.

As with learning, research has indicated that teaching has affective and social dimensions. Teacher confidence and self-efficacy play a role in their practice (Black, 1998), with teachers adopting a more tranmissive approach when they lack confidence in their understanding of a curriculum area (Carlsen, 1991). A teacher from the Learning in Science Project (Assessment) (Bell & Cowie, 2001), for instance, described how her confidence in her pedagogical knowledge of expansion in metals and her confidence in and knowledge of the skills of her students in discussing ideas contributed her decision to allow time for class discussion of the effect of heat on solids. Despite this, she noted that her confidence in her own pedagogical content knowledge wavered when the class seemed to be coming to the wrong conclusion. Affect plays a key role in supporting and constraining teacher change (Hargreaves, 2001). Bell and Gilbert (1996), Bell and Cowie (2001) and Jones and Moreland (2003) found that, for teachers, changing their practice was as much an emotional as an intellectual challenge.

Likewise, research highlights that teaching is a responsive relational activity (Darling-Hammond, Wise & Klein, 1999). The New Zealand teachers in Bell and Cowie's (2001) and Jones and Moreland's (2003) research were concerned that any feedback they provided to students not only supported student learning but also their relationships with students. This concern is well supported in the New Zealand and international literature. Building on this, Leach and Moon (1999) suggest an appropriate unit of analysis for pedagogy is the "pedagogic setting" composed of "the practice that a teacher (or teachers) together with a particular group of learners, creates, enacts and experiences" (p. 267). This unit is perhaps too limited; teachers are members of and are held to account by a number of communities each with their own expectations.

Schools as the settings for teaching and learning are increasingly being implicated in teacher practice. Teachers are members of school staffs with particular expectations and practices that shape their actions. It seems that, over time, school staffs develop a *school way* of doing things into which newcomers are inducted (Fullan, 1999; Putnam & Borko, 2000; Spurr, 2003). This is possibly why just over three quarters of teacher respondents in a recent New Zealand national survey on curriculum implementation described colleagues in the same school as the most effective curriculum support for teaching (McGee et al., 2002). The school

organisational and physical environment also acts to shape what is possible, particularly with regard to principal support (Fullan, 1999). Evidence from Jones and Moreland's (2003) study, where the momentum for change and development has been sustained past the direct involvement of the researchers, is that it was important that the school staff as a whole became involved in the sharing of ideas. In this way the learning trajectory of the research teacher group intersects with, is informed by and shapes that of the staff as a whole. Put another way, there is a body of research that affirms the importance of collaborative and whole school professional development. Alongside this, secondary and specialist teachers tend to affiliate with their subject subcultures and these then frame what they consider possible, practical and professional (Jones, 1999). Teachers who draw meaning (identify with) their subject specialty may resist changes to its structure and to what it means to be a teacher (Bell & Gilbert, 1996), unless this is re-negotiated with other teachers of the same subject.

Analyses of teaching that construe it as the management of dilemmas also draw attention to the wider setting (Lampert, 1985;) but in a way that highlights the contradictions and conflicts in teacher roles and responsibilities. Wallace and Louden (2002), for instance, suggest that teachers of science face a range of dilemmas that derive from the nature of science as a subject and the ways science knowledge is represented, from the diversity amongst students and from issues related to teaching and learning. These dilemmas include the need to reconcile teaching practices with a particular view of learning, to balance the learning needs of students who might continue on to be scientists and those who might not and the challenges associated with responding to curriculum change. New Zealand teachers, it seems, struggle with how to meet the need for individual understanding and for class curriculum coverage (Bell & Cowie, 2001), with how to respond to student needs and interests and national curriculum demands (McGee et al., 2001) and with how to prioritise different government initiatives such as environmental education, numeracy and literacy. In terms of this wider context, Hill (2000) in New Zealand, Reay and Wiliam (1999) in England and Johnston, Guice, Baker, Malone and Michelson (1995) in the United States provide compelling evidence of the impact of national assessment policy on teacher practice. Teachers are influenced by factors from both outside and inside the classroom

This review of research on teaching, short though it is, illustrates some of the complexity with which teaching is now understood. In this field, research has added to our understanding of the significance of teacher personal characteristics and qualities in a manner consistent with a cognitive constructivist view of learning. It has also detailed the ways in which teaching, learning and the setting (physical, social and political, and inside and outside the classroom) are inextricably intertwined in a manner more consistent with social views of learning. There are many possible candidates for a unit of analysis for teaching.

DISCUSSION

Although views of learning can serve only as a guide for how teaching might be accomplished (Wenger, 1998)they do have implications for the meanings and consequences of teaching and learning actions. Firstly, they highlight that the same activities and actions can serve different purposes and have different meanings depending on the perspective adopted. For instance, social interaction can be viewed as part of the context for learning or integral to the learning. A

teacher working from a social perspective would be interested in finding out about student ideas as a starting point for further learning rather than as something to be challenged as in the cognitive constructivist perspective (Howe, 1996). Just as importantly, both views indicate that teaching is also a learning activity. It would seem, therefore, that teachers could benefit from being clear about the view of learning that underpins the curricula they are charged with teaching and the meanings of the actions they take to do this. Unfortunately, teachers not only struggle to conceptualise learning from, for instance, a constructivist perspective (Bell & Gilbert 1996) but the view(s) of learning that underpin a curriculum may be neither coherent or explicit (Bell, Jones & Carr, 1995). For example, in research conducted on the curriculum stocktake, a teacher expressed a desire that, in the professional development phase of the implementation of the science curriculum, the view of learning implicit in the curriculum document be made explicit. Such clarity would seem all the more important when current views of learning and concomitant descriptions of teaching construe learners and teachers as active.

Different views of learning support different educational goals (Greeno, 1997). While educational goals are always contestable, the 'knowledge society' currently advocated is generally consonant with a sociocultural view of learning and the development of students' identities as life long learners (Greeno, 1997; Ministry of Education, 1993; Wells & Claxton, 2002). The teacher working from a social-situated perspective needs to foster students' abilities to learn and come to see themselves as critical 'knowers' and 'doers' in a particular domain (Brown et al., 1993). The teacher, therefore, requires a complex appreciation of the subject of study and of the wider implications of teaching actions and interactions. The "renewal of culture as well as its reproduction" (Wells & Claxton, 2002, p. 5) is a focus and so teachers and students need opportunities to participate meaningfully in the processes of curriculum development (Wenger, 1998). Thus, a sociocultural perspective highlights a contradiction in the current context: How can teachers develop students' identities as lifelong learners in a setting where the trend is towards curricular prescription and teacher accountability for student achievement of specified learning outcomes (Crooks, 2003).

The two broad views of learning discussed here indicate that the individual teacher or the situated social system – where this could be the classroom, the school or each and all of these as part of the wider community, for periods from a few minutes to a year or more – are possible candidates for a unit of analysis for teaching. In line with current thinking in relation to learning, it would seem sensible to consider these two broad views/units as complementary (Greeno, 1997; Salomon & Perkins, 1998) with each contributing, albeit in different ways, to our understanding of the complexity of the teaching process. For researchers who wish to inform teaching and teachers interested in changing their practice the decision about a choice of the unit for analysing and informing teaching is more problematic. Teachers it seems rarely draw on research when actively seeking to enhance their teaching. Black (2003) argues the issue here is more to do with the transformation of knowledge into actions than the translation of research findings. Teachers require a fine grain analysis of the teaching/learning process (Boaler, 2003) because they are not simply interested to know that discussion is beneficial, for instance, they also need to know how to set up and support productive discussions. Suggestions for units are 'the lesson' (Hiebert, Gallimore, & Stigler, 2002), 'activities that work' (Appleton, 2003) and 'classroom practices' or sequences of action and interaction that encompass the development of ideas over

time (Boaler, 2003). New Zealand research indicates a need to focus on teacher affect, beliefs and pedagogical content knowledge along with the wider school (and policy) context that might support and constrain teaching practice (Bell & Gilbert, 1996; Bolstad, Cowie & Eames, 2003; Jones & Moreland, 2003). In terms of the picture of the woman who can be both beautiful and an old crone, the conundrum is how to keep all these aspects in focus at the same time – dialogue amongst researchers and between researchers and teachers would seem the most likely solution.

To sum up, this paper has outlined, albeit briefly, the implications for the relations between teaching and learning, for teacher roles and responsibilities, and for the goals of education and curriculum-making of two contemporary views of learning. The proposal here is not that either of the views is right or better but rather that each foregrounds different aspects of the teaching-learning process and supports particular ways of acting and interacting and hence learning and teaching. Social and situated views of learning do, however, challenge the assumptions that seem to underpin the current emphasis on evidence-based or informed policy and practice and the concern to 'scale-up' research initiatives.

REFERENCES

Appleton, K. (2003). How do beginning primary school teachers cope with science? Toward an understanding of science teaching practice. *Research in Science Education, 33*(1), 1-26.

Baird, J., & Northfield, J. (1992). *Learning From the PEEL Experience*. Melbourne, VIC: Faculty of Education, Monash University.

Barker, M. (2002). Ripping yarns – Science stories with a point. *New Zealand Science Teacher, 101*, 38-39.

Bell, B., & Cowie, B. (2001). *Formative assessment and science education*. Dordrecht: Kluwer Academic Press.

Bell, B., & Gilbert, J. (1996). *Teacher development: A model from science education*. London: Falmer Press.

Bell, B., Jones, A., & Carr, M. (1995) .The development of the recent national New Zealand science curriculum. *SAMEpapers 1995*. Hamilton: CSTER, University of Waikato (pp. 3-44).

Black, P. (2003). Turning research into practice: How does the D fit into R&D? Paper presented at the 2003 American Educational Research Association Conference, Chicago, 21-25 April.

Black, P. (1998). *Testing: Friend or foe? The theory and practice of assessment and testing*. London: The Falmer Press.

Boaler, J. (2003). Studying and capturing the complexity of practice – the case of the 'dance of agency'. Proceedings of the 2003 Joint Meeting of PME and PMENA. Honolulu, Hawaii, 13-18 July.

Bolstad, R., Cowie, B., & Eames, C. (2003). *An evaluation of environmental education in New Zealand schools: Volume 1 – a summary of research findings*. A report commissioned by the Ministry of Education from New Zealand Council for Educational Research and CSTER, University of Waikato.

Boniface. S. (2002). Stories for chemistry. *New Zealand Science Teacher, 101*, 38-39.

Brown, A., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A., & Campione, J. (1993). Distributed expertise in the classroom. In Gavriel Salomon (Ed), *Distributed cognitions: Psychological and educational considerations*. Cambridge: Cambridge University Press.

Carlsen, W. (1991). Questioning in classrooms: A sociolinguistic perspective. *Review of Educational Research, 61*(2), 157-178.

Cobb, P. (2002). Reasoning with tools and inscriptions. *Journal of the Learning Sciences, 11*(2/3), 187-216.

Connelly, M., & Clandinin, J. (1999). *Shaping a professional identity: Stories of educational practice.* New York: Teachers College Press.

Crooks, T. (2003). Some criteria for intelligent accountability applied to accountably in New Zealand. Paper presented at the 2003 American Educational Research Association Conference, Chicago, 21-25 April.

Darling-Hammond, L., Wise, A., & Klein, S. (1999). *A License to teach.* San Francisco: Jossey-Bass.

Driver, R., (1989). The construction of scientific knowledge in school classrooms. In R. Millar (Ed.), *Doing science: Images of science in science education.* (pp 83-106) London: Falmer Press.

Driver, R., & Newton, P. (1997). *Establishing the norms of scientific argumentation in classrooms.* Paper presented at the European Science education research Association Conference, Rome, September. (pp. 83-106).

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science.* Buckingham: Open University Press.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 5-12.

Duschl, R., & Hamilton, R. (1998). Conceptual change in science and in the learning of science. In B. Fraser & K. Tobin (Eds), *International handbook of science education.* (pp. 1047-1065) Dordrecht: Kluwer Academic Press.

Fullan, M. (1999). *Change forces: The sequel.* London: Falmer.

Gilbert, J., & Boulter, C., (Eds.) (2000). *Developing models in science education.* Dordrecht: Kluwer.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher,* 26(1), 5-17.

Grugeon, E., & Gardner, P. (2000). *The art of story telling for teachers and pupils: Using stories to develop literacy in primary classrooms.* London: David Fulton.

Hargreaves, A. (2001). Emotional geographies of teaching. *Teachers College Record, 103*(6), 1056-1080.

Hewson, P., Beeth, M., & Thorley, R. (1998). Teaching for conceptual change. In B. Fraser, & K. Tobin (Eds.), *International handbook of science education* (pp. 199-218). Dordrecht: Kluwer Academic Press.

Hiebert, J., Gallimore, R., & Stigler, J. (2002). A knowledge base for the teaching profession: What would it look like and how can we get one? *Educational Researcher, 31*(5), 3-20.

Hill, M. F. (2000). Remapping the assessment landscape in self-managing schools. Unpublished Phd Thesis

Hipkins, R., Stockwell, W., Bolstad, R., & Baker, R. (2002). *Commonsense, trust and science: How patterns of beliefs an attitudes to science pose challenges for effective communication.* Report prepared for the New Zealand Ministry of Education. New Zealand Council of Educational Research.

Howe, A. C. (1996). Development of science concepts within a Vygotskian framework. *Science Education, 80*(1), 35-51.

Huberman, M., & Grounauer, M. (1993). *The lives of teachers.* London: Cassell.

Jones, A. (1999). The influence of teachers' subcultures on curriculum innovation. In J. Loughran (Ed.), *Researching teaching.* (pp. 155-171). London: Falmer Press.

Jones, A., & Moreland, J. (2003). From classroom-based research to school wide reform in science and technology teaching practice: The case of Mountview school. Paper presented at ASERA, Sydney, July.

Johnston, P., Guice, S., Baker, K., Malone, J., & Michelson, N. (1995). Assessment of teaching and learning in "literature-based" classrooms. *Teaching and Teacher Education, 11*(4), 359-371.

Kirshner, D., & Whitson, J. A. (1997). Editors' introduction to situated cognition: social, semiotic, and psychological perspectives. In D. Kirshner & J. A. Whitson (Eds.), *Situated cognition: Social, semiotic, and psychological perspectives.* (pp 1-16) Mahwah, NJ: Lawrence Erlbaum Associates.

Lampert, M. (1985). How do teachers manage to teach? Perspectives on problems in practice. Harvard Educational Review, *55*, 178-194.

Laugksch, R. (2000). Scientific literacy: a conceptual overview. *Science Education, 84*, 71-94.

Lave, J., & Wenger, E. (1991) *Situated learning: Legitimate peripheral participation.* Cambridge: Cambridge University Press.

Leach, J. & Moon, B. (1999) Recreating pedagogy. In J. Leach & B. Moon (Eds.), *Learners and pedagogy* (pp. 265- 276). Milton Keynes: Open University Press.

Lemke, J. (1990). *Talking science; Language, learning, values.* Norwood, NJ: Ablex Publishing Corporation.

McGee, C., Jones, A., Bishop, R., Cowie, B., Hill, M., Miller, T., Harlow, A., Oliver, D., Taikiwai, S., & MacKenzie, K. (2002). *Teachers' experiences in implementing the New Zealand national curriculum.* Waikato Institute for Research in Learning & Curriculum, Centre for Science & Technology Education Research and Mäori Education Research Institute.

McGee, C., Cowie, B., Jones, A., Bishop, R., Miller, T., & MacKenzie, K. (2001). *Curriculum stocktake: National school sampling study, Milestone 1: Report on national teacher focus groups.* Waikato Institute for Research in Learning & Curriculum, Centre for Science & Technology Education Research and Mäori Education Research Institute.

McKinley, E. (1997). Mäori and science education: participation, aspirations and school curricula. In B. Bell & R. Baker (Eds.), *Developing the science curriculum in Aotearoa New Zealand.* (pp 213-226). Auckland: Addison Wesley Longman,

Millar, R., & Osborne, J. F. (Eds.) (1998). *Beyond 2000: Science education for the future.* London: Kings College.

Ministry of Education (1993). *The New Zealand Curriculum Framework.* Wellington: Learning Media.

Osborne, R. J., & Freyberg, P. S. (1985). *Learning in science: The implications of children's science.* Auckland: Heinemann.

Putman, R., & Borko, H. (2000). What do new views of knowledge an thinking have to say about research on teacher learning? *Educational Researcher, 29*(1), 4-15.

Reay, D., & Wiliam, D. (1999). "I'll be a nothing": Structure, agency and the construction of identity through assessment [1]. *British Educational Research Journal, 25*(3), 343-354.

Salomon, G., & Perkins, D. N. (1998). Individual and social aspects of learning. *Review of Research in Education, 23*, 1-24.

Schon, D. A. (1983). The reflective practitioner: How professionals think in action. New York: Basic Books.

Shulman, L. (1992). Toward a pedagogy of cases. In J. Shulman (Ed.), *Case methods in teacher education* (pp. 1-29). New York: Teachers College Press.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57,* 1-22.

Spurr, R. G. (2003). Teachers' experiences implementing the New Zealand Curriculum Framework. Unpublished Masters thesis, University of Waikato.

Taylor, I. J. (2000). *Promoting mental model-building in astronomy education.* Unpublished PhD Thesis, University of Waikato.

Uhrmacher, P. (1997). The curriculum shadow. *Curriculum Inquiry, 27,* 317-330.

Wallace, J., & Louden, W. (2002). *Dilemmas of science teaching.* London: Routledge Falmer.

Wells, G., & Claxton, G. (2002). *Learning for life in the 21st century.* Oxford: Blackwell Publishing.

Wenger, E. (1998). Communities of Practice: Learning, meaning and identity. Cambridge: Cambridge University Press.

Wertsch, J. V. (1995). The need for action in sociocultural research. In J. V. Wertsch, P. D. Rio & A. Alvarez (Eds.), *Sociocultural studies of mind.* (pp. 56-74). Cambridge: Cambridge University Press.