

Appendix 3

Transforming the teaching of university first year physics - 1999 - 2000

Questions:

What are the issues in assisting in the transformation of science teaching?

What are the different cultural memes that scientists operate under as scientists and science teachers?

How is the reformer transformed?

Introduction

In this chapter I describe a collaborative research project I was involved with at a university physics department to improve teaching and learning of first year physics courses during 1999 and 2000. I describe university teaching practices and explore the attitudes and habit patterns that act as barriers to successful adoption of new pedagogies, despite the best intentions of the participating lecturers in the project. I suggest that in transforming science education we need to deeply understand the 'who' that is doing the teaching of science – who they are as a scientist, a person, their beliefs about science and learning, their learning styles and temperaments and the culture that they are in.

I then draw on transformational learning theory to analyse several key aspects of the project and how different project processes helped or hindered transformation. Following this, I bring a spiral dynamic lens in trying to understand the big picture patterns that seemed to emerge.

The beginning of a relationship with the university physics department

March 1995. I am sitting in a small lecture theatre with about 40 first year physics students. We are in tiered rows listening to the lecturer at the front – Dr Brown. It is the first physics lecture of the year – the topic is 3 dimensional unit vectors – the basic building blocks of any spatial physics.

I am here by accident. I really came to the university to give a workshop to about 10 physics lecturers around some of my ideas about teaching physics, based on five years experience teaching Year 11/12 physical sciences courses at college level. I was invited by a lecturer who I had been working with on various physics syllabus committees. Following the workshop Dr Brown, a participant, said “Why not sit in my lecture and give me some feedback.”

So here I am sitting, held in place by this enveloping chair and tray, facing the front. This is the first lecture of the year and I watch at a loss at what Dr Brown is doing. Why, when there is an ocean of possibilities which could excite and stimulate students to be curious explorers of this physical universe is Dr Brown starting with this small dry pebble? Bumbling, as he tries to balance his wooden pointer and his two arms to show the three dimensional co-ordinates.

I start writing. Why can't he see the students are flummoxed, why isn't he asking them questions? Why is he the one in control of the talking – why can't he allow students to talk among themselves to tease out their questions and understandings?

Why, instead of starting with the maths, isn't he starting with an interesting context so that students can see the usefulness of the vector modelling to a real situation?

Why has he answered that student's question in that way, can't he see the underlying question behind it, why isn't he probing deeper? Can't he see the dissatisfaction that the student has with his answer?

*Why is he so focussed on **telling**, rather than helping students to understand? I look at how students are taking notes squinting at the scrawled chalk marks on the board. Is there any time for them here to think about what they are hearing and writing. Is there another way of doing this?*

Why on earth hasn't he had a three dimensional co-ordinate model made so he can pass it around the students so they can see in 3D space how a vector might deconstruct into the unit vectors, rather than this indecipherable hand waving and poorly drawn diagrams?

I am caught now in the minutiae.

But the lecture is over and my four ex-students from my 1994 Year 12 Physics class now rush up to me. They had previously greeted me enthusiastically, wanting to know why I was there. Now they roll their eyes at me “Have I made the right choice?” asks one.

“I thought physics was going to be interesting.” says another. “I want to explore the cosmos, to think, to ask the big questions! Where are the questions?”

“Is it going to get any better?” asks another. “I think you have given us unrealistic expectations of what physics can be.”

What have I done? Have I let my students down by giving them incorrect expectations? Can I help make it better? I am feeling really cross. Here I have done my best to excite students about physics, encourage them to think, to be curious, to delight in coming to understand something and gain new insights. And as a result here are four students who were ready to go the distance – to get a degree in a physics. And after the first lesson they are having second thoughts.

As I leave the lecture theatre Dr Brown asks me what I thought. He looks down at my notes surprised, I think, at how much I have written. “Do you really want to know?” I ask. He nods as if he is bracing himself.

I can't help myself. It all pours out... my questions and thoughts about his teaching ... almost accusingly. It is like a vomit. And he is just standing there straight and silent. I begin to realize what I am doing. Telling. Seeing him as an object to inform, change, rather than a human being. The enemy. I put my hand over my mouth and stop abruptly.

“I am really sorry”, I say and I explain about my conversation with my students and how it had made me really cross and I didn't know what came over me. I am really embarrassed.

“You have certainly given me something to think about.” He says and we part.

Based on that episode, it would be hard to imagine that I might have a continuing relationship with the university physics department, but over the next few years it grows.

What is my responsibility as a Year 11/12 science teacher towards creating successful experiences for my students in their continuing science pathways? I had never seen it as my issue before – the dry university degree was just something you had to put up with before you could do ‘real’ physics or science. It was a means to an end. But could it be an end in itself? Could I be active in creating change of how physics was perceived at university level?

Its purpose, the way it was delivered, the way it might engage and challenge students to continue to grow?

Yes, it was time I made it my business and it seemed that despite that tactless episode with Dr Brown that the university physics department was keen to get me back. In 1996 I acted as a critical friend for one lecturer assisting in his implementation of constructivist pedagogies in his classes. That led to workshops which we ran for other lecturers and state science teachers. With the decline in numbers of students taking 'pure' and 'applied physics', the physics department was looking at ways of attracting students and in 1998 the department applied for a federal grant to run a collaborative learning project looking at improving the teaching and learning for first year physics courses. The project began in 1999 and I was invited to be co-ordinator. Five lecturers and two post-graduate students were part of our collaborative action research project.

By then I had gained a few skills and a little wisdom in professional learning and transformation issues, though the project would challenge my understanding and push me to new perspectival levels. I had also developed a strong working relationship with a number of the project participants and certainly no longer perceived them as 'the enemy', although I was just as passionate about the need for change. I also had had two and half years of doing my own action research for my doctorate and had begun to unpack my own attitudes, assumptions and practices in science education.

Dr Brown is a keen supporter of the project and despite my tactlessness he tells me he took quite a bit of what I said in 1995 on board... "Sue, you really made me think!" His first lecture is now an overview of where the course is leading, the research questions that the department is engaged in, including his own questions and dilemmas in his own field of research. He has joined the project, keen to develop a greater understanding of how his students come to understand, what misconceptions they have and how to challenge these, how to encourage a thinking classroom so students gain a deeper understanding of physics ideas.

But what about the big picture? Being better constructors of knowledge is still within a paradigm where physics is seen as knowledge to be acquired... *Physics as a body of knowledge*. Is there another way of thinking about physics?

How can an under-graduate university physics course take students on a continuing journey of rigor, of thinking, of scientific inquiry, of invention of ideas, of participation in a

dialogical scientific community, helping them to be critical of science while at the same time inducting them into it? How can such a course encourage their own development as human beings and challenge them to explore both self and the universe? How can it develop a sense of *ethical agency* – a passion not just for the pursuit of knowledge and following one's own curiosity - but also in helping the world be a better place? How can it help them experience other perspectives and research modalities so that they are effective participants in multi-disciplinary inquiry?

Yes, I have a vision of what an undergraduate physics course could be about; I can even see structures in my head which might facilitate it – different styles of delivery from more content based to inquiry based to multi-disciplinary problem based projects. Topics which might not just introduce physics ideas but also lend themselves to philosophical critique, or ethical dilemmas. Student run symposiums... the possibilities are endless.

Whoa Sue, reality check! Just because I am co-ordinator of the project doesn't mean I get to impose my vision and my methods on others. When I talk enthusiastically about the possibilities to the participants it is clear it is just too big and too overwhelming a change. Even though the lecturers are doing their own innovative scientific research and are used to facilitating open ended research that their graduate students are undertaking, it seems that they have been enculturated into a way of thinking about undergraduate courses. *There is foundational content we need to get across and the students don't have enough understanding to do their own projects.*

So what can we do? How can we infuse the current structure of the first year physics courses with the goals of the team. And what are these goals and how do we explicate them?

This is the beginning of a transformational journey for all of us. I learnt a lot about the difficulty of helping others to adopt new ways of thinking and practices and how important it is to look deeper for underlying reasons. I realized that often very little outward movement actually requires enormous inward movement in thinking and perspective. I learnt I could not generalise, that everyone was very different and as facilitator I needed to work at an individual level as well as a group level – unpeeling the layers of another's habitual practices and thinking, their deep goals and passions – and unpeeling the relationship of myself with others as I helped them to see themselves.

It was difficult and frustrating and I made quite a few mistakes as I tried to balance my various roles and find an ethically tactful, self-reflexive way of being. It is only now in

reflecting on the experience that I can see how in working as a leader/teacher of others I fell into the same trap as the lecturers had with their students – seeing ourselves as holders of knowledge and constructors of that knowledge – in my case the knowledge was educational theory and pedagogies.

Is it worthwhile telling something of our process and our dilemmas? I think so. Perhaps this physics department is not representative of all physics departments, but perhaps it indicates the difficulty in creating sustainable change. So whereas in Chapter 12 I proposed a new Integral vision for science, this chapter acts as a balance to that... perhaps serving as a cautionary tale for reformists.

So here I am in 1999, in a position of working with others to help take them on a journey, armed with my own experiences, some educational theory, and a little pedagogical leadership experience. Even though I think I have made explicit my assumptions, values and ideas about science and physics education, this project now takes me to a new level – causing me to make sense of my own journey of 10 years of physics teaching. I begin to realize my ‘physics teaching head’ is a very different headspace to most other teachers. Yes, I am in ‘*Sue’s wonderful world of physics*’ and ‘*Sue’s wonderful world of educational understanding*’ and through this project I begin to realize how different this world is to others. I realize it isn’t a right way of doing things or a wrong way – but just different and that it can add an interesting dimension to any conversation about science teaching.

However, even though I am learning to be more pluralistic in my perspectives, I still have a strong modernistic streak which I am constantly doing battle with... wanting to find the truth, the answers, the strategy. Yes, as the physics lecturers seem to want to find a strategy in their teaching which will help students understand better, I want to find a strategy with working with them that will push them forward.

Action research project to improve teaching and learning of first year physics courses – getting started

It is March 1999 and I have a plan.... We are using *action research* as our method of inquiry into the teaching and learning with the first stage involving setting some tentative goals for the project... what do we want to achieve?

Although each of the physics lecturers brings to the project different experiences of teaching and different educational philosophies, they all agree that they want to make the learning experience for the students more enjoyable and meaningful; helping them understand more deeply and stimulating their curiosity in physics and the world. This sounds good but it is problematic and we have to unpack this further. What is it that the students *need* to understand? And what does this mean to each lecturer? Is it about making their content-bound lectures a little more interactive; involving trivial constructivist techniques which help students build up concepts and challenge misunderstandings? Is it about making the lab sessions less instruction based and more open ended? Is it questioning the purpose of lectures, the choice of topics or the very notion of what science teaching is about?

How can I begin a conversation where we look beyond the need to *construct content* into the very heart of how we perceive science teaching? What does it really *mean* to be a scientist? Can we help our students experience what it means to be a scientist? What might this look like and feel like? Yes, I ask the lecturers, what is it like for you as you do science?

I have a model which I have developed which is a map of the territory a scientist might cover as they engage in scientific inquiry. I ask the lecturers to reflect on their own research and map their research journeys around the model.

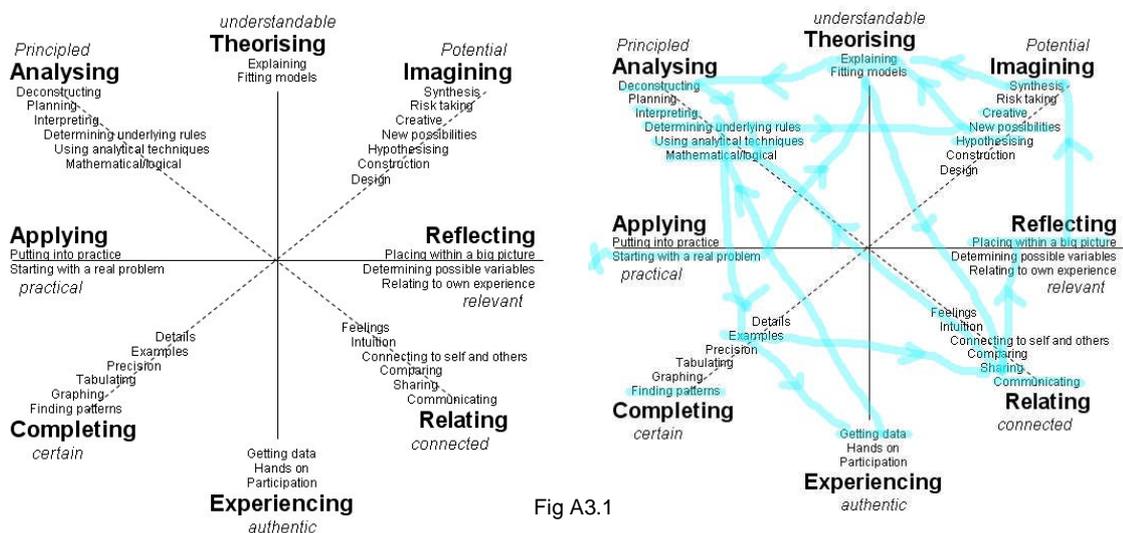


Fig A3.1

In doing this we discover that each of us takes a different journey and has preferred areas where we might spend more time, depending on whether you are a theoretical physicist or one that also engages in experimentation or observation. We do seem to cover the same territory. And quite a bit of this territory, while valued by the scientists themselves, is not something which they might normally consider ‘science inquiry’ and certainly not something

they actively or explicitly encourage in their teaching – for example, processes like intuition, sharing, imagining.

So perhaps ‘inquiry’ is more an *attitude* rather than a set of *procedures* - where the individual is engaged in personal meaning making, following their curiosity, gaining insights and being creative in development of theories and practices. As part of this inquiry they discerningly use a tool kit of processes and procedures as they aim to come to know. And they are engaged with a greater community which acts as a sounding board, moderator, source of ideas and information - so meaning making moves out of the personal into a collaborative endeavor.

“Being a scientist,” says one lecturer, “is a way of life. It is a type of thinking and looking at the world that you bring whether watching TV or doing a research project.”

“It is about questioning, discernment, wanting to look deeper, being open to possibilities,” muses another.

“But how do we move from how we are teaching now, to creating an environment where students can experience this sense of inquiry?”

This project is primarily looking at improving teaching in first year Applied Physics as well as the pure physics course. The students who are doing Applied Physics are from courses in Agricultural Science, Pharmacy and Surveying as well as from general science courses. We decide to ask these client departments what it is they hope their students will gain as a result of doing the Applied Physics unit.

So some interesting discussions ensue where it seems that while some minimal foundational content is required for some of the client courses, the key concern is that the students experience a ‘physics way’ of doing things, or a physics style of thinking. What do these departments mean? What is a *physics style of thinking*? Procedural, logical, solving problems, exploring concepts, seeking evidence? How was this different to other types of science thinking? And are the students in the program gaining these skills from the current teaching methods?

So now our project team is teasing out what it means to develop physics thinking and we are wondering how much thinking the students might be doing already. What are they understanding? What questions are they thinking to themselves as they listen to lectures? How are they relating what they are learning about in physics to their main course of study? How do the lab sessions enable inquiry based thinking to occur?

So how do we find this out? We decide to do peer observations of the two lecturers who are currently involved in teaching the two first year courses – Dr Brown (pure physics) and Dan (Applied Physics). I suggest that the observers also interview the students afterwards and discover what they are thinking, but they do not feel comfortable with doing that, so I become the interviewer and thus an intermediary between the students and the lecturers.

Over a couple of weeks of lectures I am observing students, their participation, their body language, their questions and how they might chat to each other when the lecturer is talking, sometimes eavesdropping on what they are saying. I listen to their talk if the lecturer schedules time for think-pair-share. And then afterwards, after each lecture, I pull aside about six students and interview them, asking them how they were thinking during the lecture – were they understanding, what unanswered questions they had, how effective a particular pedagogy might be. I am listening from a context of my own experience as a science teacher and expectations of what effective inquiry and learning might be.

I write these responses up in note form and then provide this feedback to the lecturers at our fortnightly meeting where we all share our observations of the lectures we have been to. (see Appendix 7 for an example of these.) The student responses are problematic and individual. While some students might be following the concepts, others have switched off. Some do not expect to think in a lecture and just sit passively, saying they learn best if they can read over it later. Others might be frustrated because they are still seeking something more – understanding, plausibility, significance or relevance. Some are making connections to their own lives and other courses, but others have compartmentalized what they are learning.

When I probe further as to what the students might have understood from a lecture, I often find ‘misconceptions’ or students saying, “Oh, now I think about it, I don’t really understand it, why does this happen?” Often after that they are so keen to understand something that I find that I am reconstructing their understandings. This helps me understand their thinking better which is very useful when I relate to the lecturers what is going on in the students heads and how they are stumbling over particular concepts and why. But I wish the lecturers were experiencing this first hand as I am learning so much about the students as a result of these processes of inquiring into their thinking.

The sort of detailed feedback I am giving to the lecturers is quite new to them. Although they work individually with students in tutorials to help them understand something, most don’t seem to have gone into this much depth in understanding their thinking. So the help they are

giving students is more from a teacher perspective, rather than from the student's perspective.

The fact that the student feedback about the lectures is so varied initially seems worrying for some lecturers – they had expected that if they adopted new pedagogies then these will work for all students. But it becomes clear that this is not going to be the case.

Dan throws up his hands “But if it is all based on individual preference how can we plan what to do?” So the need to try and make sense of the variety of data now opens up the door for looking at what educational theory can help explain this and help us plan better. I now introduce the notion of *learning styles* and ask whether we can look at the student responses using this as a lens; seeing that some students are coming from certain preferred learning styles. Some of the lecturers had been quite wary of educational theory and anti the university's own teaching and learning unit, so coming to a point where learning theories are seen as useful seems to be a significant step. But does the notion of learning styles really sink in?

Dan has just given a test and shows me the paper, saying “I just threw in this question to make up the marks – it is just writing the right symbols on the diagram - it is easy. But only 50% of the students got it right! Why didn't they get it? I must have explained this at least three times!”

I grab a piece of chalk and draw a make believe formula on the board with a variety of symbols and ask him if he would be able to understand that. He looks at me horrified and shakes his head “I can't do that now... I would have to take it home and look over it, substitute some numbers in, maybe do some quick graphs in order to get my head around it... I haven't got time for this.”

*“Hmmm,” I say, “So **me** explaining it to you three times wouldn't work?” I give him a cheeky glance, raising my eyebrows. “Perhaps,” I continue, “if you feel like that then it is likely that quite a few of your students will feel the same.”*

He looks at me thoughtfully “OK, I see where you are going with this... yes I could do a little exercise which helps them get more familiar with this.”

With each lecturer now, I am trying to help them reflect not only on what it means to be a scientist but also a learner. I am trying to put them in their students' shoes in as many ways as possible and tease out the differences and similarities between how they and their students think.

Getting more inquiry happening

Dr Brown has started giving questions in the middle of his pure physics lectures for small groups of three to discuss which they then share with the whole group. I have helped him in thinking about designing intriguing questions that might probe student understanding, moving them deeper into applying concepts and discussing their plausibility.

He is quite taken aback at the sort of responses he initially gets which reveal many 'misconceptions'. He wonders whether this has been the case all along in his teaching of physics, but he just hasn't asked the right questions to tease out these issues. He becomes intrigued with constructivist and misconception research and finds a diagnosis tool for the topic of motion. He applies it and is shocked that these students, who have completed Year 12 Physics, have major misconceptions about Newton's laws and momentum. He now asks "Why do they think that? Where have they got their notions from? How can I challenge these views?"

We have conversations where we tease out how students might be constructing understandings and what might be influencing these. He now revises how he constructs his lectures, what examples he uses and what he is aiming to achieve. So rather than just intending to *cover* a topic, he has a need to ensure the students *understand* it. He now asks more questions during the lecture, checking for understanding. And soon the atmosphere of the lectures change. The students seem to have more initiative in interrupting and asking questions and most students now are engaged in coming to understand the concepts in class.

Dr Brown seems energized by the lively discussions and his flexibility has enabled him to adapt on the spot to the students' questions and needs. He seems to enjoy inquiring into the questions that the students raise; gaining skill in opening these up to class discussion, rather than always being the 'expert knower' who gives the answer. When he gives a post diagnosis test on the topic he is delighted to see an improvement in student understanding. Dr Brown seems to have achieved an attitude of inquiry in his pure physics lectures, but this unfortunately hasn't been the case in the Applied Physics lectures.

Dan wants to get more inquiry happening in his lectures as well. He tells me that he wants to ask more questions. So I am sitting here observing a lecture, listening to how he asks questions and the impact on the students.

There are about 60 students scattered in this lecture theatre which could take 200. Dan is down the front giving a talk on optics, using a Power Point presentation which carefully constructs the concepts using well designed diagrams.

Dan has asked a question. "Another application of a prism is...?" I look around at how the students are reacting to this. They are shifting a little in their chairs, some are tilting their heads or looking at their friends, some are leaning forward. They seem to be thinking and now hands are going up from all around the lecture theatre. One student says "a telescope?"

Dan says "No... well yes, but that isn't the one I am after So another application of a prism ... isa ...?"

*Another student tries but it isn't the right answer and finally Dan says "Another application of a prism is **The eye!**"*

There seems to be a change in energy in the room. It seems colder.

A bit later on Dan asks another question which is also closed. This time students are holding themselves, waiting. Non-committal. One person right at the front puts up their hand.

After the lecture we head over to the morning tea room and as we grab a cup of tea I say "Actually Dan, I noticed that you asked quite a few questions. Did you notice how the students responded?"

Dan tells me that he doesn't really see what is going on because he is so focussed on remembering what he has to say next.

"Are you aware of the difference between open and closed questions?" I ask.

No, he hasn't really thought about it. I explain how the students seemed to shut down when they were expected to come up with the one answer that he was thinking of. Perhaps the issue isn't how many questions you ask but the type of questions... giving students an open question that could have several possibilities, encouraging them to be more speculative, allowing for different approaches, valuing any thinking they are doing... that way students are encouraged to participate. I am warming to my theme.

But Dan is looking horrified. "I can't ask them an open ended question." he says. "I wouldn't know what possibilities were reasonable and what weren't. I would have to work out all the possibilities before I could ask a question like that. I can't think on the spot ... I need time to think. I would be totally stressed." He is getting more and more agitated.

Hmmm. "When presented with several possibilities perhaps you could imagine yourself as a scientist then, rather than a teacher... what techniques do you use to decide whether something is plausible... look for justifying theory, test it out, do a thought experiment? How could you ask your students to be scientists with you?"

Dan is not convinced that he can carry it off but he says that he will go away and think about it. A few days later he tells me he has an open ended question that he thinks he might use in the optics lab session the next day. He feels there are two options for his question and that he would ask the students to test these out.

The lab session starts with Dan up the front giving the students instructions on putting together optical benches, lenses and mirrors to see different aspects of optical theory. There is not much discussion between students in their pairs... just practical conversations... "look through this", "place this here", "where has that bit gone to?". There are three other lecturers in the room observing, standing back against the walls.

Dan now asks his open ended question and asks each group to discuss possibilities. There is a lot of discussion and then Dan asks for ideas. There are three main possibilities that students come up with. Dan writes them all up on the board as I have suggested. He is looking very uncomfortable as he writes up the third one. He then asks the students to think how they might test each of these out and to go ahead and work out which one might be the best explanation.

The energy of the room has completely changed... the students are fully engaged, theorising, exploring, testing. The observer lecturers are drawn from the outskirts of the room and start engaging with the students as they are trying to come up with theories... these lecturers are enjoying the dialogue... challenging students to be more analytical as well as speculative. One student, who I have interviewed several times over the last weeks and is getting to know me, grabs me and says "Sue, I have been thinking how this might be relevant to... and I am wondering..." I am really pleased and think that this is now an inquiring classroom.

Dan is still up the front of the lab looking at his next lot of notes, head down. Oops, it is supposed to be him having these sort of conversations, not me.

Dan now calls everyone to attention and asks students to share what they have found out. There is a good discussion and he eliminates all but one possibility from the board and then gives the formal explanation.

After the 3 hour lab session I ask him how he felt his open ended question went. "I was not happy," he says, "When that third possibility came up I panicked. I couldn't think whether it might be true or not. I remembered what you said and I wrote it down on the board, but I really didn't want to put it up there."

"But it was such a success... the students were really engaged in some good scientific thinking. It seemed to be the highlight of the session."

"But I ended up running out of time. It took a lot longer than I thought. Now I have to cover more in the next session."

"Could you cover less content and give yourself time to do something like this?"

"I am going to have to think about it. I really don't feel comfortable with this sort of thing."

How can I help Dan to be more comfortable about this? Practice? Is this just about pedagogy, or does this reflect who Dan is? Can he change who he is, his very nature? Should I be expecting him to? What is the difference between Dr Brown and Dan? Is it learning style? Is it personality? Is it an attitude to science? What sort of scientists are they anyway?

How can we improve scientific discourse?

April, 1999. It is a month later and Dan is running a lab session now on electricity – series and parallel circuits.

I am standing at the back of the room along with two other observer lecturers and a lab assistant – a post-grad student. We are continuing to explore how we can encourage critical and inquiry based thinking. We have had several meetings where we have looked at my reports of the type of student discourse in lab sessions. When engaged in following the instruction based experiments the students seem stuck in procedural questions, not moving into other areas of inquiry such as theorising, analysing, hypothesizing, imagining, and connecting. Why not? When Dan gave them the open ended question they did move into much richer scientific discourse. Is it the type of activities which limit their discourse or the way they might be designed? Is it the conversations that they are having with their teachers? The observers are keen to listen into what is happening as well as try to stimulate some scientific discourse.

Dan has just explained the first experiment. I watch and listen as the students struggle to make sense of their diagrams, instructions and lab equipment asking each other procedural

level questions “Where does that go?”, “How do we connect that?”, “What does this do?”. There are hands up around the room and I listen in as the observers from around the wall get drawn in, giving a helping hand.

I listen to what the observer/lecturers say and do as they help the students. The post-grad student, when asked about how the circuit goes together, just puts it together for the group. A lecturer talks another group through his actions: “You put this here, connect this, and then you can turn it on.” The students are quiet watching.

I have heard these lecturers engaged in iterative and rigorous conversations about their own science amongst their peers, so they themselves are competent in critical thinking and scientific discourse. They have the intention of engaging in more dialogue with the students, yet it is not happening. Why not?

I wonder why it is so different to my own students who in a similar situation would be discussing issues with the procedures, or circuit principles or the nature of electricity. Why isn't this occurring here? Is it the lecturers, the students, the environment, the expectations, the lack of questions to probe understanding? Do the students need something problematic and intriguing to catch their interest?

We move onto the next experiment which involves a parallel circuit and there are more hands up than before seeking assistance. Why can't the students work out how to construct the circuit for themselves?

All the lecturers/observers are busy and one group of students see me against the wall. They call me over and ask for some help. I am not supposed to be doing this but I can see the other lecturers are run off their feet with questions.

“I just don't get it,” says a student with frustration.

“So how are you thinking about this? What are you seeing when you look at the circuit diagram?” I ask, without thinking and as result start a conversation. I discover that one student doesn't really get the idea of the circuit diagram. So here am I constructing her understanding... asking her to think how the diagram corresponds to the physical components... asking her how she imagines an electron might move around the circuit. And I soon discover that she has the notion that an electron will move around a circuit even when the switch is off. She explains how when the switch is opened, the electron continues to move around to where the switch is, then finds it can't get across and then the current stops. I ask

her where she got this idea from and she explains to me about a role play she did in Year 10 of being an electron.

I unpack this further and in doing so discover I have an audience of five other students who all start asking me questions about electricity, how electrons move, what happens when they reach the parallel part of the circuit, why an electron might choose one path over another. Each tells me about their own prior learning experiences in electricity and we end up having a very interesting discussion coming up with the problematic nature of trying to model what is going on in a circuit by thinking of it as moving electrons. They are intrigued about the deeper issues of electricity and wish to understand the hidden meaning of circuit diagrams.

I look up and realize that Dan is waiting to go onto the next experiment and we are too noisy. Oops.

I step back against the wall again and ponder what just happened. Was it the question I asked the girl "How are you thinking about this?" which was the key? Why didn't the other lecturers in the room question the students more deeply about their understanding? Didn't they see that the difficulty with setting up the equipment was a possible indicator of issues with understanding the concepts?

After the lab I talk to the post-grad student who had gone in and 'properly' set up students' circuits. I told him my experiences with the students I had talked to... how some found it quite difficult working out how to translate from the diagram to a real circuit and how they were interested in how the circuit operated in terms of what happened to the electrons. He looked at me quite surprised. He said it never occurred to him to question why the students were having difficulty putting the circuits together, that if you show them enough times they get the hang of it. That that was the way he learnt how to do circuits.

We then ended up discussing how we made sense of different types of circuit diagrams. I confessed to him that as soon as a circuit has a capacitor, inductor or diode in it that I just can't imagine how it might work. He says "Why should you? I would never try to work out what is happening... you just learn what certain types of circuits do."

*I wonder then why do I need to have a conceptual understanding of what is going on? Do I expect more than what is feasible? Is it because I am a female and need to have 'connected understanding' as suggested by the research into **women's ways of knowing** (Belenky et al. 1986)? But this seems to be what the students are wanting as well, even the boys I spoke to.*

I then go and talk to Dan, letting him know that a number of his students have major 'misconceptions' about electricity. We begin to discuss these and then get into a nitty gritty discussion of how electricity really works. The conversation lasts for over an hour and involves lots of diagrams, examples and thought experiments. I am thinking that perhaps this conversation will be very helpful for Dan in orienting him towards the problematic nature of electricity so that he can then teach it in a more inquiring way.

But Dan throws his hands up in the air and admits defeat "I have never questioned electricity before, just used the equations to work it out. It made perfect sense to me that way. Now I really don't know what to think. Sue, you have confused me and I don't like it. I would need to talk to someone who really understood electricity before I would feel even comfortable talking about these things with the students."

Following this incident, I begin to wonder what habits of mind each of the physics lecturers have about 'physics knowledge'. We have had conversations about the theories of critical constructivism – the contingency of scientific knowledge and how interpretation is based on paradigms. Most of the lecturers see the tentative nature of their own research, saying that current science is contingent and based on continual revision and iteration. Yet in contrast, some are quite adamant that the foundational knowledge of physics is pretty certain. I wonder then whether they have an attitude about this 'old' knowledge (which makes up the undergraduate courses) which makes it difficult to bring a sense of inquiry into it.

How much have they leapfrogged from this knowledge into their own research, how much of their use of it has been habit, how much is unquestioned repetition of how they were taught it? How much of this certainty is due to the fact that they think of it in terms of internally consistent mathematical equations rather than concepts? How do they think of physics and how distant is this from how their students think? Maybe it just doesn't occur to them to ask students *what they are thinking* because for them it is something that you don't really think about?

What might it mean to conceive such knowledge in new ways and bring a speculative eye to it?

I also wonder how much these attitudes about physics knowledge then sets up an environment where lecturers value their 'authority to know' as the currency of student respect for them. So being speculative or uncertain about concepts might challenge this

perceived respect. Setting up more inquiry based discourse might therefore mean trying on new roles, which can be a vulnerable process.

But is this the issue with Dan, or does it go deeper into who he is as a scientist? He confesses to me that his research is different to the others. He describes himself as data-collector, rather than a theoriser – someone who bunkers down in the research lab. I wonder then whether he has been attracted to the sort of research which matches his temperament and learning style, and whether he is then incapable of the thinking-on-the feet theorising and inquiring that Dr Brown seems to do with ease in his teaching. Who is Dr Brown as a researcher? Someone on the leading edge of his field, a conference speaker, a leader of a research group, a theorist, a manager and more of a people person.

So I now find myself trying to diagnose the lecturers as if they have an illness. What might be the specific barriers to helping each of them see into students' minds and engage in successful discourse with them? How can they reconceptualise the physics they are wanting to teach?

Yes, I begin to realize, that seeking to improve the quality and opportunity for inquiry learning in university science is problematic. Not a simple matter of creating an intention, or developing pedagogical strategies, but it is also dependent on each lecturer's habits of mind and a deeper sense of being each of which seems to be creating different barriers. And these are much more difficult to shift despite a keenness by the participants to embrace inquiry based teaching.

A new phase

May, 1999. We come to a point in the project which is the nadir. Our fortnightly meeting has ended up being a moan session, despite the successes that Dr Brown has been achieving. Two lecturers now have taken topics in the Applied Physics course and are feeling frustrated because of lack of progress and the mounting contradictory evidence from the students. Jeff has tried to be innovative in his use of constructivist and collaborative pedagogies but the responses from the students are mixed with a lot of suggestions for improvement. He also has evidence from his own questionnaire which he gave the students and is disappointed with what he has read. Part of the issue is that his questions are a bit obtuse, but at least he is asking them, rather than relying on me. Part of the issue is that although he is a great planner and thinker, when he comes to do something it doesn't quite work out, but I have yet to understand why.

One lecturer says in complete frustration, “What is it that the students want? We are trying our best? We are trying to make it more relevant and inquiring! Why doesn’t that work?”

“They are just not used to hard work any more – they expect to be entertained – for us to hand it out to them – when I was at uni I was expected to go home and do the work to understand it.”

*“They say they want it to be relevant but what does that mean? Most of the stuff you learn at university isn’t relevant until you leave and start using it. They expect it to be relevant **now** but perhaps relevance is a luxury.”*

“Yes, the undergraduate course is something you get through before you get to the interesting stuff – sitting in lectures taking notes worked for us, why do they need something different?”

Is this what they really thought? I was horrified. I had thought I had done a good job of shifting the lecturers into student perspectives, understanding that today’s learners are a different breed with different needs and helping them see more about how they thought. Creating a sympathy and empathy for the students. Did they really mean these comments, or was it a past mindset on its last frustrated fling? How could I challenge this?

“Can you remember anything memorable from your university course?” I ask. They shake their heads. “Well,” I say, “I remember in my Honour’s year when my High Energy Physics lecturer rushed into the room all flushed and excited to a lesson on quarks, crying out “Wiesenberger has just discovered the Omega boson!!!!!!!!!!!!”” (‘High energy’ physics was both the topic we were studying and the state of the lecturer.)

The lecturers look at me, seemingly electrified.

“Really? Wow! I wish that had happened to me, how exciting!!!!”

“Why aren’t we doing that?”

“What sort of course would you like to have done in physics?” I ask.

And we end up having a very deep conversation about possibilities, preferences, dreams...

“Why can’t we share our excitement and love of physics in how we teach?” muses one lecturer.

So it seems to me now that this nadir has become a key turning point – not just finding motivation but an actual shift in thinking about what it is we are teaching and why. Perhaps

we are moving deeper into unpeeling the layers and as part of the process we need to revisit previous mindsets to try them out before we throw them away for good.

This is a crucial time for us as we are moving into the second stage of the project where we are looking at visioning how the second semester teaching will go in Applied Physics. First semester has been about experimenting with practice within the confines of the established course and through that gaining some insight into student learning and the issues of science teaching. So at this stage we hope to use that understanding to redesign what and how we deliver the course in second semester. We make a quick decision to eliminate one of the five topics to give more time to go a bit more deeply in the remaining four topics and we change their focus. We now have four different lecturers taking each of the four different topics.

Whereas the first semester topics were only tinkered with to make them a little more interactive, three of the lecturers are looking at rethinking and re-orienting what they are doing for second semester. It seems they have left behind the need to cover specific content; rather, they are looking at what student learning a topic might yield beyond specific content ideas... for example, grand themes of science, science history, contingent nature of research, inquiry based thinking, including bringing in their own cutting edge research.

Janice decides to introduce her own research as well as a historic context in the exploration of some key quantum ideas... showing students how science is constructed historically. Dr Tim uses his own research in bio-electricity as a way of asking students to critically reflect on the usefulness of applying electrical models to biological situations. Jeff is interested in using case studies to help the students inquire into concepts of physics to do with heat, particularly giving concrete and connective experiences. Dan decides to keep his current structure, intent and slides from last year and just work on getting more discussion and questioning happening.

We also decide to redesign the second semester lab experiments so that they take students more on a scientific inquiry journey; some experiments requiring a more theoretical approach, others requiring students to creatively design the experiment and to reflect on the effectiveness of their design, others which start with real problems or challenges. The students are required to do four experiments out of a choice of 12 and present one of these as an individual experimental write up, and another as a group presentation to the class. They are given criteria on which they will be assessed.

In making these changes, different lecturers are now bringing in different understandings from educational theories like trivial, social and critical constructivism, learning styles, or women's ways of knowing. From being anti the educational jargon, the lecturers are now using it with relative ease, though still challenging me if I get into educational abstracts. It seems the contradictory nature of the student feedback and the gap between intention and action has required the lecturers to seek out educational understandings which can support their journey of planning, action and reflection.

Some are demanding educational papers on particular themes, or seeking them themselves, while others are still reliant on me for extracting and dispensing key elements relevant to what they are doing. I seem to have analysed their learning styles and am adjusting my own input based on that. For example, Dan says "Just give me one strategy at a time, not several – it is too confusing. I don't want to know the theory" and I do that, but in our debriefing discussions I bring in some theories to help Dan understand what is going on. So I am trying to move Dan through various modes of inquiry in understanding his teaching and the learning that is occurring.

With all this are we seeing any improvement in teaching? These lecturers are moving out of their comfort zones and experience and to expect them to perform well first time in a new approach is unrealistic. It has certainly been my experience that any new pedagogy I adopt often requires enormous focus the first time which makes you blind to many of the other things that are going on. So a lecturer might organize a great activity which he is trying to remember, but forgetting some of the glue that might make it work. For example, Jeff often loses where he is in lectures so I give him a simple strategy of writing up on the board at the start of the lecture a list of what he is intending to cover. He now refers to this list throughout the lecture and the students can see where he is and what he aims to cover. We refer to it as creating *signposts*. So now he doesn't have to keep the organizational aspects in his head.

The lecturers now are more engaged in getting their own feedback – designing questionnaires and emailing students. Dr Tim asks all his students at the end of each of his lectures to fill in a sheet using my Critical Thinking schema: "What have you understood? Do you think it is plausible? Do you think it is useful? Are you willing to believe it? Why / why not?"

He then uses the answers to infer student understanding and interest and to design the content and style of his following lecture – for example, whether it is providing more background, a deeper case study, more opportunity for student discussion, or a tutorial style

session. This seems to suit Dr Tim's nature and learning style. He seems to be more of a reflective learner – one who likes to stand back, see the bigger picture, gain all perspectives and then consider possible options before deciding to act.

The lecturers still feel uncomfortable asking students for feedback about the sessions face to face, but at least now I feel that they are not totally relying on me as a go-between, though I am still debriefing students after the sessions.

We are beginning to hear increasing quantity and quality of scientific discourse in lectures and in lab sessions and many students seem to be engaged in a *process of inquiry*. But we are still getting contradictory feedback as to the effectiveness of what is being trialled. At the end of the year the students are given CLES surveys (see Appendix 8) and an outside interviewer runs two focus groups which are videoed. When we look at the data from these, the feedback from lecturer questionnaires and my student interviews we begin to see a pattern.

It seems we can class the students in two groups. One group, which has adopted the metaphor of *physics as inquiry*, enjoys the thinking involved, has begun to value the inquiry and thinking skills that they have gained even though they might not value all the content they have had to learn. So the relevance of the physics doesn't just lie in the relevance of the content to their other courses or lives, but rather the relevance of developing a scientific way of thinking. They appreciate the efforts the lecturers have made, and are sympathetic to the fact that they might not have got it right all the time.

Then there is another group who seems to expect that physics should be taught as a *body of knowledge*. Some of the concerns of these students are:

- Too many different approaches – don't know where I stand.
- Which bits are being assessed? What do I need to learn?
- I expect to learn information to help me with the tests.
- I don't want to have to think in lectures – I just want to take down the notes.
- We don't have to do this in our other courses.
- When we are asked to look deeply into something in a lecture it takes time away from getting the content of the course.

We hypothesized that these students became enculturated very quickly into a passive learning culture as a result of the different courses they were exposed to. But why had the

other students adopted the inquiry approach? Was their style of learning more suited to that approach? How could we help the '*physics as a body of knowledge*' students move to a place where they valued inquiry learning?

Perhaps we hadn't made it clear enough to them what we valued? Were the tests giving mixed messages that we still valued *content* over *thinking*? How were we explaining the different approaches we were using and their relevance to the students? It seemed that while the lecturers had gone on a journey from *physics as a body of knowledge* to *physics as inquiry*, they hadn't been explicit with the students about this and taken these students on the same journey. Why not?

In seeing the two discrete groups we also asked ourselves is it possible to have both – *physics as a body of knowledge* **AND** *physics as inquiry*... that each supported the other. How could the lecturers make clear to the students the appropriate dance between them?

And how did the project meet up with my own vision for undergraduate physics courses? It seemed that perhaps we had barely inched along the path that I had envisaged... the lecturers had perhaps opened a door into greater possibilities and different ways of thinking but were still in the process of stepping through, some with more confidence than others. And each saw different things through that doorway, based on their own values and experiences. These were quite different to what I had envisioned at the beginning of the project based on my own context of holistic education.

What had the lecturers gained? A questioning of the nature of physics and the habits and assumptions which they brought to their science teaching? An expectation that they could share their passion for science and science thinking in their teaching? A realization that student perspectives are very different to their own and the need to find out what these are? Skill and ease in engaging in meta-discourse about their own teaching? A confidence in experimenting with their own practice and determining its effectiveness? A greater flexibility and ability to deal with pluralities and contradictions? An awareness and interest in the nature of learning?

These are skills that we might call 'learning how to learn'. It wasn't so much about achieving measurable improvement in student learning outcomes as an inner change of attitude towards what it meant to teach physics... an orientation towards being a learner of one's teaching practice. So the project was more a seed for each lecturer's continued journey. How did the seed grow? That perhaps is another story.

2006 - Reflections on the project and the role of feedback

At the time of doing this project I was coming up with insights about processes which might help or hinder the lecturers in their journey. Over the years these insights have grown and changed, helping me to see within that experience rich sources for further learning about the nature of transformation and the role of transformational leadership.

For example, at the start of the project I felt it would be valuable for the lecturers to be engaged in face-to-face conversations with students about their learning – to be able to see into students' minds, come to know them as well as developing an empathy for them. The process of coming to understand my students was a key aspect of my own journey in improving my teaching and learning practice; causing me to be more self-reflective and critically aware of my underpinning assumptions, helping me to develop new understandings about how we learn. My own philosophy of learning was one where I saw an important part of the learning process as gaining feedback from multiple sources - the system you are in teaches you. Without feedback, what would stimulate growth?

However, very early on in the project, I realized that many of the lecturers were not seeing nor responding to the clues that the students were giving. How could I get lecturers to see and read the feedback that was already present ... students' body language response in lectures, the deeper issues in their questions or in their answers to assignments? What did those tell us about their engagement, their understanding and the way they thought?

I was also hoping that the lecturers could start a process of reflexive practice by, for example, simply asking students at the end of a lecture what they have learnt, what worked and what didn't, what they valued and might use.

However, the lecturers did not feel comfortable asking these sort of questions – for some it was hard enough asking a student face-to-face “*Do you understand this?*” I didn't know how to solve this issue at the time, and I didn't want to press it, as I thought it would cause too much stress at the beginning of the project. So I took on the role of gaining student feedback through interviewing students after sessions and then relating this to the lecturers at our meetings or debriefings. Then I wondered whether by me doing this I had taken the opportunity from the lecturers. Perhaps this was a mistake, I worried, given how much I was learning about student thinking and needs as a result of my interviews with students.

But now, I think that it was important that I started the process of gaining feedback, rather than requiring the lecturers to get their own feedback, because getting the feedback was essential to the movement of the project – not just a movement in terms of getting action started, but that the style of questions which I was asking and the subsequent student responses pushed the lecturers into new layers of thinking about science, their teaching and student learning. It also removed a potential source of stress which might have reduced the goodwill that the different participants brought to the project. How to balance the amount of discomfort – enough to stimulate growth, but not too much to close down the effort?

As a result of our discussions about the feedback from students and each other's observations of the sessions, it seemed that most of the lecturers built up a better awareness of what to look for in the visual, physical and verbal clues that the students were giving us during sessions, and over time were able to pull out aspects of a teaching session and unpack it for themselves. This led to them devising their own questions, which they then got me to ask the students. So it seemed that they had begun to bring a scientific eye to our process; inquiring into the business of teaching and learning, albeit at a distance. We got into a rhythm at our meetings of sharing, interpreting, theorizing, clarifying the dilemmas which led to devising new questions for the students.

When one lecturer initiated his own student feedback questionnaire after taking his topic two months into the project, I was taken aback. Why didn't he go through me? Hmmph!! Uh oh, I thought, where is that coming from? Isn't the whole point that he build up confidence to do this for himself? I felt like a mother not yet ready to let my child have its independence. So, his questionnaire wasn't exactly well written and the answers he got back showed the confusion of the students, but at least he had a go at framing the questions, and thus getting feedback about his feedback device. Next time he was a lot more effective, independently devising suitable questionnaire questions. As the others took up teaching of the various topics they too got involved in writing their own questionnaires or emailing the students and I realized the importance of allowing each of them to work out an effective process for themselves.

However, most didn't take the next step of moving to face-to face conversations with the students about their learning. How could I have helped them build up skill, confidence and attitudes of mind that would enable them to engage in meta-cognitive talk with their students? Did they need to build up a meta-cognitive language between themselves, practice it before they had enough confidence? Was it their perceived relationships with the students? Could I have used role plays? How could I have helped them unpack this further?

When I reflect on my own journey as a science teacher I realize that I too started slowly in getting student feedback... using questions on the end of their worksheets which asked my students what they had learnt and how they could improve their learning. I built up an ease in asking these questions on paper, giving me time to reflect and unpack them before talking to my students. It gave me a distance, a time to get out of a defensive mode. After such 'training' I could then move into the immediacy of a face-to-face discussion about such things, using an attitude of openness and inquiry.

Yes, I realize, perhaps I was expecting too much. My competence with seeking feedback was based on a long slow process as I was engaged in an action research process where I brought Torbert's (1991) 'critical subjectivity' to my thinking. Perhaps it is a reflexive process that as we gain the skill to ask such questions of students, we see more, we move into different paradigms, and the questions we ask change. In a sense, I was trying to short cut this with the physics lecturers in just one year. I was trying to balance the questions they wanted to ask from their current perspectives along with the questions I felt that they should be asking that would reveal underpinning assumptions and lead them to higher perspectives.

So how might I do this differently? I think if I was to work in such a project again I would be looking at ways of assisting participants to move towards an autonomy in the area of gaining feedback about whatever it is that they are doing. But at the same time I would be ensuring there also was feedback beyond the level of perspective that they might be operating at that could draw them forward in perspective. I would assist in helping them move from single loop inquiry cycles (plan-act-reflect processes which aim to improve craft) to double and triple loop inquiry (critical subjectivity which aims to question underpinning assumptions and values).

I would try to *occasion* opportunities which demonstrate the value of feedback – how useful it is to our learning. I would help the participants understand the problematic nature of feedback; the issues related to each respondent's perspective as well as the paradigms we adopt that shape the questions we ask and the interpretations of the responses. I would see conflicting evidence as a way of creating learning moments; opportunities to question underpinning paradigms and habits of mind. So I would be highlighting these, rather than trying to explain them.

OK, so far that is not much different to what actually happened – but I think now I would be more aware of the process rather than learning on the run, as it were. And I wouldn't just

keep that process to myself. I would try to make transparent the processes of transformation and try to name the issues that are developing. I would possibly make explicit goals about what we want to achieve in terms of self-learning processes as well as the project outcomes ... for example, *by the end of the project we want to be comfortable in seeking student feedback for ourselves, developing ways that suit our own learning styles.*

But perhaps I can only see this now because I have moved from educational theories based in a constructivist paradigm to those which are more congruent with a transformational learning paradigm. My questions to my students are now not just *What do you understand?*, or *How are you thinking and learning?*, but also *How are you changing?* The feedback I am seeking has a dual purpose; to inform me but also to help develop self awareness and reflectivity in my students, where they can explore their thinking, learning and self-transformation processes. And I help my students name what is happening to them, seeing the patterns and realizing that their angst is just part of an overall process.

So what is that process?

Mezirow (2000) has detailed some of the characteristics of the process of transformation which I think quite well describes what we experienced in the project. So in the next section I am going to share some of the emergent insights I gained about managing such a project and bring some Transformational Theory analysis to it. As I undergo this process of analysis, I discover that my own understanding of what was going on changes. It is problematic and I am wary of claiming too much or pinning down my contingent understandings. In moving into this analytical mode I am wary of moving to more of a modernist perspective which I ask you to read in counterpoint with my more postmodern descriptions and speculations in the previous sections.

Transformational Learning Theory

When we talk about *transformational learning* it can relate to transformation of **perspectives** and the ways we operate (e.g. Torbert's (2005) **Action Logics** or Gordon's (forthcoming) **perspectival levels**), transformation of **self** (movement in **ego stages** (e.g. Kegan 1982) or **development lines** (Gardner (1985), Wilber (2000b)) or transformation of the **cultural paradigms** in which we are situated (e.g. Beck and Cowen's **Spiral Dynamics** 1996).

I am going to suggest that as a result of this project transformational learning occurred in the perspectives and cultural paradigms we brought to the thinking about and teaching of science.

A characteristic of movement to the next stage of perspective is that the stage you were in becomes explicit – it is something you can now reflect on and control (Kegan 1982). The Action Logic research (Cook-Greuter personal communication , 2005) suggests that one will tend to teach at the perspective stage lower than what you are operating at yourself.

So how does one move in perspective? It is the reflexive process of examining what you are doing – making it explicit. But there are layers and layers of this... one might just make the outer layers explicit and nothing much will change. It is usually by questioning one's underpinning values and assumptions that enables the paradigm shift that moves you into a new perspective.

Mezirow (2000) has suggested that the transformational journey has different phases which people might experience. When I look at this list I see that much of this occurred during our project.

Disorienting dilemmas

Our **disorienting dilemma** first started with the problem of declining numbers of physics students. Why were they leaving? What was the physics courses lacking? Was it just a change in global careers or was it that we were no longer providing the sort of learning that students wanted? A bit of both it seemed. From the university administration questionnaires given to all students over the previous five years, the physics department had not done

Transformative Theory

Transformations often follow some variation of the following phases:

- A disorientating dilemma – also paradox, enigma, anomaly
- Self examination with feelings of fear, anger, guilt, or shame
- A critical assessment of assumptions
- Recognition that one's discontent and the process of transformation are shared
- Exploration of options for new roles, relationships and actions
- Planning a course of action
- Acquiring knowledge and skills for implementing one's plans
- Provisional trying of new roles
- Building confidence and self-confidence in new roles and relationships
- A re-integration into one's life on the basis of conditions dictated by one's new perspective

The transformative process may also involve:

- Encountering a "missing piece" that provides the integration necessary for a transformative experience
- A revisioning of self in the eyes and responses of similar others
- Making public, primarily for ourselves, the historical dimensions of our dilemma - and confronting it as a difficulty to be worked through.

Mezirow (2000)
Fig A3.2

well in terms of providing effective learning opportunities.

So this was a key impetus to be involved in such a project. And the disorienting dilemmas kept coming; the ‘misconceptions’ that students were having, the conflicting responses to the new pedagogies, the limitations of the lecturers’ current understandings of learning to explain what was going on. It would have been quite easy to try and explain everything, but being in a state of confusion and doubt seemed to be important in moving most of us beyond current perspectives and ways of operating.

I recommend a strategy of making the tensions explicit, keeping them alive and establishing an attitude that it is okay to have such tensions... how do we live our way into solutions or new ways of being where we have transcended the tensions? Now this may require practicing a new mode of thinking where we move from linear thinking into dialectical thinking.

Questioning underpinning assumptions

Questioning underpinning assumptions about what it means to be a scientist and do science was also an important part of the process. This involved making explicit what it is we value and what it is we do. This was one of the first conversations we had as a group and it was something that set the scene for discussions throughout the project – we could always bring issues back to the key question – *What is it we value in science and how does this action we intend help us articulate this?*

Asking this question about assumptions enabled the lecturers to expand their view of what science is and what scientific inquiry is. Making the inquiry process explicit was the first step in thinking about how to bring that into the teaching. The next step, which was making it happen, was far more difficult.

However, I wonder if the lecturers would have been able to articulate this expanded view of science without my help. Because I had already gone through this process and had questioned the prevailing notion of the scientific method, coming up with my own expanded and richer version, I was able to help the lecturers tease out what it was they did. I don’t think that by themselves they would have realized that creativity, discourse, community and intuition are as important to scientific inquiry as are procedural and analytical processes.

So I don't think it is enough to question one's underlying paradigms and values without doing so in a context that enables one to see other possibilities... whether it might be talking to someone who has gone before on the perspective journey, or talking to people from other disciplines and learning other ways of seeing. Otherwise, it would be very easy to just stay exactly where you have been.

Collaboration – admitting feelings – shared purpose – meta-discourse

Another key aspect of the project was the **collaborative nature** – the **shared purpose** and sense of ease that each of the participants had with each other and with me, the partial outsider. I was astonished at the first meeting how open each participant was about their **feelings** about the project.

I had used de Bono's 6 hats in starting the project and one of these is the red hat – *How are you feeling about this?* When I first asked this question, one of the participants described how fearful he was – how he had worked very hard over his holidays in creating Power Points of his topics for first semester and just felt overwhelmed at the thought of having to change them. This helped us to unpack a bit more what our aims might be and how we could still experiment within current structures. I emphasized after this how useful it is to listen to feelings because they often lead us into new insights that we might not have if we just bring an analytical eye to something.

6 Hats

Blue hat: what processes are we going to use?

White hat: what information do we have?

Red hat: how do you feel?

Yellow hat: positives
Black hat: negatives and obstacles

Green Hat: possibilities

Fig A3.3

The wonderful thing about de Bono's hats is that it gives a *process language*, one which we used throughout the project... so you might hear a participant say "can we put on the green hat for a while as we look at this?" or "I need to put on the red hat today." So this technique values and honours people's feelings. I also encouraged everyone to invent their own hats and once one of the participants said "Let's put on the 'Sue' hat." I asked what that one was and he said "It's the big picture hat", a comment which helped me see myself a bit better from the participants' eyes. So the hat idea was a very playful tool which gave permission to expose our vulnerability as well as allow for creativity. It also paves the way for **self-examination** and honesty about self to others. It cuts across adversarial thinking to give new perspectives.

I also believe that this technique helped to circumvent embarrassment that the lecturers might have had in allowing their peers observe their sessions. In my experience with teachers, having someone watching what you do is one of the most frightening things... and I admit myself to being self-conscious. So the ease at which the 'guinea pig lecturers' allowed project participants to sit in labs and lectures and then critique them was a testimony to the relationships that they had with each other, and to their movement to an attitude of distancing their own egos from their teaching prowess.

So, a key to acquiring skills to do this project was not just the teaching skills but the meta-cognitive tools that could help us explore and unpack what we were doing in a supportive environment. Further was overcoming the difficulty with the educational jargon. Even though at the beginning of the project I tried to speak in plain English, the participants would look at me and say "What on earth are you talking about?" It wasn't so much the actual language and the jargon but the educational concepts and the perspectival level that I was bringing to my interpretations.

So, although I shared with the participants a physics background, some of the time the educational language that I was using was outside the lecturers' language register thus part of our process was building up a shared language in which we could discuss learning from a meta-level. I deliberately used physics metaphors to explain learning principles which some of the lecturers found very stimulating and others mind-boggling. (e.g. Do we have to build up physics concepts *bit by bit* in a Newtonian way, or can we use the idea of the *hologram* where you can see the whole in each part of the hologram? Or can we use a systems approach where we look at interconnecting ideas?)

It was important to have lots of examples to explain what was meant by the learning theory, and to use again and again as references actual situations that the participants had experienced... "Like that time when...". We were making up our own stories which became part of our mythology and part of our language. So peer observations weren't just about comparing another's practice or looking for particular things; they also became shared experiences which became part of the common language.

It occurs to me that when you do not initially have a reflective or meta-cognitive language then the stories, the myths and the metaphors can bypass the conscious mind and work at other levels. Telling our stories to each other and hearing different interpretations of them can take one to a new level of understanding – able to see one's own experience with new

eyes. Listening to another's stories can enable you to try out your tentative educational theories in applying to their narratives.

However, while I had in my head lots of **living educational theories** (Whitehead 1998) which I was modifying, I hadn't made this explicit to myself at the stage of the project – it is only now in writing my thesis that I can perhaps understand the significance of living educational theories. How it is important to create tentative models that can help you explain; but then expect for these to be perturbed. I think I could have been far more aware of how the lecturers were constructing models of learning and better helped them to understand the significance of this process. I was more trying to construct understandings for them... dishing out theories based on what I thought they needed.

I bumbled around, sometimes making mistakes (e.g. not recognizing when I should have supported one lecturer more in helping him find educational theories as he showed readiness to do so). And sometimes just the serendipity of the moment led to wonderful 'learning moments'. So, it isn't just about being *strategic* in knowing how to assist others, it is also about being aware of the value of a particular situation in assisting learning. A state of mindfulness in myself as facilitator, but also making this process transparent to others... how can we all learn to be more mindful and aware of our significant learning moments?

Over the course of the project our meta-discourse changed. The lecturers had developed an ease in talking about educational issues as well as scientific ones, which was evidenced in how they talked to their colleagues from other disciplines as well as to each other. I believe that a key to this was the regular fortnightly meetings where we had new student data to reflect upon as well as peer observations and the reflections of the 'guinea pig' lecturers. It also helped that our conversations weren't just formal – but happened in corridors, morning tea room, one-to-one debriefings, etc.

One lecturer, in his end of project paper highlighted the role of the collaborative nature of the project, saying how important it was to engage in such discourse about teaching and learning. He really enjoyed it and it was a highlight of the project for him.

Trying on new roles

Trying on **new roles** was also an important aspect of the project, but not one which I understood fully at the time. I knew that many of the lecturers were moving beyond their comfort zones and I was trying to assist in diagnosing barriers and helping build up

appropriate skills or attitudes. One lecturer said to me that, whereas he was happy experimenting with his teaching for the first year Applied Physics course, he wasn't comfortable in doing it with second or third year pure physics students because he was concerned about what they would think of him. At the time I made a throw away remark and shook my head in mock disapproval "That is not like you, Tim." And I didn't stop to think what the reasons might be behind his concern.

I now wonder whether the role that Tim was taking on in the Applied Physics course was quite a different one for him... he was moving from the *expert knower* into someone who was being vulnerable to the students – inquiring with them, and perhaps not coming across confidently in his management of that. Perhaps the respect that his pure physics students had for him was based on his *authority to know*?

Where was the source of respect that my own students had for me? Was it from my competence in inquiring, my flexibility and responsiveness to their learning and my relationships with them as real people? Yet, I still 'knew stuff' and they could rely on me to ensure they would achieve well on the exam. I would hate to teach the physics course without any sort of knowledge at all. Yes, I still was an *expert knower*, even though I might be engaging with my students in the inquiry process.

And in my relationship to the participants of the project I was still *an authority* - of teaching - and this is what lay behind my own comment to Tim... an arrogance stemming from my authority as an educational expert. Hmmm.

Perhaps in helping Tim extend his pedagogical experimentation to third year physics I should have helped him make explicit to himself his confidence in the science content and processes – to come to a self-realization of his own competence and value – to determine what he did know and didn't, demarcating the boundaries of this 'authority to know'. I should have realized that it is one thing to try on new roles in a supportive environment where you are part of a greater project, with students aware of the project and on-side, and another to experiment by yourself in isolation.

Yes, I should have listened to his concerns rather than looking at him askance and saying "That's not like you." But at the time I saw the notion of *authority* and *respect* in teaching as outmoded concepts based on metaphors of teaching which I assumed came from a traditional teaching culture. I saw myself as a *facilitator* and *occasioner* of learning, rather than an *authority* figure.

In moving from one type of metaphor to another, rather than integrating appropriately I was rejecting my earlier self. This is a typical response, according to Kegan (1982), as we move in ego stages – rejection followed by integration. So, while I was undergoing this process of personal transformation I could not really see and understand all that what was going on with others, valuing their experience and concerns.

In hindsight, I see that I should have helped Tim unpack some of the reasons why he couldn't transfer his newfound teaching approaches and help him to come up with possible strategies. He wasn't yet able to integrate these tentative new roles into his wider sphere.

Democracy in learning

Now Mezirow (2000) suggests that a supportive environment is one where there is a democracy in the management structures... all participants are learners, including the leader. I certainly learnt a lot from the project and this learning was something that I made transparent for the other participants (even though some might not have understood my thinking processes)... there was a sense that we were all learning. Yet, I had a certain authority as the educational expert which still remained. In future I think I would be more vigilant in being self-aware of the power structures and what I might be creating; trying to develop more humility and thus opening myself to learn a lot more from my colleagues.

Making it public

Towards the end of the project three of the participants wrote papers for various conferences around Australia and we all contributed to a website which captured various perspectives of the project (students', mine, lecturers', outside interviewer of focus groups, reference member's analysis). At the time that the lecturers were preparing their papers I was very sick and so they were written without any involvement from me, which in hindsight I believe was an excellent thing.

At the time I was worried whether they would really understand all that we learnt from the project. Would they capture all the insights that were made, particularly some of the big picture analysis that I had done towards the end? Yes, this concern I had about capturing the 'the truth of it all' is really quite laughable. Because it is clear that each of these papers is entirely personal, reflecting each lecturer's own journey, what they valued and what they gained. They all became advocates for change in their discipline – each advocating

something different, wishing to share *their* insights with their community. This is a wonderful result – ownership, multiple perspectives showing the richness and value of the project.

The act of writing such papers enabled them to reflect on what they had learnt and valued and what they would do in future. In making it public it also enabled a celebration of that learning and opportunity for feedback from their broader community of physics colleagues in Australia.

The style of the papers was very different to their normal scientific papers; not just in the very personal nature, but also the speculative frame of mind that valued the journey as much as the results. In standing up in front of their colleagues they felt at ease and were confident in discussing educational issues.... Or so I have discerned from their descriptions of these events.

In hindsight I would encourage all individuals involved in a project like this to make public what they do to a bigger audience than that of the project... to **test** their new understandings in a bigger context of community discourse in addition to the testing ground of pedagogical experimentation.

Note: For the sake of maintaining the anonymity of the participants I have not referenced their papers.

Spiral Dynamics

If I was to analyse the project in terms of **spiral dynamics** (Beck and Cowan 1996) I would say (simplistically) that by the end of the project most of the participants were operating in the *green meme* (plurality of perspectives, reflexive collaborative inquiry, journey as important as the result) in *thinking about and discussing their teaching of science*.

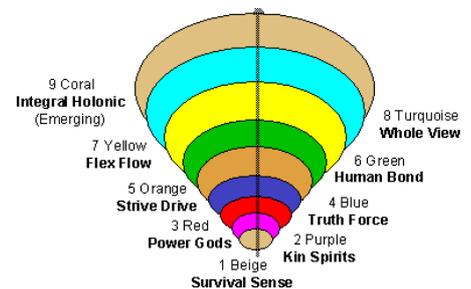


Fig A3.4

At the beginning of the project, I think most were operating *as scientists* in the *orange meme* (innovation, autonomy, inquiry, transparent goals and standards), but had not made that explicit – so were teaching in the *blue meme* (authoritative knowledge). Through the process of self-reflection and discourse they could make explicit what they were doing as scientists

and thus take the first steps to teaching in the *orange meme*. (They were also operating within other meme cultures in other aspects of their lives.)

However, half the students in this project preferred their teaching to be at the *blue meme*

level, while the other half preferred operating in the *orange meme*. What might be their preferences today?

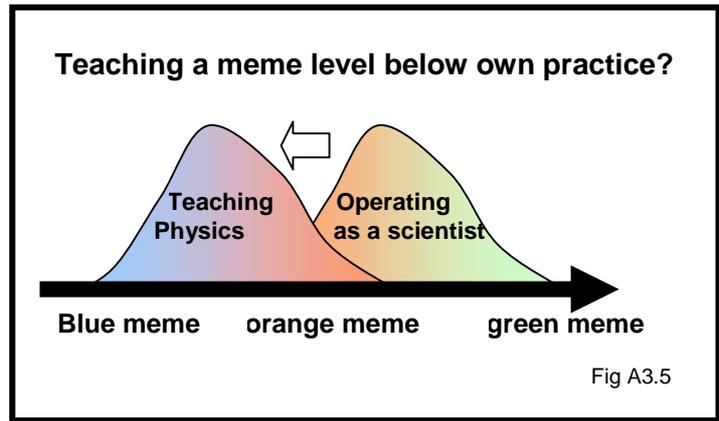


Fig A3.5

As I discuss in *Chapter 11 – The Enabling Classroom*, understanding the underpinning teaching and learning culture becomes critical when thinking about science education from kindergarten to university. As students develop and move in ego and perspective levels their learning is better supported by being in a teaching/learning culture which aligns itself to their development. In the current Tasmanian education system the adoption of the **Essential Learnings** is giving

students science learning experiences across blue, orange and green memes. So, if university science is not to be counter-evolutionary then I believe it is important that it takes students to the next step.

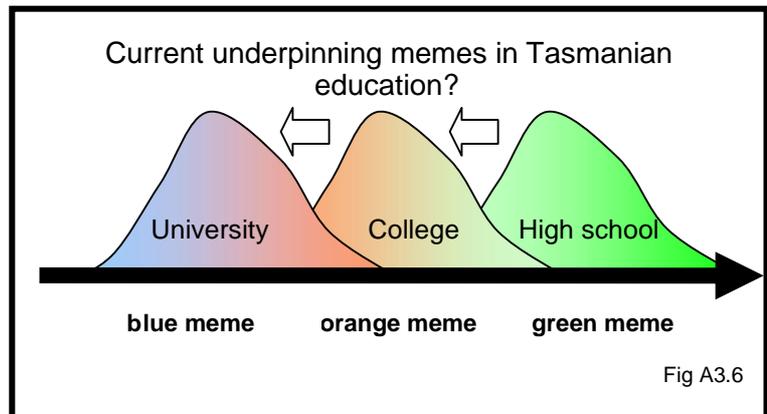


Fig A3.6

This project shows the difficulty in a faculty moving from a traditional *blue meme* dominated teaching culture to a more inquiring *orange meme* culture... but that is only the beginning. What might a *green* or *yellow* (integral) university science learning culture be like? And what transformations might be needed to get there?

I think I was operating in the *green meme* in terms of managing the project – trying to be sensitive to the needs of the lecturers and making transparent the processes, yet when it came to ‘teaching’ the lecturers about educational theories I was working at lower meme levels. In doing this project it assisted me to continue to move in perspective, causing me to get inside the very process of transformation and thus graduate to more integral perspectives which I

am now still easing my way into. I now don't think that there is anything wrong with working at the lower meme levels. However, there is a difference between being stuck in them, unable to think outside the box, versus strategically or attentively entering different meme operating methods because they might be the most effective for the time and place.

Spiral Dynamics suggests two ways for people to facilitate the transformation of others...

1. Someone (usually a person that is 'leading edge'), who has been through the process and is slightly ahead on the spiral, helps to draw others from one cultural perspective to the next and in the process continues to move themselves.
2. Someone (a spiral master), who can see the whole spiral and can go in at any point, takes on the perspective and the culture of those wishing to move and tunes into what is needed to stimulate and sustain movement.

So what was my role in all this? Perhaps, I was someone on the leading edge helping to draw forth others, not always succeeding and sometimes causing opposition and stress. Perhaps now I have a greater perspective to understand why and to act differently. Have I graduated to spiral master? The proof perhaps lies in the pudding and I still have a ways to go.

Post-script - Discovering my humanity

In my own teaching practice prior to 1999 I had found in myself a deep care and understanding of my students – a compassionate non-judging. I felt close to them, concerned about their needs and wanting to be an advocate for those needs. It concerned me that their capacity for soul expression was not being activated in their other subjects. So I might often get quite frustrated with my colleagues' practice in my own school environment.

Being involved in the collaborative project with the university lecturers changed my perspectives about teachers and has perhaps helped me to be more compassionate in my relations with educators.

When I started the project it was very easy to stereotype the lecturers. I had read a study by Taylor (1997) of university teaching of science and maths in the USA. He created two impressionist stories – Dr Stern – a conglomerate of male lecturers he had observed and interviewed (who taught traditionally, distanced themselves from students and expected the real learning to happen outside the lecture theatre) and Mary – a conglomerate of female

lecturers (who was very caring towards her students, building relationships, although she still taught in a traditional way).

When I think of all that is wrong with university teaching of science I think of Dr Stern. I know many of my science colleagues also remember their experience of the first few years of university in this way – you are only treated as a person once you get to third year or honors. Yes, some of the lecturers could have been Dr Stern, but were they really?

Underneath they were very caring and warm people, concerned that the students enjoy and be excited by physics and experience learning success. It was very easy for me to make value judgments; I had to stop myself, and make an effort to come to know them, their thinking processes, their aspirations. To look behind what they might be doing and saying for the deeper reasons.

In a sense they represented to me an ‘otherness’. I could identify with the story of Mary – my classes were built on the notion of relationships and care. Now I had to identify with the other perspective, rather than rejecting it. This was a little tough. I was often frustrated when well planned activities for lectures or labs ended up being pedagogical disasters. I wondered what on earth had happened and why.

For example, a really good idea for group work in a lecture might only partly work because the lecturer hadn’t fully explained the process of the group work enough and had minimal information on the cards he handed out. Yes, the students told me how confused they were in the interviews afterwards and how long it took them to actually work out what they had to do. So now I listen closer to his instructions and explanations of physics ideas and I begin to realize that he often skips steps. Why?

Then one day I am sitting quietly in an office when he and a post grad student come in and start using the whiteboard, writing up furiously lots of equations, talking a foreign language. They are fully engaged in this shorthand language and I have no clue as to what has been said. It shows me a completely new side – a highly competent thinker and researcher, totally at ease in his own milieu – a vast contrast to the way he seems in lectures – which comes across as a little incompetent.

So, I now watch the lecturer as he explains ideas one-to-one in a tutorial to a student and then I have worked it out. He is just too clever to teach this course. His first language seems to be mathematics and that is how he thinks – he does not need English explanations to tie

the maths together. In order to speak to students he has to translate his language into one that they understand.

OK, so now I have a theory of why he finds it difficult to construct others' understanding, I talk to him about it and tell him that I think he is too clever. He laughs, pleased. "Perhaps," I say "You need to see yourself as a *translator*, rather than explaining what you know yourself in your own physics language, you need to understand the students' physics language and thinking which is very different." This seems to be a useful metaphor. So now we look at some of his notes and assignment solutions and I pretend to be a student asking him to explain the ideas to me. We practice until he gets the hang of adding five more steps to each of his one, and remembering to put in the English. I try to give him the perspective of a student, explaining what understandings they are bringing. Perhaps we are both translators.

He now has to be vigilant in his lectures and tutes, checking with students he doesn't go too far too fast. It works until he gets asked a question in a lecture which causes him to talk as he is thinking. He totally loses the students because he is now talking at his level of reasoning not theirs. Yes, it is a long process of improvement. But he feels empowered. Now he can begin to see why things don't work, despite his creative planning and well articulated intentions for a lesson. He has been frustrated too, and annoyed with his incompetence. Why didn't I realize this and show him some compassion?

When I am observing his lectures now, I am doing so with much more understanding. I can see when he goes off into his own mental world and realize that this is a big habit pattern for him to change. I can forgive him for confusing the students. We can roll our eyes together at the end of the lecture and laugh about it as he says to me "I know! I did it again... I realized it though, and stopped, and that was a good thing!"

Perhaps assisting in the transformation of others requires a deep level of insight where one enters their world, being with them, laughing about imperfections as one tries to move towards new ways of being.

Barriers to adopting new pedagogies:

Denial of need for them – "my way works OK, just another fad"
– help them to see students' perspectives, use their scepticism as part of keeping the process of change manageable

Overwhelmed by what needs to be done – help them make a plan with manageable steps & goals, time for processing

Disconnection – others are engaged but you aren't and feel left out – help them to find their new fit into the group and vision

Feel incompetent as adopt unfamiliar pedagogies – help them to understand that this is part of process, don't go too far too fast, look for reasons.

Dread of going into classes – a combination of the above.

Fig A3.7



Ying/yang -

*In coming to know the 'other
I discover in myself
my deep humanity*