

Towards a pedagogy of supervision in the technology disciplines

CASES FROM THE TECHNOLOGY DISCIPLINES

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Cases

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TALKING ABOUT SUPERVISION IN THE TECHNOLOGY DISCIPLINES

This program aims to develop a framework for the pedagogy of supervision in the technology disciplines. The framework will be developed by investigating technology discipline supervisors' thinking and by searching the relevant literature. The viewpoints of technology supervisors will be collected using a qualitative methodology.

The outcomes will support strategic change in higher education institutions for the enhancement of learning and teaching at the HDR level. HDR supervision and its diversity has been a significant national issue for some time. There is a considerable literature attending to both what should be learned and how it should be learned or taught. As yet, however, we have little understanding of the value of these concepts to supervisors in the technology disciplines.

Significance: The process will raise awareness of HDR supervision as a teaching and learning practice, encourage sharing of practices amongst supervisors, and enable reflection and learning from research and scholarship.

Goals:

- To investigate and document technology educators' ways of thinking about supervision as a teaching and learning practice.
- To develop a framework, representing key aspects of a pedagogy of supervision, for use by supervisors and leaders in the HDR context for enhancing HDR supervision in the technology disciplines.
- To design recommendations for taking this agenda forward in consultation with key stakeholders across Australia.

Key Fellowship Activities: All strategies are designed to raise awareness of HDR supervision as a teaching and learning practice in different ways.

STRATEGY 1: BRINGING THE PEDAGOGY OF SUPERVISION INTO FOCUS I. This will involve using interviews and focus groups to investigate and document technology educators' ways of thinking about supervision as a teaching and learning practice.

STRATEGY 2: BRINGING THE PEDAGOGY OF SUPERVISION INTO FOCUS II. This will involve drawing together existing research and scholarship with the outcomes from Strategy 1 to develop a framework for use by supervisors and leaders in the HDR context for enhancing HDR supervision in the technology disciplines.

STRATEGY 3: RAISING AWARENESS OF COMMON AND COMPLEMENTARY WAYS OF SEEING THE PEDAGOGY OF SUPERVISION IN THE TECHNOLOGY DISCIPLINES. This will involve designing recommendations for taking this agenda forward in consultation with key stakeholders.

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INTRODUCTION

'practitioner's beliefs about teaching are central and powerful in determining their supervisory goals and their predisposition towards particular pedagogical approaches to achieving them.' (Murphy, 2004)¹

This document is a collection of 'cases' adapted from interviews with supervisors of higher degree research students from the technology disciplines. The supervisors come from a wide range of sub disciplines and represent many levels of experience.

We follow in this document Hammond and Ryland's (2009)² suggested ranking of supervision experience:

- No completions – No experience or new supervisors, with no doctoral completions as principal supervisor
- Experienced – 1 to 5 doctoral completions as principal supervisor
- Very experienced – over 6 doctoral completions as principal supervisor

The cases focus attention on thinking about supervision as a teaching and learning practice; a dimension of higher degree research supervision that is increasingly being recognized as important.

They are offered as prompts for individuals and groups of supervisors in thinking about their supervision as a teaching and learning practice.

¹ Murphy, N. (2004) *Orientations to research higher degree supervision: the interrelatedness of beliefs about supervision, research, teaching and learning*. PhD Thesis, Griffith University, Brisbane.

² Hammond, J. & Ryland, K. (2009) *Interim analysis of a survey of higher degree research supervisors in Australia and New Zealand*. University Graduate School, University of Technology Sydney. Retrieved May 15 2009 from http://www.first.edu.au/public/Carrick/Research_supervisor_survey.pdf

A. WHAT TECHNOLOGY SUPERVISORS EXPECT STUDENTS TO LEARN

A1 LEARNING TO BE A RESEARCHER

What I expect them to learn... is how to conduct research... using my approach. I do not pretend that I am going to teach them every possible way of research, rather because I consider myself quite a successful researcher I believe that the way I do it works and therefore I try to teach it the way that it can be done. A good way of doing it... Also as part of it I expose them to other ways of doing things, other publications, but I think most people in my specific area work similarly. So I guess it is the master-apprentice approach, where you basically teach them how you do it. How you paint. I can't teach them all the styles, if you want that you've got to get a general degree in painting... If you want to work with Salvador Dali then you're going to paint this crazy stuff... not that I'm Salvador Dali!

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I might be bit mad,... I don't think I'm quite as talented... But... this is the general expectation. So, I really expect that when the student has finished working with me they will be confident, they'll feel that they can tackle research problems, they will be able to design a research plan and I hope that they will have the capacity to supervise other students using that relationship as the model.

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Well, I guess discipline... I'm very big on weekly progress. I think the only way to finish a PhD on time is if you make progress every... I hope they get that, they get e-mails from me at three in the morning so they know I'm reading their stuff at ungodly hours! I am a night creature. I go to sleep late and wake up late... I got up early for this interview!

.....

So, I would like my students to realise it's an intense, full-on occupation, being a researcher. Most of them come from coursework - you go to a lecture and you take notes and you forget it... and two weeks before the exam you cram, and then you forget it again. You just do the obligatory lecture attendance. It's a very different mode. Here I like my students to know that it's really like a full-time job. Virtually all of them accept it. The one case before that I mentioned when it failed the student was simply not prepared to work in that mode. They were more happy to procrastinate... and to enjoy the experience of being a PhD student, without doing the hard work. So I'd like my students to also learn to be hard workers and tenacious. Isn't that wonderful? (I1, male, experienced)

A2 LEARNING TO LEAD RESEARCH

First of all, I would say I want them to learn a scientific method because we work in science so they have to learn a scientific method of research. So, trial and error, to try a certain experiment, see if the experiment is successful, if it is not successful try to find answers. So, learn how to drive, how to lead an experiment.

The other work is to search for the experience of the others, try to build up a base of knowledge of what you are doing. So, you need to have a certain knowledge of what others have done otherwise you may waste a lot of time. So, they have to learn to search in the literature, I think this is part of the standard problem for a HDR candidate, search in the literature, have a critical vision of the literature, find which are the points in literature which are not clear and where you can give an answer, and comparing with what you have in your laboratory, what you can do, and try to find a way to do it.

So basically it is to design an experiment and to lead an experiment. So, find the reasons for this experiment and lead the experiment. And give an account of this experiment in a proper way. It could be surprising, but most of the students are not able to distil what they have found in the experiment and to write a paper. It is part of the job of the supervisor to help them to write papers. The way I do it is I ask the student to put down a draft and I give corrections so they understand what they have to do and how this must be presented, and they give it back to me and I refine the corrections so that I can finalise this with them to a level that is expected for publication.

So, first of all research in the literature, second - lead the experiment... of course, you have to learn a number of techniques depending on the field you are working in and you have to master these techniques in order to give a result that is at an international level, and finally reporting this. This is what the student must learn... then, to have the capability to lead your own research is something that is for the Post Doc, I'd say. (I4, male, experienced)

A3 LEARNING TO BECOME LIKE ISAAC NEWTON

one of the things we start with is we give them an induction and we talk to them about what it is to... do research. It's not really just about mimicking, it's about coming up with new ideas, new and substantial ideas. So, we start talking to them about vision...

Hopefully, after a while... something is working, something has succeeded, then I say to them "Okay, now you need to be starting to be the master of your studies. You need to become the expert, so you need to start coming up with your own ideas. You're going to be graduating before too much longer, you need to be coming up with new ways of doing things." I say it to them directly.

One of the things I will say is that it's one of the things I found most challenging about being an academic, actually getting students to achieve. I think it's that... a lot of students still have the vision of being a mimicker, copying others... they often get beaten by various obstacles. They don't want to do stuff that's hard. They don't want to do stuff that's a little bit unsure. They don't want the rejection of doing things that might fail.

I expect them to learn how to become an expert, how to solve problems on their own, how to do things that are substantial and how to develop those habit patterns of just being able to learn whatever it is, learn things that are difficult and innovative, create their own very substantial solution. It's to develop habit patterns of creating their own substantial and innovative solutions. And, I guess, solutions to complex problems, as well, not just simple ones... something that I would consider worth publishing. Something which international experts believe hasn't been done before and is not trivial.

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What I would like them to become like is Isaac Newton. He is someone from the technical field... actually, one of the reasons I think that he was so effective in making groundbreaking answers was that he was both very thorough and very diverse and so he had a huge grasp of knowledge and skills and techniques across a huge range of areas. All of the scientific areas but also across a lot of the non-scientific areas, as well. It was that huge diversity and that huge level of thoroughness that enabled him to... make linkages. So, I would like them to learn those kinds of things... and I'd also like them to develop as a person as well... to be able to work better, more effectively with others.

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I guess the ability to reflect very effectively, on their processes to improve them, to be able to contribute better to society. I mean, this is all theoretical because I just find it really difficult to get them to be able to do all these things, but if you ask me what I would like, this is what I would like. (12, male, experienced)

A4 LEARNING ABOUT SELF

They need to learn about themselves, to get all soft and fuzzy! I actually don't think a PhD is a particularly academic exercise, you don't have to be really smart to do a PhD, it's an exercise in discipline, it's an exercise in organisation, it's an exercise in hard work and frustration. A lot of the guys I have now are orthopaedic surgeons or guys who want to be orthopaedic surgeons. A lot of them are studying because it's going to help them get on the training programme and help them understand what's going on, but for them I want them to understand that research is difficult, that's the main thing that they have to understand. If they want to go to a lab and say "Grow me a cell" or "Build me this" it actually takes a hell of a long time and you have to understand that an experiment that you could run in a week can take a year to actually get to the experiment. So much more goes into it than just coming up with a number. So, as clinicians and surgical leaders of the future they're going to understand when they're working with students and others that this is a difficult process and never is as simple as it looks... they are learning slightly different things from a fresh student who has just come through.

I guess they've got to learn the rigours, that badly done research is pointless and so if they are working with an engineer and it frustrates them that they have to spend so much time designing an experiment or a technique, that they understand that that is valuable at the end of the day. If you're going to do it, you've got to do it properly. Good research is always a worthwhile exercise and bad research is not worth the effort. So, they have to understand the rigours of the process...

If you do get a finding then it might change people's reasoning and understanding, so there has to be a level of integrity and honesty in your research. So, they need to learn to tell the truth, hopefully most of them do anyway... and that's why we often set up a project where it doesn't matter if it's a "yes" or a "no". So, "Is this gene controlling this process?" is valuable if it's "yes" and it's valuable if it's "no". If you try and take out that necessity to find an answer to solve a problem... it makes for a much more intellectually honest research and much less stress if they understand that no matter what they find, that's a valuable finding.

They all need to learn that a PhD is frustrating, that it's a long, slow process. I say, "When you've finished your project you should be the world expert on this field on the study of that implant under that circumstance and understand it better than anybody else." They have to understand that they are going to know a hell of a lot about not much. I find they start out and they want to solve arthritis or they want to solve cancer. They have to understand that research is iterative... they're not going to sit down for three years and answer something that millions of dollars and thousands of man hours have not answered yet. They're not going to come out of it with a Nobel Prize. So, they have to have very real expectations and understand that the contribution is still valuable. So, that is managing an expectation that what they are doing is worthwhile and they have to understand that what they do is worthwhile.

They have to learn about themselves; that they can take a subject, understand it and develop it and learn a level of independence. It's very different to a student who has just finished their degree, who comes to you and says, "I want to do a PhD." They have to learn very different things... every student doesn't learn the same things. Some have to learn to grow up because they're perhaps twenty and they're used to being fed and they have to learn that this is their work... It's a bit like having kids, every student's got a different personality and they all need to learn slightly different things. (15, male, experienced)

A5 LEARNING TO WRITE

This is something that is very important to me, as a supervisor; and I have discussed this in some of the seminars that I've gone to.

You can divide a research project, particularly a PhD research project, into two sections: you have the research that the student has to do and then the other part of it, of course, is communicating that.

You can be Einstein, and you can be as brilliant as anything, but if you can't produce a thesis and communicate that in writing to other people it's all just an internal thing.

The other model that comes along, particularly coming from a technical background, is: "I'll go and do all this brilliant stuff. I'll write a program. I'll do all this fantastic stuff and then in the last two weeks I'll produce a thesis." That really irritates me... particularly because I'm going from the technical to the broader stuff.

I like to get the students to use the written communication to feed their thought processes, to feed the written communication, to feed... all the way along. Sometimes it's a big leap for them.

One student I'm working with is trying to get everything down to the nth degree before he starts writing. But I know this particular student. I've supervised him in a research project and his writing was atrocious. So, for him it's not going to be the research that's the big issue, for him it's going to be the write-up. So, I'm trying to get him to do it early.

Some supervisors don't like to have students who can't write English...they don't feel competent and they feel very frustrated with it. I don't mind that, but the student has to produce so that I can give feedback. I've gone down this track before, some of them start and they are atrocious with their writing and I spend probably more time than I should giving them direct feedback and the good students pick up on every bit of feedback I give them and do actually improve their writing.

This one today... I've got to get him writing stuff and I've got to get him in the train of thought of thinking like a research student... "OK, let's write it down"... because when you write it down and then you read it back, you might think, "Oh, no. That's not quite right." And that helps you to clarify it in your mind. "In my mind, I made this leap and when I write it down this leap is an abyss. I can't do that." So, that way they are training their mind; and then when they flesh that bit out a bit more, they go back... So, that's very important to me - the thought processes and actually producing something in writing. I'm more a generic type person. (17, female, no completions)

A6 LEARNING TO COMMUNICATE PASSION WITH RIGOUR

They will learn to communicate with other people. I'm just thinking high level here. I may be naive, I probably am naive. I like to think... rather than, "Here is a research student, you're going to learn something from me." I prefer to think of the process as, "Here's a student who has an urge to write a PhD, so I'm happy to help him along that path." I prefer to think of it that way, rather than he's coming here and I'm going to teach him stuff, because I don't know stuff!

It's their PhD... I like the student to own their PhD. So, if they are going to own their PhD, then they are going to need to have created it, rather than have accepted what I have given them on the plate. Because I feel that there is responsibility there. If I give them something on a plate... six months later they can say, "Well, you gave it to me..." I like them to own it from the start and I know it's painful for them, it is like pulling teeth but, hey, a PhD is not easy.

It's a bunch of hard work. I've got one PhD student who started out and he had romantic notions of a PhD, but I went with it because I know that he's got good qualities in himself. He couldn't find anyone else to supervise him because he has very firm ideas, in a generic sense of the kind of thing he wants to do, and I guess I identified with that because I was like that. I know he's got good generic qualities, so I went with him because I knew that he would stick with it. I know that he's got very strong, ingrained values, generic values.

So, he wanted to go with this thing which was a bit unusual... and he's coming up towards the end now... but we're having trouble writing up what he's doing. It's quite painstaking, it's like pulling teeth, but it's generically something that he wants to do. He wanted to do something with small, not-for-profit organisations, which is really off the beaten track and doesn't fit into the traditional idea of information security and what we do, but he's got his passion for not-for-profit, save the world, all this sort of stuff. I'm impressing on him all the way, "You can do what you want, but we have to fit it into an academically acceptable structure." And he is sticking with it, as I knew he would, and he will be doing it but we're going through a very painful part right now because he's taken on an action research methodology... I don't know that much about the methodologies because in the technical, information security they don't worry about methodologies or anything like that!

So, this is new to me as well. Writing up the methodology is like pulling teeth. My co-supervisor is directing on the methodology but she only knows about information security what she knows from me... So, what we're going through now is what the essence of his PhD is, so it's going to form a chapter and it's sort of the essence of what it is, all the other chapters will come off this because this is the action part that he has actually done. We've been working on it for the last month and we're about halfway through it now. So, hopefully in another month he'll have the second half sorted out and then that's the essential essence of it and once we get that, we can build the other chapters around it. He is achieving generically what he wanted to do, even though it is very painful. Because I let him do what he wanted to do, he sits there and says, "Yes, I know that it's very painful, but it has to be done." He knows that it has to be done. I don't have to convince him. Whereas, I feel that if I had given him something, he would be looking to me and saying, "Well, why...?" So, up front I try and bend to what they want to do but understand that there are implications... (17, female, no completions)

A7 UNDERVALUED LEARNINGS

I expect them to learn a lot about the process of being a rigorous investigator and along the way they learn about their topic. I expect them to learn about how to ask questions and think in a creative and expansive way that is not limited by what other people have said or done.

I expect that they will learn really good communication skills, oral and written - not all of them do but they all get better at it. What I've observed is that students learn a whole lot of things themselves, in the way they deal with a reflective process, that they didn't realize that they needed to know. And I expect them to learn about having confidence in their own mind so that if you've got enough information about your topic then being confident in your own intuition to know what's the right question to ask or how to go down a particular path. The topic I think is almost less important in my mind. That might be a bit controversial!

The way we structure PhDs, the research tends to be very deep and a specific part within a very narrow area of application. I'm generalizing here. And you do learn a lot more about that topic and related fields. And you do develop an expert view of that specific area of detail and sometimes that can have wide-reaching implications.

But I think those other things that wrap around that in terms of asking rigorous questions, being creative in your thinking, improving your communication skills, even things like persistence and dedication and remaining focused, I think they are under-valued learnings from the process of doing a PhD. I think it is well positioned as research training. It's more a professional or personal development activity, as I see it. (I9, female, no completions)

A8 LEARNING TO BE AN INDEPENDENT RESEARCHER, YET A TEAM PLAYER

P2: I think the ability to do independent work is very important. You're not just doing what you are asked to do but to actively find something. Of course, if you are doing research in an area you have to be familiar with the state of the art in that area.

P2: They also need to learn how to search for literature. There are a huge number of publications, so you must pay attention to what kind of journal or conference you look at. You must make sure that the literature you follow is the top, the state of the art. Presentation is also a skill they need to learn and practice. You might do a good job researching but you must be able to present also. We encourage students to attend confirmation seminars and final seminars of other students. This way they learn from other students. This is especially important for overseas students.

P2: Teamwork also... Most research work now is teamwork so this is very important. Students have their own research problem but they are all in the same area so they can somehow help each other. (I11-2, female, experienced)

A9 LEARNING TO BE A MATURE RESEARCHER

P1: I think they need to learn to be a qualified researcher. That's a very important issue because after you get a PhD you are supposed to be a qualified researcher in a particular area. So, in this period one thing is to learn how to understand other people's work first. This is not an easy job. I find most students don't understand other people's work because the papers include a lot of technical material, different methods of data collection and different ways to test the result. So, I stress this idea of understanding other people's work.

They also need to understand the whole area and understand the direction it's going in and why people are trying to do this. From the big picture, then maybe it's easier to go to the paper and understand it. That is one skill I want students to learn. The other skill is that you need to repeat this reading and not just read once. The first time you get a basic idea of the other person's work but you still haven't got a very clear picture of what they are trying to tell you. You have to dig out the ideas from the paper. Some people are very clear but some people are not. If the paper is published in a top journal, then you have to think about how it relates to your work. You have to understand what is logically different between your research and others.

After that, there are writing skills, professional writing. For writing a paper we usually have some fixed steps - abstract, introduction, then to conclusion. One key point for writing is how to show clearly your result to others. Of course, English is a problem. Another question is how to structure your paper. Some people in your area are not very close to your ideas, you have to convince them that you have made big progress, it is important, it's significant, and you can change something in the future. This is writing skill.

Of course, another is communication skills. The student needs to learn how to use the environment - e-mails, how to ask questions within one hour with the supervisor, having an efficient interaction, how to learn from your senior colleague. Also how to learn around the area, not only your area. When you go to find a job it won't only be for your research. For this reason our reading group is quite a nice idea -- the students learn about each other's work and in the future it is better for their career development, they can find a job or they might change their research direction. Independent research is another goal.

P1: It's important for students to develop an international network but this is difficult because they have limited resources. We tell them, "When you attend conferences, you need to talk to people, you need to communicate with other people." They can learn this.

P1: Another thing we try to develop is application skill, how to apply your research to the real world. But this is still quite weak. PhD research is sometimes far from the real world. That is a big question currently. (I11-1, male, experienced)

A10 LEARNING TO BECOME RESPONSIBLY SPECULATIVE

How to keep asking questions. I personally think that it's the questions that are more important than the solutions. I think research is all about the questions. I'd like them to have the courage to approach things from unorthodox ways, if necessary. So, a kind of independence of thought and not being afraid to go out on a limb, but to do that responsibly. Of course, when you do a PhD you become part of a field and that field has its own norms but still to be aware that you are not to be trapped by that. You can't always impart that, it depends on the question. Some students I've had have been more question oriented and some have been more solution oriented. So, for the ones that are more solution oriented it's a case of finding a problem that they are able to solve. For the question oriented students, I wasn't to help them to keep that, and not to fall asleep or be captured too much by the norms of the field.

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I also want them to learn to be responsibly speculative. When you're trying to do something unorthodox or different it's relatively easy to be speculative, it's much harder to be responsibly speculative. The inspiration for me in this is the Australians who went up Everest. There was a team about 15 or 20 years ago who went up without oxygen. They found a very direct route which was very steep. Now, this was highly unorthodox, they went up and they trained. Then they went very, very lightweight and four or five of them went off and two got up to the top and back. I think that's a wonderful example, a metaphor for what can happen. This is particularly in an institution which tends to follow. When you're at the institutions like the Stanfords and the Yales and the MITs, these are the ones that we tend to look to, to break open new things. So, we are like the ones trudging up those well-worn paths on Everest that others have formed.

However, can we think out of the box? Can we be like the ones who didn't need the large teams, didn't need the oxygen canisters and things like that? That's a wonderful metaphor for organisations like this which with a small team of talented people can achieve remarkable things. However, you have to be responsible when you do that. If you don't do the training and you don't think about how you are going to do it and you don't build foundations then it's just rubbish. So, that's what I mean by responsibility in speculative work. (I16, male, experienced)

A11 LEARNING TO BECOME THE WORLD'S FOREMOST AUTHORITY

P1: Something I've said to students for many years now is that they should be the world's foremost authority in the narrow area of their research by the time they complete.

And I believe that. If they are going to be rigorous enough and deep enough, then they have to be relatively narrow and it's not a stretch to assume that they will be the world's foremost authority in that narrow area. So, they should learn to be the world's foremost authority in the narrow area of their research. But also I expect that they will leave having a broad understanding of the discipline and they will have acquired a range of research skills in relation to the methods and tools.

It won't be the same combination of skills for every student but it's conceivable that they will have gained skills and abilities beyond those specifically employed in the conduct of their research. We are developing them as researchers in order that they can be productive as researchers beyond the PhD.

P2: I agree with this. I like this notion of learning that you can potentially become the world's best individual in that narrow area. It also means that your confidence can grow. So, I want the students to come out of here full of confidence that they can achieve this. I agree with understanding the right research tools. Also that they learn from other students, that they look beyond what they are doing themselves. We had an exercise where students presented each other's topics. They talked to each other and then for 20 minutes they had to talk about another PhD topic, to stress that they had to learn about other areas. They also have to develop the right social skills in terms of interacting with other academics or other industry partners, to the point that they see also commercial value in their work. We want that they present extremely well, so we put a lot of energy into their presentation skills. We often say, "To do good things and be able to talk about them." So, these things are extremely important to us as well. And then all kinds of generic capabilities like analytical thinking, critical thinking, writing well, compliance to milestones, so there would be a long list of the generic capabilities. (I12-1, male, very experienced; I12-2, male, experienced)

B. LEARNING TO SUPERVISE

B1 LEARNING TO CONSOLIDATE

As a relatively new supervisor, one of the things that I'm struggling with, and this relates to my career as an academic in that I've got a number of different roles and different interest areas, so my research students span those areas. Whilst I quite like the idea of being able to have a group of research students at different stages working in general on a common topic area, what has happened is I've acquired students across different areas. So, there's not a lot of synergy, as my students spread across those three different areas. If you had the opportunity to plan out how you were going to have research students... it's not one group, it's three groups. So, that adds a bit to the overhead. It's not difficult, per se, it's just a bit bigger as an activity. (I9, female, no completions)

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I'm starting to now consolidate around those three areas. I won't take any outside those three.

B2 LEARNING TO BE STRATEGIC

P1: I've been doing this now for 15 years and I've learnt a great deal over that time and my attitudes have changed several times during that period. When one is a novice of supervising you can compensate for lack of expertise by having more time to spend with the students. In later years, as you gain experience, one hopes that you develop some understanding of what are the pressure points, what really requires attention and how to facilitate. That allows you to be more effective. And you realize that each student doesn't require intense attention. (I12-1, male, very experienced)

B3 LEARNING FROM THE TEAM

with postgraduate supervision it might be a conversation a student has with somebody else which is the only way you can find out what the students are thinking in terms of your performance. So, you have to read between the lines and work to try to improve what you do by testing it yourself as you go. Often it's something that happens in the background of your mind. It's important because you want to make sure you're improving over time. I look at when I had my first couple of students - I do things very differently now and that's because of the experience I have gained over time. One aspect of that is when we do our team supervision, that gives me an opportunity to see what they do and how they approach things.

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I think that mentoring of supervisors is really important. I started here about nine years ago and pretty much jumped in at the deep end with supervising students. I was very fortunate to have two senior academics in my field who both, but in different projects, helped me through the supervision of my first batch. Now it's very much more of a collaborative thing but I think that the early career academics need a clear mentoring path in postgraduate supervision to help them get through the quagmire of their first couple. We have a system where you need to get a certain number of points in supervision and there is a probationary system where you are an associate supervisor first. In that case it's important for the principal supervisor to give the associate supervisor plenty of opportunity to develop their skills rather than just be in the background. So, the principal supervisor would need to have it made clear to them that they are also meant to mentor the early academic. (I17, male, experienced)

B4 LEARNING TO BE AWARE

in each student I find there are weaknesses in myself, so there is a learning process and it's not a one-way street. I have always found that PhD supervision is not a one-way street. And that learning of the weaknesses is always context sensitive according to the student and that cuts across, not only weaknesses in your knowledge of the topic which is the intellectual dimension, but also in terms of dealing with another human being.

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In each case there is a certain insecurity on my part. I don't feel that I've got this down pat because each time it's a different situation, it's a different relationship. Maybe when I have supervised large numbers I will be able to say that I have seen the spectrum. However, I think that this is healthy because the insecurity is a reminder that I have to be aware, that I don't have pre-cooked answers. The real answers have developed in the context of the relationship, they have not been pre-cooked. Obviously, there are rules of thumb that are useful but I think that the process, the relationship that has taken place and the dialogue are more spontaneous and not so pre-cooked. I think when you are too secure it becomes too pre-cooked, then there is a danger that the relationship may not work as well. (I16, male, experienced)

B5 LEARNING TO BE BALANCED

In terms of treating the students, I try to make them feel equal. That's very important to me because I think they need to get ownership in their work. They need to recognize that at some point in time they're going to be the expert on the topic and my role is to guide them to get to that point. I may not be an expert in their topic, I may be an expert in my topic which may be different from what they are doing. So, building I guess confidence. This is something I would like to learn about more. And on the other hand when you have a student-supervisor relationship which is equal there is also the problem that if it is too equal then they don't take you too seriously. It's a balance, which I am learning. (I10, female, no completions)

B6 LEARNING FROM OTHER SUPERVISORS

I've started to try to pair up with different associate supervisors to get a bit more breadth in my approach... I am very curious to see what approaches other supervisors use. I see other supervisors who are much better I think than I am at getting students' work published and getting them finished on time. So, broadening my experience. (I15, male, experienced)

C. THE ROLES THAT TECHNOLOGY SUPERVISORS ADOPT

C1 BEING A BOUNCING BOARD FOR THE DREAM STUDENT

I had one student who was absolutely self-motivated. He turned up, told me what he was going to do and did it. So, from day one it was basically just brainstorming. So, I was a bouncing board, that's it. I gave him of course a lot of ideas about how to solve problems but essentially... he would turn up to my meetings with his agenda, he would turn up with a page full. That student was so good, as far as PhD students go, if I was late because you run into meetings in other buildings and so on, and his meeting was always following another... I often would be five or ten minutes late...He would sit on the floor in the corridor, with his laptop open, typing away, so he didn't miss two minutes. Absolutely compulsive obsessive! He was like me! It was the ideal student to have, completely engulfed and interested in what he was doing. He submitted within two and a half years. That's an ideal student, I wish all of them were like that, but they're not.

So, generally the way I do work with students is that during the first year they are probably working as a research assistant, learning the ropes. This is what you have to do, you have to do the literature review and this is the kind of program you will have to write and this is how we are going to test it, etc. In the second year I tend to shift more responsibility to the student. This is usually when they start getting involved in the organisation of collaboration. I don't know if it's transportable to other supervisors but I just happen to be the chair of the international relations forum, so I have opportunities to throw students into it. Other people may have to look for something else, but there are always things that you can get your students involved in and I think it's very important. For example, you can ask them to develop open source software or develop a tool for doing something. When students do it they actually own it and I think this is important.

So, during the second year I let the student take more ownership. In the third year they are basically writing on their own and I go back to the mode of being a brainstorming, bouncing board, much less directing what they are actually going to do. It's up to them. With most students I find that this works quite well. When it didn't work the student was not self-motivated to do it on their own and not disciplined enough to do what was required, to progress. So, I don't know what would work and there's not much you can do. You win some, you lose some. But I find that approach of giving complete structure in the first year, transferring ownership in the second and in the third basically being on cruise control - that seems to work very well...

I guess also part of the role is to make sure that deadlines are met and so on, as far as the process... It's supposed to be my role but I never actually had to do it. Somehow the students know. I've never had problems with students not producing reports on time or anything like that. Usually they tell me and I pass the information on. Some of them I know are not going to meet it and I just say, "Look, off the record, everybody's late so don't panic." Because most people are late, though not to the extent that it raises an exception. In that sense, the role of actually driving the research, I think we have a good system in the faculty, most students generally know what is expected of them as far as the formalities go. They are aware ... they drive it, they come to me and say, "Can I have an extension?" before I've even thought about it. I suppose I'm answering the question, "What's not my role?" For me, this is not my role. I'm not here to basically micromanage their candidature, I'm here to manage their research, not the process. (I1, male, experienced)

C2 THE CO-AUTHOR ROLE

Q: You'd send them towards a fairly high level journal fairly early in the piece, would you?

A: Yes! I guess that's the way I was trained and so I would tend to do things the same way. I'd say, "These are the kinds of journals we need to publish in. Let's start moving towards them."

Q: What kind of role do you play as an author?

A: It depends, I'm not always the author but usually I am... I have had different students and different experiences. Particularly in the very early stages I'm the intellectual driver behind a lot of it. I get them to write it but sometimes the writing is so poor I still have to rewrite it... Sometimes they're great and they put in a lot of the intellectual stuff themselves and sometimes they will write everything. So, there are various shades in between.

At the very least I would be reviewing it and saying what needed to be changed. And I guess I give them an idea of what a journal would expect, what's the appropriate standard... and tell them to read some of the other articles in the journal just to get an idea of the kind of standard, the style of writing, etc. (12, male, experienced)

C3 NURTURING INSECURE STUDENTS

I think the other thing is, the listening. Listening to what they have to say but not only critical listening. It's more of an open listening, more of a broader sort of listening. I personally think that critical thought is overemphasised. Depending on the individual, some like and want to have a debate and that can be quite competitive. One person I know, who did his PhD under a Nobel Prize winner, said that they would have their Friday seminars and they were not considered successful unless there was blood on the floor! He came back here out of that culture and wondered why people were shying away from him or not saying exactly what they thought. That comes back to this intuition idea, some students can be quite soft or insecure and you don't want to be overly critical but have more of a nurturing approach. (116, male, experienced)

C4 THE PROJECT MANAGER ROLE

My role would be to give them some milestones that they have to fulfil in order to go on. So, I would say to them, "You have to bring me this literature review by this time. Maybe you can express this in a seminar for the students, what you have found in the literature. So, by this time you have to explain in a seminar what you have found." So, giving them goals, little by little, I lead them to the right path. The same for the experiment, "What are the things that we can discuss together, the planning of the experiment, then you have to perform the experiment and bring me the results. And you have to bring them by certain time."... One of the problems with the students, I think, is timing - it's difficult for anyone. For the students often it's a matter of finding what they are able to do easily and what they are able to do with a certain effort and what they are completely unable to do. You cannot ask them to do what they are completely unable to do unless you want them to waste a lot of time. So, you have to lead them along a certain path and find out their skills, because they arrive with certain skills and you have to build on these skills, rather than building everything from scratch, because that is difficult in the time span that you have.

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Usually, if I am able to help them personally I will help them to learn at the beginning and then I'll leave them, "Okay, now you have to do it by yourself." If I'm not an expert in that field or I need a technique that I'm not expert in, I will find an expert who can lead them to learn the technique. From another faculty or from another lab. Or, if I don't have the instrument here I can send the student to work with some colleague who has the instrument that they need.

For example, I have two students now who are in Rome because my former colleagues have two beautiful atomic microscopes that are worth millions of dollars... and they can learn from my colleagues the techniques of these microscopes. I could have told them but I don't have the microscope here, so that's a problem. So, one of the points is to build up a number of skills to perform these experiments and this must be done during the time of the candidature. But you have not to spend all your time just in learning, you have to spend probably just about ten percent of your time in learning and then the rest of the time in getting good results. You may send students to summer schools or conferences... this is part of the business, because a summer school can give you some new ideas or a new technique, sometimes these schools are practical schools so you can get some hands-on experiments to do... or you can at least talk to someone who is very expert in a certain field... I organised last year a school which was very successful... and this always gives the student a big 'kick' because they see what others are doing much quicker than just reading it in the literature... and also it is much more rewarding of course because you can talk to the people, you can understand better and you feel part of a certain environment. You will talk also to other students, so you get to compare your work with their work. (14, male, experienced)

C5 GUIDING ALONG A JOURNEY

I'd have to say I have probably never had a lot of formal training in HDR supervision, it's something that I've simply done. I seem to do it reasonably well, by all accounts, my students seem reasonably happy, but if you were to say, "Is there a name for my technique?" No, there isn't. I usually say to students when we start out that I see this as a shared journey, and that it's a destination I've not been to before and so I can't lead them or guide them in some sense on the journey because I haven't been there either, in terms of that particular area of research that we are trying to find the answer to.

Based on my own experience of research, I like to think that I'm "wise to the ways of the forest", so I guide them in that spirit but I've not been to this particular destination either... I think that's important for students...it's not as if I'm sitting here with the answers and I'm just trying to get them to come up with the same answer.

In that sense, I see the role of supervisor is asking the right questions that might help lead students to finding the answer... obviously offering them advice on things like, "This is looking like a dead end. Why don't we back off and see if there's another way that we can try to get where we're going?" I think that an important part of the role of a supervisor is the timekeeping of the project. You have a timeline that you draw up at the start, sure, but we all know that you don't exactly follow it to the minute because when you start out there are many unknowns in the project. You start out with your best guess.

So, I see my role as supervisor to try and get the student to a timely completion and that's a responsibility that weighs even more heavily on me given my current role, of course, because I also feel as though I have to lead by example... You know a student scholarship will run out, so you have an obligation to be timely and that means you do have to try to draw a line across unproductive avenues of research that are going on. You also have to be conscious of the endgame. Again, I talk to the students from day one about what's the end goal of the thesis. At one level it's the research topic... the other thing is a thesis that will be read by two examiners and they've got to pass it, so they can officially say that you are a smart person and you deserve to get a PhD.

Let's be honest, there is a mechanical goal in this, and that is producing a thesis to the standard of satisfying those two examiners. When you look at the overall research plan, students are always overambitious about what they will get done in the three years. You also have to have in your own mind, and I usually even have that explicit conversation with the students, about possible exit points earlier in the timeline and about organising the order of work. So I say, "I know you want to do those three things and then pull them together, but what if things get behind schedule on those three things? Is it possible if there are two of them that we do first, could they still be pulled together to give us sufficient material for an acceptable thesis?" I think you've always got to be very focused through the whole thing... not slavish observance to the timeline, but watching the timeline, backing out on activity if it's not working, putting a time box on perhaps a different approach, or working towards a chapter which explains, "We tried this and that but we could not get this to work and we're not convinced it's feasible at this time", and tackle the other part of the project that we talked about and see if we get a more positive result out of that one... So, always having a plan about how the thesis progresses and how the thesis is going to end up, given the progress that you're making and the timeline... (I6, female, experienced)

C6 CARING FOR THE STUDENT

And also I think for students that are international students, I also tend to be a bit of a mother as well. I will offer personal advice where one is aware that there is a girlfriend crisis... I might be old-fashioned but where there's a student in front of you in tears because his girlfriend has left him, you've got to give him a hug and you've got to just be mother. Whether this is because I'm a woman I find it easier to do this role, I don't know if male supervisors give their students a hug... It's not just the international students, but I think the ones that are a little bit further from home maybe they haven't got a local support network... I guess I get a little bit involved in helping them out in a broader personal sense. I feel very strongly that I have taken on an obligation and as someone who has actually changed jobs while supervising HDR students I have generally continued to supervise the students from the new role. I do think that I have made a commitment to them that is deeper than the job that I hold and I have continued to supervise students during periods of unemployment, as well... (I6, female, experienced)

D. TECHNOLOGY SUPERVISORS' APPROACHES TO SUPERVISION

D1 SEEKING PERSONAL INTEREST

I try always to push the students to have an interest in what they are doing and finding the motivation for the research in the personal interest in what you are doing. And so, going deep into a subject, trying to solve a problem is what will give students motivation. Sometimes a student is compelled with the results and I tell them, "Don't look at the final result, what is important is that you understand step by step what you are doing." Because sometimes in the research, and especially in science, you don't know if the final result will be what you expect, it could be completely different. So, if you don't follow step by step your path of research and you try to understand your daily results you will not find the right path to finish. And maybe the path has to change at some point, you have to deviate from what you were thinking and to go into another direction. (14, male, experienced)

D2 STAGED EXPECTATIONS

I only really have one macro level approach, which has three stages -- a beginning stage, a middle stage where the bulk of the work gets done, and then the finishing up stage. But there are steps within each of those phases. There are a set of principles which overall guide my approach. Firstly it's about providing the right level of guidance for each student. So, it's not about having hard and fast rules about what I do, it's about trying to meet the needs of each student. It's an intensive form of teaching. Each student's needs are different. Some students need a lot of guidance around the more traditional side of research and others are very intuitive about that but are not very good at writing it down. Regular meetings is another principle. It's almost at a pragmatic level but I don't like seeing my students any less than once every three weeks, as a general rule. I try to have a regular schedule of meetings which occur for six months and then we re-agree what that's going to be for the next period. If they are doing a lot of data collection you don't necessarily need to see them often but if they're getting to a part where they are doing data analysis it's good to keep track. So, regular meetings that are agreed for a period of time, at a scheduled time. The third principle is being clear about expectations in terms of academic rigor. That's about the deliverable but also about coming to meetings, being prepared, having done the work. But also what the student expects, so coming to some agreement about what they need to get out of the research project. I have a variety of approaches that I use but it's within those general principles. (19, female, no completions)

D3 GETTING HANDS-ON

I get hands-on. If they're writing software, I like to see them run it in front of me, because most of them carry laptops these days, so I like to see it run. I like to "What happens if we do this with it? What happens if we do that with it?" If they come and it's got a bug that they can't see I'll say, "Pull up the code, two eyes are better than one." I'm probably a little less hands-on in my current role than I used to be in my previous job where I did have more free time and my students were more able to just pop their head in and say, "Can you just spare me five minutes?" In my current role my students just cannot do that, they just can't get that gap in my life. To clarify, I come from the technology end of IT, the hard end, not the soft end! So, the work we do is mainly with software tools. (16, female, experienced)

D4 AN APPRENTICESHIP

I believe it's an apprenticeship to being a professional researcher and that it's not just supervising them in the topic at hand but helping them to acquire as much breadth of skill as opportunity typically presents me to involve them in, around the broader research activity... So, publication... Around the process of supervision itself I generally articulate to the student why we're doing things, I don't keep my supervision practice as a surprise to them and just simply let them know the outcome of some decision I've made. I usually have those discussions with them so I hope I skill them up in at least my approach to supervision. They will supervise their own students. If I can I get them to supervise honours students or vacation students in the course of their PhD, I will do that... because if they go into an academic role they'll be expected to supervise students themselves immediately on getting their PhD, so you need to have them ready to go... The process is an apprenticeship - the PhD remains one of the few examples of the masterpiece. It used to be from the Journeymen to Master, where you could have your own store where you could employ Journeymen. You had to go to the Masters of your Guild to present examples of your work which were your masterpieces and if they were accepted then you were then a Master and that's where the term "masterpiece" comes from. The PhD is one of the few areas of life where we still have the masterpiece. And that's exactly what you're doing with examiners, your thesis is going to the examiners, the existing Masters, who judge it to see if you should be admitted to their ranks. The PhD still operates very much on the old Guild model. So, the Guild of people with PhDs. (16, female, experienced)

The other aspect of my approach, such as it is, is I believe that it is very much a master/apprentice relationship... and I actually have a responsibility which is more than just the research and the production of the thesis. I think I have a responsibility to try to do general professional development. So, obviously if I'm involved in reviewing for a conference or organising a conference, I will always try and drag my students into being involved in that, for two reasons, partly because they need that experience themselves and partly because it's less work for me if I can offload a bit of it onto them!... You involve them in the conversations and discussions and decision-making so they can understand... if you're a program chair how did you, given all these disparate views on a single paper, how do you come up with the ones that you are going to accept? So, I think it's useful for them to be observers... to gain that experience because one day they are going to have to do these things. I think it's part of my job to train them in as many aspects of being a researcher as I can. Because I am not actually engaged in teaching, I don't tend to extend my obligation to making them a good university teacher but I suspect there are some people who are more involved in university teaching that probably do... I see my responsibility as making them good researchers, not necessarily as making them good academics, because I've spent most of my working life not as an academic but as a researcher and so I probably bring a slightly different mindset to the destination of my students than I think perhaps the average academic does. The average academic tends to think that their students will go into academia like themselves, for better or for worse... My own mindset tends to be about turning out a researcher. Whether they research in an academic role or another role, I want them to be a researcher. (16, female, experienced)

D5 ESTABLISHING A RELATIONSHIP

I think the first thing is to establish a relationship with the student. To come to get to know them, I think that's the first thing I try to do. Actually, before that, you first get approached. What I said was assuming that you are actually going to start. So, a student approaches you and they want to do a PhD. So, you have an initial talk. I always tell them that I do not give them the problem. So, they have to come with the problem and it has to be something that they are passionate enough about. This is all contextualised with my background and expertise, but I think it's important that they come with the question. The reason I say that is because they have to run that project for three years. They are going to have high points and low points, and it is not up to me to tell them, "You do this." It's also a wonderful opportunity in your life -- I appreciated mine. You have three or four years to actually explore this space and it's a wonderful time to learn things. Later you often don't have the time to deepen yourself in these things any more. Out of the wonderful experience I had, I'd like to at least try to provide the environment for students to have the same sort of experience. So, they should come with the question, that's the first. The second thing is to build a relationship with them, a human relationship. In a way, it's like having a girlfriend or a boyfriend for three years, because it's quite a close relationship. It's not just an intellectual one, there are other dimensions to it. Of course, the intellectual one is primary but there are other dimensions. Through that, through forming a relationship, you can build up an awareness not only of them but of the process. There are two people involved. The awareness of them is about trying to identify their strengths and their weaknesses and really the supervision is, in the context of the problem, trying to allow the strengths of the student to be deployed as much as possible while being mindful of the weaknesses or doing things to bolster the weaknesses.

Also, in each student I find there are weaknesses in myself, so there is a learning process and it's not a one-way street. I have always found that PhD supervision is not a one-way street. And that learning of the weaknesses is always context sensitive according to the student and that cuts across, not only weaknesses in your knowledge of the topic which is the intellectual dimension, but also in terms of dealing with another human being. So, in summary, it's about forming a substantive human relationship with this awareness aspect to it. That has to be continually refreshed and out of that there is a respect. Some students like to meet regularly and they want to talk a lot, and others you understand that they want to go away and they don't want you to bother them. Then there are others who might go away but they don't come back, so you have to keep checking in the early stages how they are travelling. Some are not very introspective about what's going on or are not assertive enough at least in the early stages until you've got an established relationship which allows communication to happen.

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I just talk. In the initial stages the thing is to have the conversations as open as possible. Shoot the breeze, really. The intellectual stuff is often the road into it because they've learnt things and you've got things so you talk around the topic. But that is really just the way in to try to form this substantive relationship. To be honest, it doesn't always work. With one student I felt as though I just couldn't connect with them but for all the others it has worked. (I16, male, experienced)

E. TECHNOLOGY SUPERVISORS' STRATEGIES

E1 WEEKLY READING GROUP

P1: After one year we try to change the students' role. They need to understand that they are the research leader for their project. For this we organize a reading group that we both attend as supervisors. This is to make it a more formal meeting, otherwise students will just think it's an informal one. Because we're both at these meetings most students attend.

P2: They organize weekly meetings by themselves. They call for speakers, organize the topics. Six or seven students are involved

P1: The weekly meetings go for one hour; they are an extra one. The individual meetings continue. And the basic strategic plan here is we want students to be a leader in their research project and then they try to use us. Rather than I give them tasks each week that they have to finish, I say to them, "It's your job to finish your research. To do this you need something. You can ask me if you come across some difficulty. So, you think about how you can use me." That's my basic idea when I talk to the students. "If you are very active you'll know how to use me. Because of my time I can only meet you once a week formally. Of course, if you have a problem you can see me several times in the week but I can't guarantee my time because I have other jobs that I need to do. So think about how you can use me. I supervise not just one student but several students -- sometimes you may need to give me a long time, if you are trying to finish a paper you can't expect me to give feedback within one day, I might need one week or even two weeks. So, you need to think about how you use my time, my knowledge and by experience." Using this strategy, sometimes the students do very well and they become leaders. (I11-1, male, experienced; I11-2, female, experienced)

E2 DIRECTED READING

P2: The first year is very important, especially the first half year, I think. So normally at the very beginning I ask the students to make a plan. I want them to control their time because we have three months before something is due. I ask them to give me a plan, month by month, and the first month week by week. The first month and is normally the literature review. They give me the list of what they are reading and I give them some papers. I control the literature that they are reading to make sure they are on the right track. Even by doing this some students have to ask for an extension because they can't finish. The literature review is okay normally, just the research problem, sometimes they can't understand and we have to discuss and spend much more time on it. So, I think the first six months are quite important. We have to plan carefully for that part. (I11-2, female, experienced)

E3 EXPECTATION MANAGEMENT

P1: We have agreed that we want to bring our research groups closer together... I'm a little bit concerned about this because the other group makes a lot of money and I am not sure how that's going to influence the students in my group, will they start to covet this? And would it influence the things that I have them involved in? Within our own group, we have a full time PostDoc and I am trying to make it clear that I don't want them to spend too much time with their PhD students... And it creates expectations amongst the rest of the group as regards to the amount of time that they should be getting from their supervisors... I think broadly our group gives students more attention than they should get and that's not going to be a good influence as students in your group start to sense that they're not getting sufficient attention. This is expectation management in terms of supervision contact and I think we need to do a better job of managing it. It's happening in a piecemeal way. People spend more time than they should with these students and we need to somehow be consistent in the message that we're conveying to the students with regard to what we expect of them and what they expect of us. (I12-1, male, very experienced)

E4 CREATING COMMUNITIES/NETWORKS

P2: In terms of further approaches, the students appreciate very much the building of a network and we stress very much, "If you're not going to use the benefit of the network you may as well stay at home. If you don't talk to other people, you'd better sit at home and we'll use your desk for better purposes. I want when you come here that you interact and this is obviously a key attraction of this opportunity." I'm reading this book that talks about why people are successful and talks about talent, hard work and being at the right place at the right time. There's nothing I can do about genetics and talent, we can enforce hard work, and what we try to do is provide them with the best opportunity to do the work. (I12-2, male, experienced)

E5 QUARTERLY PRESENTATIONS

P2: Talking about pressure, we have established quarterly meetings where a PhD student has to present. They get half an hour, 15 minutes presentation, 15 minutes conversation. What we are working on is that every academic in the room has to sign off this performance has been achieved. The idea is that every quarter the students demonstrate progress, or there might be reasons why they've struggled with progress -- they had teaching or someone was sick. But every quarter every academic in the room has to evaluate every presentation and we can identify early students who are struggling. So, I think it's very much the idea of working on a highly relevant topic that gives you satisfaction, creates momentum and an ongoing desire to do something useful, stressing that they benefit from the group. To a certain extent I have to fine tune milestones. And make sure that the supervisor does not become the critical bottleneck. (I12-2, male, experienced)

E6 STUDENTS TAKING RESPONSIBILITY FOR DECISIONS

P1: What I have been trying recently, is trying to get them to own their research and I've been trying various tricks to make that happen. Recently I keep saying to them, "Why in the world are you doing this?"

I want them to stop from moment and think. I try to get them to use some common sense when they think about things and they don't do that often enough. They think it's some kind of a black art and there is some black magic approach. So, I often ask them, "What do you think?"

Some of them have industry sponsors either sponsoring research or as a source of evidence for the research and I basically said to them, "It is your responsibility to ensure that this sponsor organization gets value for what you are doing." We've got this impact tool and approach, and we are working hard to extend its generalizability and to demonstrate its ability. If it doesn't give results that have value to practice then I want to dump it and move on to something else. I'm trying to impress upon them that if organizations that have a stake in it are not satisfied, that it is the students' fault. You need to take ownership and when you're asking yourself questions like, "Should I do it this way? Should I do another pilot?" You need to ask yourself, "How is this going to help you in your goal of ensuring that this company is going to get value from this research activity?" I'm trying to get them to think: from that perspective, what do you think about doing another pilot, is it worthwhile? Well, what are the costs? Then they start to think about the costs and benefits and they start to weigh these things up and take it a bit more seriously because up until then they're just looking for me to tell them what to do next and explain why.

P2: I think you can package this up as learning to satisfy different stakeholders. They learn how to satisfy us, there's peer pressure, when you go to a commercial or to an academic event that you learn what buttons to press, that you are able to sell the same core to a very different audience in a very different language, to understand what are the expectations of the audience and what buttons to press for what audience. This is why I try to send them to as many events as possible to present their work. (I12-1, male, very experienced; I12-2, male, experienced)

E7 MATCHING THE RESEARCH EXPERIENCE TO THE STUDENT'S PATH

P1: I used to think, I'm not too sure how I feel about this any more, I talked about Maister's practice area continuum. He is a consultant to consultants, he wrote a book about how to manage professional service. He talks about big brains, grey hair and procedural consulting type work and how practice areas tend to move along that continuum. They start out as a big brains problem, as we gain experience with them clients want people who have experience with a similar problem, and gradually we develop programmatic solutions and move along that continuum. The importance is in aligning the business with these practice areas and recognizing when they are moving because they require different kinds of skills and capabilities. My thinking is maybe we can do the same thing with research. We can think of big brains problems, which are discovery grant applications, we can think of more procedural kinds of work where we are leveraging existing knowledge, take an instrument to develop it in another language, address a few gaps that we have identified, it's more systematic, more predictable, lower risk and we try to align the student to the kind of research they do, based on their capabilities and their career aspirations. So, I still think it's possible that at the end of the day the examiners aren't interested in which of those was pursued. They want to look at the contribution to knowledge, and that's it. And typically we do too, so we tend not to talk about aligning things and having different expectations as result. Ultimately, we have the same expectation -- we want them to publish in a journal. I suggest however that this is important and I often have conversations with students about what they want in terms of a career and we try to somehow take that into consideration in devising their programme of activities. A student has recently informed me, fairly late in the game, that they want to pursue a consulting career. So I want to try to ensure that they have the necessary breadth and range of understanding in order that they can interact with practitioners, not just go deep into esoteric academic topics but rather ensure that they know the means of evaluation that are used in practice and then emphasize that in the thesis. We can ideally tailor the student's experience to some degree, in the light of their career aspirations.

P2: I think this is a very important point, that we understand whether they want an academic career or not. That means that they need different learning experiences. There is still common ground, they need a PhD that is good enough in the eyes of an external examiner. I would add project management overall as something that they should learn, to think in terms of milestones, to take 3 years and decompose them into smaller chunks that are realistic, challenging enough, that they can map expectations against resources.

P1: If they are planning to become academics then we need to try to facilitate their experience of tutoring and lecturing, if at all possible. (I12-1, male, very experienced; I12-2, male, experienced)

E8 THE STUDENT LEARNING CIRCLE STRATEGY

The general approach I use, particularly with our students at the moment, is trying to get them involved in the... [student learning circle] group so that they are discussing things with other students through various stages of the PhD or Masters journey... through the [student learning circle] process getting feedback from other students.

I'm a real admirer of the [student learning circle] program, I must admit. Even though they're not necessarily doing the same method, I think the students can see what the other students are going through. The students are not unintelligent. It's a research partnership, it's not a student-teacher relationship in the same way it is as an undergraduate student. I've learned an awful lot from PhD students and from Masters students. Some of the suggestions you hear in [the student learning circle] from the so-called 'students' are excellent. So, I learn a lot from the students themselves. (I8, female, experienced)

E9 REGULAR MEETINGS

In terms of practice, I expect to see them every week, I accept that occasionally they won't turn up because they have been ill and sometimes if they email me and say, "I haven't got anything done and I don't see any point in wasting your time and mine", I say, "Fine". I always save emails, though, if they say they are not turning up... I've never had a lot of issue with students just not turning up without saying something... I file those emails just in case it becomes a serious pattern of behaviour, that I can go back and have a look and see what's being said... but most of the students I've had have been reasonably diligent about attending... We normally plan to meet for about an hour, although I tend to try not to schedule anything for the following half hour, as I find often discussions do run over. I often have the associate supervisor present, that may be in part because my partner in crime works in another organisation but supervises a number of my students with me... I always have an understanding with students that if I've got other meetings and can't make the meeting time, and it's not trivial to reschedule in my diary... then they just see the associate supervisor... and so generally between us we tend to ensure consistent supervision. (I6, female, experienced)

F. SUPERVISORY ENVIRONMENT

F1 NO RESEARCH BUDGET

What also helps, of course, are resources. This is also what impedes us because we don't really have control in the faculty over the budget. Everything you need, you've got to put your hand out. You can't go and order stuff. You can't prioritise how the research budget will be spent. I would like to see a bottom-line budget that the supervisor manages, so the supervisor can decide which conferences, if at all, should be attempted. For example, why should a PhD student go internationally, is it really necessary? You can go to three national conferences for that sort of expense, probably four. For some students it may be sufficient to send them to one or two conferences nationally and then submit to a journal and then maybe spend two or three thousand dollars on equipment. So, what impedes research in IT is the fact that we don't have a research budget... So, first of all I want control over the budget... number two I want the budget to be genuinely determined on the basis of need rather than on a fixed assumption that all students are equal.

.....

you're not only up against bureaucracy but you're also up against people who don't really understand what you need. So, you always have to justify your judgement and this is a problem. Infrastructure – this is probably the biggest problem we face as far as what stops us doing research, we have no money, that's what stops us. And it's not much. A PhD student gets five thousand dollars for travel and gets a little bit of equipment, fifteen hundred dollars worth of equipment maybe, for the three years. The supervisor gets travel money and gets the equipment, which is exactly what the student gets, over the three years. The staff member you're paying one hundred thousand dollars a year, if they're here for good, you can really expect them to carry the research forward, the legacy, and you give them what you give a student who is here and gone... I get what my students get... all I get is more travel. I sometimes go twice a year internationally if I have a good reason. Most people don't – they go only once... Pick any senior lecturer... have a look at how much we pay them every year and what we expect from them, then ask what research support we give them – none!...

If I had a budget, if they said, "Here is three thousand dollars to spend on your research." I'd get the receipts, I don't mind still getting the signature of the Head of School, at least they have to trust my judgment that this is how I want to spend the money and I'm happy to write down why I need it, what I need it for... but it should be a control function, not an approval function. They should be the auditor, not the person making the decision. I should make the decision, they should audit it. It's the other way around here. Everything you ask for they control... and I think this stops us doing research... The kinds of projects I offer students is completely determined by the kind of... If you put it in perspective... if you gave every researcher three thousand dollars a year and said, "OK you can use this for research only" and you can have auditing... then you could start doing stuff that normally you wouldn't do... I think that if you give every staff member five thousand dollars a year... you can do so much with that sort of money, that at the moment we couldn't even contemplate, but you just can't get your hands on the stuff. (I1, male, experienced)

F2 NO FUNDING

P2: Now we only have the ARC grants that we can apply for. Student scholarships are also a problem. Sometimes we have good students but we cannot find scholarships for them.

P1: Sometimes we need research assistance for some program. If you ask a student to do the whole program it takes a long time. QUT asks students to finish the programme in three years, this is very challenging. Because for IT we need testing, experiments, working on data collection, developing a method, analysis, statistics. The whole process needs a long time. For one student to finish all of it is sometimes impossible. Usually we have several PhD students doing the same project, using the same data, and this can save some time.

P2: So, we need some internal funding. We have some project proposals not big enough to get an ARC grant but that is the only resource currently. If we had internal funding then we could apply there.

P1: Before, QUT had internal grants that were not only for ECRs.

P2: And the faculty also had seeding grants. Not very big, but still helpful. You could have a low-level assistant just doing programming. (I11-1, male, experienced; I11-2, female, experienced)

F3 POOR WORKLOAD ALLOCATION

Our workload allocation is a pain -- if you have one student you get the same number of half days per year as you do if you have five students. If you go to six, it jumps up. And then it stays the same until you get to nine or ten. So, that's a bit ridiculous. So, in practice the allocation does not work. There is no demarcation between the principal and associate supervision and no difference according to the percentage of supervision. That needs to work better. The undergraduate teaching calculation is very precise, according to the number of students, what kind of teaching, whether you've done it before. That is very different. (I18, female, no completions)

The workload is very heavy. We hope in the future it will be better. There are many changes -- the unit, the teaching group, the faculty structure. We hope there will be less teaching workload to give more people time to research. Teaching is very important, we understand, but for long-term development research is vitally important for the university because most people talk about a good university in terms of their research achievement rather than their teaching. That is the usual standard for a university. Time is important, we need time. PhDs are quite important for a University - they are an important resource, to produce a good research student. The active staff cannot produce too much, so we have to use the PhD students, we have to give them good supervision and a good environment. (I11-1, male, experienced)

F4 NO DEDICATED LABORATORY SPACE

What makes it difficult in my role as supervisor here at QUT in particular is the fact that I do not have a fully established laboratory for myself and my colleagues. This is something that is really critical because my students have to jump from one lab to another to do different things and this makes them lose a lot of time. There is something I want to get off my chest: if you want to have good research you have to provide good infrastructure, not only buildings and offices, you need to provide laboratories and you need to provide a laboratory for each group in which the group can have its own instruments, materials and everything. It is very difficult to perform scientific research using common laboratories because it's something that makes you lose a lot of time because you are never the owner of the instrument that you are using, this means that the instrument can be broken at any time and you don't know why and you don't know who it was that broke the instrument...

So, this is very important to have an established, long-term lab... this is difficult to get here because of historical reasons - the university is very young, there are no established groups and to build up a group you need now days a lot of money and to get this money you need to apply for funds but the funds are usually given to the ones that have the higher track record and the higher track records are in the groups that are already established, and so on... And this is my concern for having a fully established HDR strand in QUT. If you want to have higher degree research students you need to have labs and you need to have... established groups that have worked for a long time in that area and have all the instrumentation, because the competition is very harsh in the world and all the groups around that produce good publications and good science and good engineering have good laboratories with good instruments. It is very crucial to have the facilities and the background.

On the other side, having common laboratories could be an advantage in the sense that some instrumentation of common use like electromicroscopes are used much better if there is an expert to whom you can relate to get the knowledge you need and to quickly produce your work. This is okay for a certain kind of research.

For world-class top-notch research what you want to do is something new, you cannot rely only on those instruments, you have to rely on an instrument that you build up or you build up in a laboratory and you put together in a certain way to produce something that is completely new. (I4, male, experienced)

F5 POOR TECHNICAL SUPPORT

P1: ... technicians frequently need to talk to us. Sometimes we need a high level of control but currently the technicians who come here don't know what to do.

P2: This is very bad. Not just for the students, but for the staff as well. If you have a problem with your machine it takes a long time to get it fixed.

P1: Sometimes the technician comes in and says, "I don't know what to do. I just set things up." They can't provide any service. It'd be better if we had our own professional technicians, rather than it all goes to the university. In this case, we could help the students frequently to set up systems, otherwise they have to do it themselves and it takes a long time. It is very bad here compared with the USA and Japan. In the USA they have software engineers to set up systems who are quite different to the student. This is why they can produce high-level work, not because they are much more clever but because they have good infrastructure. In Japan each professor has their own lab and they have a budget to buy equipment. Students set up their own software in the lab in a distributed environment and they can test different things.

P2: The environment is getting worse here. There are many students in one, big lab. Because of the specific situation we can't solve this problem but it does affect the quality of the work. We just hope that the university will allocate some money in this area. (I11-1, male, experienced; I11-2, female, experienced)

F6 LACK OF FEEDBACK

I think we're measured on some fairly blunt instruments with our role. One is how many papers we produce, one is how many completions we produce. It's obvious that our role is being measured but quality-wise it's not the same sort of measurement as for example undergraduate teaching where we have the survey instruments when the students are surveyed. But these are not appropriate when you have a sample size of one. You have to ascertain over time your own feedback from the students in terms of how they progress through, where they end up working. So in terms of our role, performance feedback is an interesting challenge. That is, in giving proof to the university in general. With undergraduate teaching you can pull out the survey results but with postgraduate supervision it might be a conversation a student has with somebody else which is the only way you can find out what the students are thinking in terms of your performance. So, you have to read between the lines and work to try to improve what you do by testing it yourself as you go. Often it's something that happens in the background of your mind. It's important because you want to make sure you're improving over time. (I17, male, experienced)

F7 UNSATISFYING EXAMINATION PROCESS

There is something that I have to say about the process of assessing the PhD. The formal process is okay, the way in which the process is organised is not, for me, from my experience, in my opinion, is not satisfying for the student in the sense that there are different steps. Step one is the presentation of your literature and of the project, about three months after the beginning - this is okay. Now, the confirmation seminar is another good thing because you have to present what you have done until then. Sometimes this confirmation seminar could be a problem because if you had some change of mind... but anyway it is reasonable. Then before the final thesis you have to present another seminar to get the thesis accepted by the faculty, that is not the end of your PhD because the thesis must be sent to external assessors, assessed and this judgment can arrive a year later and is not satisfying for the student. In many nations the end of the PhD is the end of all, in the sense that you send your thesis to be assessed before the final seminar, as happens in France, in Sweden, in Italy, many other countries. But the Australian way of doing it doesn't give the possibility to the student to have a formal acknowledgement of the success of his thoughts because you present your thesis to a little commission in the faculty that says, "Okay, the thesis is good. You can send to the assessor." But maybe the assessor says, "This is all crap." Or the assessor judges the thesis as fantastic but no one knows. The student has no satisfaction for this.

You can give the possibility to the faculty to assess the thesis, then the thesis is sent to some assessors, or maybe you just have your supervisor that gives the okay to send the thesis to the assessors and the assessors could be part from the faculty and part external, and you set up a panel that judges your thesis on the spot. They have to read the thesis beforehand. If the thesis is approved then you can go to the final seminar and at the final seminar you get all the questions and answers but this gives more satisfaction to the student. I don't know why it is not done like this, it is probably a habit that was taken years ago and it is going on...

We had a student that had done a good job, he went to Singapore to finish his thesis because we did not have all the tools we needed, he came back to do the final seminar, the thesis was sent to the assessors and six months later he received the final okay, it's something that is a bit strange, I would say. It does not give satisfaction to the student, it also does not give satisfaction to the supervisor because if you have a good student you would like your good student to be praised also by an external member of a panel, someone who is an expert in the field. (14, male, experienced)

RESOURCES DEVELOPED FROM PROJECT AND AVAILABILITY

A range of resources have been made available from this project to support supervisors in the technology disciplines. These are openly accessible to individuals and groups via the ALTC exchange, and some materials also through QUT e-prints.

The materials are freely available for use and adaptation in workshops and other development programs.

Table 1 Resources developed from the project

Resource type	Title
Papers	1. Bruce, C. & Stoodley, I. (2009) <i>Fellowship plan and conceptual framework</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
	2. Bruce, C., Stoodley, I. & Gasson, S. (2009) <i>A review of the conversations and their content</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
	3. Bruce, C. & Stoodley, I. (2009) <i>A pedagogical framework for the technology disciplines</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
	4. Bruce, C., Bell, J., Gasson, S., Geva, S., Kruger, K., Oloyede, K., O'Shea, P., Stoodley, I., Raymond, K. & Wissler, R. (2009) <i>Summary and recommendations</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
Resources	5. Bruce, C. & Stoodley, I. (2009) <i>Resource for supervisors</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
	6. Bruce, C. & Stoodley, I. (2009) <i>Student resources for the use of supervisors</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
Workshops	7. Bruce, C. & Stoodley, I. (2009) <i>Workshop for supervisors</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.
Cases	8. Bruce, C. & Stoodley, I. (2009) <i>Cases from the technology disciplines</i> . (Towards a pedagogy of supervision in the technology disciplines series.) Brisbane: QUT.