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Learning to Work: Becoming a Research Scientist Through Work Experience Placements [†]

Chris Eames

Centre for Science and Technology Education Research, University of Waikato, Private Bag 3105, Hamilton, New Zealand

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How can students make the transition between academia and the science and technology workplace, and translate their academic learning into practice? Do work experience placements undertaken as part of their educational qualification aid the process of enculturation into the science and technology profession? These questions form the framework for research into learning about working through a cooperative education program at the University of Waikato. This research is a longitudinal study that is following a cohort of students as they pass through their degrees, which include two separate work experience placements. Data gathering is by semi-structured interviewing at various points of their studies and an interpretivist methodology is being employed to analyze the data. Alliances of the data to sociocultural views of learning are being considered. This paper reports on one case study that illustrates the thinking and praxis changes that one participant has undergone as he has progressed through his degree and particularly his work placements. The development of ideas of what it means to do research, and what it means to do science is discussed. The implications for the training of new practitioners and the value of work experience components are explored (*Asia-Pacific Journal of Cooperative Education, 2003, 4(2),7 -15)*.

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There is a belief amongst employers, as evidenced by anecdotal discussions, that with any new graduate they take on there will be a substantial gap between the skills they have gained from their qualification and the skills they will need in the workplace. Further, employers state that graduates will need to undertake substantial training before they become useful.

What if the graduate was able to gain those work skills during work placements as part of their qualification? Would that make their transition from academia into the workplace easier? What does the student learn during their work placements to gain a better understanding of what it means to work in their profession?

There has been increasing recognition over the second half of the 1900s of the value of gaining work skills in an integrated program of learning. This recognition has led to the development of significant numbers of educational programs that incorporate some experience in a relevant workplace. One type of these programs is cooperative education (co-op) where the often espoused aim is to marry the predominantly academic learning within an educational institution with the mainly practical learning of the workplace. These programs form a partnership between a student, an employer and an educational institution, and include periods of time when the student works for the employer in a field relevant to their qualification.

That co-op programs are effective in one sense has been shown by their operational success, showing tangible outcomes. This success has been measured by a steady growth in the number and size of programs across many countries including New Zealand. In addition, research (Auburn, 1972; Eames, Kumar, Rowe & Hitchcock, 1996; Henry, 1978-79; Porter, 1982) has identified positive outcomes and benefits to all parties in these programs. Students are able to apply their academic learning, enhance their career prospects and clarify their career choice;

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Correspondence to: Chris Eames, email: c.eames@waikato.ac.nz

employers gain highly motivated and productive, temporary employees and a preview of potential future staff; and, educational institutions gain enhanced industry links and student attraction.

There is further evidence pointing to key operational outcomes of co-op programs (e.g., Dubick, McNerney & Potts, 1996; Hayes, 1978; Somers, 1995; Wessels & Pumphrey, 1995; Willis, 1980-81). What have been more difficult to ascertain are the educational outcomes and the process of learning in work placements. This difficulty has led to a paucity of knowledge about *learning* in the work placement, due in part to a lack of educational research expertise amongst those who run co-op programs, namely, the co-op practitioners. The inability to place co-op on a sound educational basis through a deficit in theorizing and research has prevented clear recognition of work experience components as learning opportunities. Co-op programs have often been criticized for their inclusion of work experience in an academic program, particularly within the university setting; the criticism based on the premise that the work component is not 'academic'. As Van Gyn, Cutt, Loken and Ricks (1997) point out, the traditional view is that cooperative education is an effective *training* strategy rather than an *educational* strategy.

Previous research into the educational benefits of co-op by practitioners (e.g., Lindenmeyer, 1967; Smith, 1965) has been criticized as being too descriptive or having failed to control for dependent factors such as ability at entry to the program. Most of these studies have attempted to apply quantitative survey techniques and educational achievement instruments which, whilst providing some indicative data, have failed to take into account the diversity of different programs, and of work placements within these programs. They have also tended to concentrate on measuring changes in academic performance as an indicator of educational benefit, rather than the actual learning experiences that can occur during work placements. There is increasing recognition that qualitative methods may reveal a richer vein of data about the students' experiences in the workplace (Coll, 1998).

An understanding of the learning that can occur, how it might occur and who might contribute to this learning would help co-op educators to structure their programs to maximize the learning outcomes and process and to ease that transition from student to working professional. The aim of this research was to understand what and how students learnt doing work placements in science and technology and how they gained an understanding of the workplace practice as a new social and cultural environment for them. As such the research is examining whether sociocultural views of learning could be useful in explaining learning through cooperative education.

Sociocultural Views of Learning

Sociocultural views seek to describe the relationships between human mental functioning, and the cultural, institutional and historical situations in which this functioning occurs (Wertsch, del Rio & Alvarez, 1995). The views have a complex origin that has been ascribed to the field of cultural psychology and the ideas of Vygotsky, (1978).

Vygotsky's contribution is the notion of mediation (Wertsch, 1991). Wertsch (1991) explains that Vygotsky sees higher mental functioning as mediated by tools and signs such as language and artifacts, which are products of sociocultural evolution and situated in a sociocultural context. For example, in a science and technology setting, a cooperative education student could be exposed to terminology and 'jargon' that is unique to their particular workplace or technical discipline that would determine what was learnt about that setting, and how the student would act in response to that learning.

A second notion underpinning sociocultural views of learning is that learning is socially situated, and that it can only be understood within the context in which it occurred (Lave, 1991; Lave & Wenger, 1991; Wenger, 1998). This notion sees learning occurring as a 'newcomer' to a context learns by increasing participation in a community of practice (Lave & Wenger, 1991; Wenger, 1998) and gradually appropriates, through guided shared involvement, the knowledge and skills of the community (Rogoff, 1995). In this case, a co-op student may undertake a form of apprenticeship into the ways of practice of a research scientist by working in a research institute on placement.

Finally, sociocultural views of learning see knowing and understanding (cognition) as being jointly constructed (Salomon & Perkins, 1998) by those interacting in a way that is influenced by social, cultural and historical factors. Cognition becomes distributed (Cole & Engeström, 1997; Pea, 1997) amongst the community in a way that is shared rather than divided up, but that cognition is not always accessible to everyone, all the time (Salomon, 1993). In a co-op placement, a student may find that some individuals hold certain knowledge about the workplace practice, while others do not, yet all members have a sense of their collective endeavor.

The influence of social and cultural factors in learning about working in science and technology offer potential for understanding how and what is learnt about becoming a scientist. Sociocultural views of learning emphasize the significance of context and the focus in this research is the transition between the context of the university and the context of the workplace.

As Billett (1994) pointed out, workplaces are where "learners are able to observe, participate and be guided by experts within an authentic culture of practice" (p. 9). Moreover, Brown, Collins and Duguid (1989) stated that "given the chance to observe and practice in situ the behavior of members of a culture, people pick up relevant jargon, imitate behavior, and gradually start to act in accordance with its norms" (p. 34). This emphasis on culture, or community, of practice provides a foundation for investigation of enculturation of students into science and technology communities of practice.

The Context for the Study

A co-op program in science and technology, the BSc(Technology) degree, has been offered at the University

of Waikato, in Hamilton, New Zealand, since 1974 (Coll, 1996). The program has grown significantly over the past 10 years, from 38 student placements in 1987, to 160 in 2003. Many employers offer student placements each year and many graduates are employed permanently by their placement company upon completion of their degrees. Research has shown that, of graduates available for employment, over 80% had secured positions before completion of their degrees and all graduates had secured positions within six months of completing (Eames & Meech, 1997). As such the program can be viewed as operationally successful.

Nevertheless, the changing face of tertiary education in New Zealand, with increasing competitiveness amongst institutions for students and greater auditing pressure from central government, means that there is a need for co-op programs to be able to justify the inclusion of work experience components and to have a very clear understanding of how they help to prepare the graduates for the workplace.

In addition, the demands of the business sector continue to grow apace and the emphasis is on rapid delivery of service and adaptability to the global marketplace. Employers want graduates who can 'hit the ground running' and make a rapid contribution to productivity. Government and the employment sector will look to support those educational institutions which can deliver such graduates.

This paper provides a case study of one co-op student in a longitudinal study project and his learning on placement about a community of practice of science research in New Zealand.

A Longitudinal Study

The case study is part of a longitudinal project that has examined the perceptions of their learning progress and process of a cohort of students as they passed through their BSc(Technology) degrees at the University of Waikato. The study employed an interpretive methodology and used interviews as the prime vehicle for data collection. All interviews in the main study were conducted one-on-one with the author, were semi-structured, and transcribed verbatim. Analysis was carried out using a coding system according to categories that emerged from the data.

The cohort was selected from all second year students in the BSc(Technology) program. Participation was invited in such a way that a balance was attempted across gender, across subject majors in proportion to the total population, and across a range of industry sectors.

A group of 22 students agreed to participate in the study, 12 males and 10 females. Each participant was interviewed individually on at least four occasions as specified below in Table 1.

In addition five students were selected for more regular interviewing as 'case studies' during their second work placement. This paper provides data from one of those case studies. A participant-approved pseudonym has been used. All interviews were taped and transcribed verbatim and participant validated. Excerpts provided here have been edited lightly for sense. Additionally, students were encouraged to keep journals of these experiences and some data arose from these.

The interviews investigated the learning experiences of the students in their science and technology workplaces, and the integration of these experiences with their learning at university. This paper will focus on how one student perceived his learning about his science research workplace.

Learning to Become a Research Scientist: A Case Study of 'Joe'

Joe was a chemistry major in the BSc(Technology) degree program. In his university-based courses he achieved excellent grades, scoring in the A range (i.e., 80-84%) for all his university courses. He attributed his grade success to hard work, and he gave the impression of being very conscientious, often being seen with hefty textbooks under his arm or ensconced in the library.

Joe is a New Zealander of European descent and was 19 years old when he entered the placement program in his second year of university. He had enrolled at university in the year after finishing his secondary schooling, and had not held any full-time jobs other than summer vacation positions prior to attending university. He had moved to Hamilton, the site of the University of Waikato, from a slightly smaller city not far from Hamilton. His father worked in the trades and had some trade training, while his mother worked as a housewife, and had no tertiary education.

Joe felt that his parents had had no direct influence on his choice of study and career. He attributed his interest in pursuing a career in science to a decision he made at school at the age of 15. He said:

> I sort of went through the process of trying to decide which sort of general area I wanted to get into. So I decided that science was an intriguing area for me and also it was an area where I was likely to get good employment.

Joe felt that he hadn't been particularly influenced by any teachers at school to do science, although he admitted that a particularly good chemistry teacher at school had fired his interest in chemistry. However it was his perception that he had made an independent decision to pursue a science career based on his interest in science and his knowledge at that time of the career opportunities.

Although Joe had chosen a career in science he, like many other students in the study, struggled to explain what science is. Prior to his first placement, whilst in his second year of university study, he compartmentalized science into the various branches that he could recognize such as chemistry and biology. This indicates a view of science that is constrained and controlled by his experiences of learning science couched in the compartments in which science teaching has come to operate, and had left Joe apparently unable to see a commonality that would allow him to explain what 'science' is.

Joe did, however, have a clearer view on the process of science as investigation. He noted:

Table 1
Schedule of interviews

Interview 1	Before beginning first placement, at end of second year of study
Interview 2	Towards the end of the first placement in the workplace
Interview 3	After first placement, before second placement, while in third year of study
Interview 4	During second and final placement in the workplace.

> I see it essentially as a logical process of hypothesis, experimentation and assembling the results and interpretation of those results. Just going through that entire scientific process.

Joe had a view of the experimental practices that for him constituted doing science. He would have been exposed to these practices to varying degrees during the course of his science education at school and at university, and had developed an understanding of experimental science as a process.

Joe's view of technology was again typical of others in the study. Joe saw technology as an application of science:

> Well, technology for me is to take I suppose the knowledge that science generates, the 'how' and the 'why' and looking at how they can be applied to create something, a system or object that can improve the quality of life.

He saw technology as a process that uses scientific knowledge to create something tangible to improve the quality of life. He also saw technology as a process designed to make money, whereas science was not about making money.

In Joe's mind his own interest was to be involved in science that had a technological outcome. He spoke of his view that science and technology had "a symbiotic relationship," and that one could not exist without the other.

These views were given prior to Joe's work placements. As he looked forward to his first placement in a research institute, he admitted to having no idea what it would be like to work there, as he had not experienced it before. He hoped that his placement would help him understand what it could be like:

> I hope that I'll learn, or get a perspective of what it's like to work in a research environment, which is something that I haven't had at this stage and it will help me I think to decide what my future employment course is going to be. Whether I'm going to go, as I am looking at the moment, managing an industry site or to go down maybe the research avenue.

Joe was hoping to get some clarification on his possible career direction through his placements by gaining an understanding of what it may mean to him to work in a particular career. He hoped that his placements would enable him to make the transition between science students and science practitioner. The following sections describe what Joe reported he did learn about working in science and technology in his placements.

A Tale of Two Contexts

Joe had two three-month chemistry work placements over the summers of 1998-99 and 1999-2000. He worked in two different Crown Research Institutes (CRIs) in New Zealand. The CRIs are mainly government-funded and are individually focused on a particular segment of New Zealand science research (e.g., forestry, & agriculture). Inaugurated in 1992, the CRIs compete for funding from the government-based *Public Good Science Fund*, but they are increasingly expected to generate income from private sector investment and commercialization of their science and technology work. Joe was placed within research groups in each CRI and worked as a research assistant, doing experimental work.

At university, Joe had had some practical experience through his laboratory classes. The laboratory exercises that he had done were generally confined to demonstrating principles and particular techniques. Large class sizes and limited equipment often mean that undergraduates such as Joe were seldom given the chance to do practical research. The graduates generally came out of this training with an awareness of what tools are used in science research, but little or no actual experience in using them to do research.

Towards the end of his first placement Joe recognized this difficulty in learning how to research in a university undergraduate program, and the difference between his experiences there and in the workplace:

> At university it's structured, where you're being taught the theory in the lectures and tutorials, and then in the labs it's very controlled skills, they sort of feed you skills, a skill at a time as it were. [In the workplace] it's sort of bringing together all the relevant skills, teaching you how to use different machinery as it becomes necessary, and often you're making leaps forward from what you've learnt at university.

Joe emphasized here the controlled nature of learning skills at university, the feeding of skills, little by little, as opposed to the need-to-know environment that he encountered in the workplace. Through participation in the work of a scientist, Joe was appropriating the skills and knowledge required of him to function in his community of practice. He reported his feeling that immediate application of his skills in the

workplace allowed him to make great progress in his learning.

Joe's second placement had a very applied focus and he was able to discern a difference between the type of research and researchers that he had previously observed at university:

> I'm talking about the sort of technological product development that you get in a sort of an institute, that there's emphasis, at least this group's emphasis towards developing products. In the university we get exposure to people's research interests and most of the people I'm in contact with have more, sort of, I suppose, purist research interests and they're sort of more into pure research with a little bit of applied. But I'm coming into contact here with quite a lot of applied material and I can therefore make the link between the chemistry theory and the technological practice.

Joe felt that the placement was showing him 'theory in action' and giving him direct relevance to his studies. Earlier in the same interview he used the phrase "a sort of real world context which you could never get in a university" when discussing his experience of the workplace. This appears to indicate that Joe believed that the university was not able to teach him about the 'real world' in the way that the workplace can. This would be particularly significant to students like Joe who hold the view that they will soon be entering that real world as a graduate. It was, he believed, the workplace context that gave him an understanding of what it means to research.

Learning How to Research

In his two placements Joe was immersed in scientific research for the first time. As a research assistant he was legitimately able to work alongside science researchers and become involved in the process of their work, albeit as a peripheral participant (Lave & Wenger, 1991). Through being given tasks to do, and his involvement in the science research community, he was able to identify some key learning outcomes. These outcomes included gaining an understanding of how to research, and to practice science. He commented about his first placement:

> It has been very good; it has certainly broadened my horizons of scientific research and has given me a good perspective of how science works in the workplace and also how it's practiced and individual styles.

Joe had noted the existence of individual styles in the practice of science amongst his co-workers. He began to discern that the community that he was on the periphery of was not homogeneous and that there were perhaps different ways to conduct research. He explained what he meant by different styles:

> I'm thinking about the approaches that different people take towards research, and the way in which they set it out and go about it, which does vary from person to person.

By working alongside science researchers Joe had been able to observe a variety of scientific research approaches from which he could develop his understanding of the research process. Through the social interaction of talk Joe learnt about ways to solve the research problems he was encountering. He emphasized the role that historical stories played in helping him understand the research process:

> I suppose the anecdotal stories that your supervisors give you about the sort of, what they've done in the past and the problems that they've encountered and that sort of thing, it helps you to sort of flesh out your idea of the research process and the way people do things.

Joe perceived that this sharing of knowledge by the 'old-timers' about their practice in science was important in his learning of what it means to research. He noted that working alongside his science co-workers and supervisors helped "enormously" to contribute to his knowledge and ability. This can be viewed as an example of distributed cognition, in which the knowledge is shared over the community and passed on to Joe during his membership of the community.

In his second placement he spoke of how he would brainstorm ideas about the research with his supervisor and they would work together on the direction that the work should proceed. Joe would then go back into the laboratory and get technical advice on how to carry out the experiments from his co-workers. He came to understand that in a scientific research community there could exist a distribution of knowledge that had a potentially compartmentalized nature. He noted how the scientists tended to direct the research, apply for funding, and analyze the data, whereas the technical staff were responsible for carrying out the experimental work. Joe could see how each group of workers contributed to the research process.

Joe talked about how the opportunity to practice skills in the workplace that he had originally learnt at university was important to him:

> Well I learned the basic theory through spectroscopy in the second year, in second year chemistry and I was able to expand my knowledge of FTIR [Fourier transform infrared spectroscopy] and NMR [nuclear magnetic resonance spectroscopy], and electrospray, solid state NMR, just through practice and a certain amount of instruction on how to set things up and learning from [my colleague in the laboratory] and yes basically it has just been practice, practice, practice, and that has certainly polished my skills. A year ago I just about didn't know what NMR was and didn't know how to read spectra.

Joe emphasized how the workplace experience had enabled him to 'polish' his skills and expand his knowledge. In this passage he describes how his use of tools (instruments) had mediated an increase in his skills and

knowledge. He also discussed how he had read journal articles (artifacts) to increase his knowledge and had then been able to go and test some of the methods that he had read about, which led him to a better understanding of what they meant.

Joe was adamant that the opportunity to experience doing the experimental research for himself was critical to his understanding of what he was doing. He noted after his first placement: "Basically I think the principal factor was actually doing it yourself, actually getting out there and doing the research yourself and then encountering the problems for yourself."

This experience with engaging with problems gave Joe a clearer idea about the nature of research and the fluidity of its direction. He commented:

> It's sort of taught me that often the research can't be fully structured, like right from the beginning, with contingency factors having to be allowed for and often interesting sort of tangents might arise that are worth pursuing or can be pursued later. So it is sort of like a spider's web, if you like, of ideas and knowledge that have been generated.

It is difficult to imagine how a student such as Joe could come to this understanding without being immersed in a research situation. No amount of tuition and description could substitute for a personal discovery of the intricacies of the research process.

In learning to research Joe encountered in his first placement a cultural aspect to science that he had not been exposed to at university before. He noted:

> I have found that it is quite common, at least in the group I am working in, to experiment quite loosely, that is, 'dabble', to try and see if different ideas will work before doing more structured analysis. Sometimes this trial and error process forms the basis for the experimentation and can throw up interesting results or new ideas that can be further investigated. This sort of work is helping to develop my investigative and experimental skills and is very interesting.

For the first time Joe found himself in an environment where there were no clear end-points, no well-known answers to laboratory experiments performed by years of student classes. The exposure during his degree to this way of working provided Joe with a chance to find out how he felt towards research before he committed himself to a career. It has the potential to be greatly disturbing and almost frightening as the comforting boundaries of classroom science are removed. In Joe's case it was a great stimulus as he remarked in his journal towards the end of his first placement:

> These new experiences have given me a greater appreciation of the research/experimentation process in action first hand and have generated in me a sense of excitement and a great deal of enthusiasm and interest, as I am at the centre of this research process.

However, not all went smoothly for Joe, and the 'reality check' was quite revealing for him. His placements also taught him about the frustration of research: "Research seldom goes smoothly and that often there's a lot of frustration and things don't sort of go well or turn out the way you'd like."

Joe expressed surprise and annoyance with the frustration in his research work not going to plan. He added:

> It was annoying. I guess it was slightly surprising. I guess I would have liked things to have gone a bit more smoothly because when you're at university, the little labs are quite structured and they've been done before so things tend to go quite smoothly because of that.

This disturbance in thinking had created a perceptual change for Joe about how research proceeds. Having previously been exposed only to university laboratory work that proceeded as the class manual dictated, and 'incorrect and unexplainable' results had been rationalized by the instructor in terms of operator error, this new experience did not fit with Joe's construct of what happened during research experimentation. Interestingly, at the end of his second placement he had developed strategies to cope with the research not progressing as expected:

> When it doesn't go smoothly your plans tend to collapse a lot, or part of them do, and you sort of have just got to wipe those away and re-form a set of new plans to take you on. I always find that you have to think about 'what can I do next to further the research, keep the ball rolling', because it's easy to get bogged down if things don't go right, trying to think of ways to get the ball rolling towards your goal.

This type of experiential learning, where Joe, in conjunction with his supervising scientist, was able to experiment, obtain results, reflect on those results, fit those results into previous knowledge and develop a plan for moving forward with further experimentation, has some synergy with Kolb's *Learning Cycle* (Kolb, 1984). This type of learning within the sociocultural context of the research institution, in which the student works alongside practicing scientists and gradually appropriates their practice holds clear promise to explain how learning occurs within cooperative education work placements. The experiences that Joe had, led him to develop a view of what it means to practice in science and become a research scientist.

Becoming a Research Scientist

Over the course of his degree and his work placements Joe felt that he had come to an understanding of what it means to practice research science. He had been able to identify some key characteristics of the profession and had perceived that he had been enculturated into its community.

In his first placement Joe felt that he developed the skill of thinking like a scientist through doing his work. He wrote in his journal:

> When problems have arisen I have had to recognize and remedy them and have discovered where potential pitfalls lie, for example, pH adjustment of a solution, being 'canny' about where to stop addition of acid or base to get the right pH, and where in a synthesis it is safe to stop and store the product and which solutions/mixtures to retain and which to discard. In short I am developing the 'knack' of thinking in the way of experienced scientists/chemists when conducting an experiment/project.

Through his experience at work, Joe had come to understand that there are 'knacks or 'tricks' that could be learned which would allow him to think like a scientist. When questioned about how he had come to know that was how scientists think, he drew on a number of sources of inspiration:

> I guess it was through asking questions, through my past experience at university as well, and I guess it was sort of finding it out for myself as I went and sort of worked out what were the best ways of approaching my projects.

Joe gave credit for his understanding of how scientists think to his learning at university, and to both the opportunity to learn from his colleagues at work and from his own practice.

In his second placement Joe could see how he had developed as a science student from his first placement and his university courses:

> I would have to say I think I've learnt more here [in my second placement] than I learnt at [my first placement]. I think the standard of my work here has gone up from what it was at [my first placement], basically through my experience there and in the intervening year at university, so I've been pleased I actually seem to be contributing more ideas, doing more towards the research than I was at [my first placement]. [In my first placement] I guess I was a little wet behind the ears and they had to guide me a little bit more but here I can sort of say, no, no, I think this and this and these are more my ideas and they contribute theirs and we come out with a result we can use.

Joe talked about how he and his supervisor in his second placement would regularly discuss progress in the research and about how he felt more and more confident to contribute to the discussions due to his increasing knowledge and experience.

He could see the part his placements had played in his learning to work in science. He greatly valued his university education that he felt had given him the theoretical understanding of what he was applying in the workplace. But his placements had delivered a broader recognition of the application of his university learning to the 'real world'. He commented:

> I can see here the way in which the work that I've learnt in the university has been employed, and I can see the way people think and the way people develop products and ideas and technologies in a sort of real world context, which is something you could never get at university, and I think its given me a very wide perspective on things, even though I've just been in CRIs, it's still given me a good idea of how science and technology is being applied. It's been essential to my whole learning development; it's highly recommendable to anybody in science and technology.

Joe also believed that he had learnt that one had to be passionate about the research in order to work in science:

> I think first of all you need a passion for what you are doing, an interest in the project that you are doing. I think that's important in any job, but particularly in science because things go wrong so often, almost 99% of the time it seems, so you've got to have the zest to just pick yourself up and carry on to the next avenue and try and explore that. And I guess it's that 1% of times when things go really well that makes it all worthwhile.

Joe had come to understand that science research had a particular character that required of its community a high level of interest to overcome the disappointments inherent in the process of research. It is perhaps only through the opportunity to work in a research situation that a student would come to know whether they are suited to that type of environment.

In his second placement Joe had reached a conclusion about what it meant to be a good researcher:

> I think a good researcher is a person who is flexible and is able to adopt new paths readily and quickly when they need to, but at the same time can work out how to most efficiently use that time within that environment of uncertainty. To try and judge which avenues of investigation will reveal the best results the quickest.

Through his experiences of participating in science and technology research practice, Joe had been able to formulate a conception of the character of a good researcher. From working alongside science researchers who demonstrated their practice in, he had observed a variety of approaches, and from his own experience he had found his skill as a practitioner developing and his ability to contribute to the research progress increasing. He felt that the ability to use judgment was the researcher's key skill, as he described:

> A combination of experience, practice, having done that sort of research before, I think it develops some sort of judgment in what's likely to be a productive way to pursue the project.

By the end of his second placement Joe understood that he had learnt a lot about judgment in the science research process and felt that he had gone some way to developing into a science researcher.

The opportunity that Joe had to experience science research 'in action' left him in doubt as to the career

direction he was taking. These final words on the value he placed on his placements come from Joe's writing about his first placement. He wrote:

> This placement has been a wonderful experience which has equipped me with a whole range of new experimental, analytical and social skills that will be of great help to me in future employment. It has also helped to stoke the fires of interest and enthusiasm within me for chemistry and I will enter this year with a much clearer perception of chemistry in action in the workplace.

Discussion and Implications

Joe felt that his experiences in his work placements had given him a clear insight into what it is like to practice as a science researcher. After a total of six months work in two different science research institutes, Joe reported significant learning in his placements.

He perceived that he had enhanced and expanded on skills and knowledge gained at university. He noted the difference in learning approaches between university and the workplace, the latter being driven by a need-to-know and having immediate application to work.

Through his experiences of science research he came to understand that the direction of research changes as new data becomes available and problems are encountered. He experienced the excitement and the frustration of the research process, and how knowledge and ideas are shared amongst the scientific community. He observed how the community could be divided into participants who have different roles, each contributing to the practice of research science. As Brown, Collins and Duguid (1989) noted, it gave Joe a chance to learn the behavior of a researcher and to develop a way of working and thinking in accordance with a research culture.

Finally he began to come to understand what it means to work as a science researcher. He identified the characteristics of a good researcher and developed a perception of whether he could pursue a science research career. At the time of writing Joe had just completed his masters degree in chemistry research, and embarked on a PhD in the same area. It is impossible to say whether Joe would have taken this career route had he not undertaken the work placements that he has, but Joe is adamant that his work placements experiences gave him a much clearer idea of what to expect, enabling him to make a more informed decision.

This case study has shown that sociocultural views of learning can be a useful means to help us understand that students learn about science and technology through co-op work placements. This learning is different from that undertaken in an academic setting such as a university but is equally valid in providing a view of what it means to practice in science and technology. As science and technology educators we should acknowledge that work placements in a structured educational program can provide significant learning opportunities to the student. In placing students into science and technology workplaces, we should take care to orientate them to the social and cultural elements that can contribute to their learning, which may differ from what they have experienced in the classroom. Finally we should encourage all students to look for opportunities to engage in work placements, so that they can better understand how to make the transition from student into practitioner.

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