

Evaluating the development of science research skills in work-integrated learning through the use of workplace science tools

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Concept understanding, the development of analytical skills and a research mind set are explored through the use of academic tools common in a tertiary science education and relevant work-integrated learning (WIL) experiences. The use and development of the tools; laboratory book, technical report, and literature review are examined by way of semi-structured interviews with graduate students, and comparing undergraduate students who had completed science work placements and those who had not. Students who had experienced work placements developed a professional and sophisticated understanding of the use of the tools, science concepts and the research process prior to graduating, hence were better prepared for graduate study or moving onto a professional science arena. Non-WIL graduate students also developed these skills, but after they had already embarked on research degrees. This research shows that academic tools specific to science workplaces can uncover discrepancies between what science research skills students have at tertiary level, and what is required of them in a professional situation. *Asia-Pacific Journal of Cooperative Education*, 2013, 14(4), 233-249

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The transition between higher education academic learning and the application of that learning in the workplace is not well understood but has been actively researched for some time (see Smith, 2003 for an overview). In this work, we look at the development of the individual as a science researcher, their integration into the culture of professional science using technical tools that are common to both the tertiary science education system, and the science workplace; a laboratory book, a technical report and a literature review.

Tertiary science education endeavors to produce graduates who are well-grounded in theory, innovative thinkers, problem solvers, creative scientists and researchers (Rice, Thomas, & O'Toole, 2009) and there is increasingly more emphasis on graduate skill acquisition to increase their employability (Bridgstock, 2009; Green, Hammer, & Star, 2009). However, financial and time constraints in university teaching laboratories mean that students' experience is limited and exploration is discouraged. Experimental work is set up prior to students arriving, methods are well described and students simply 'follow the recipe' to complete their tasks. The experiments are well trialed and the end result is known before the start of the work. In a research environment this is not the case and there is a distinct change required in students' thinking in order for them to become competent researchers. The change is dramatic as the students move from carefully planned and reliable work that provides expected end results, to a 'try it, see what happens, then try another avenue' if the results are not leading towards an answer. There is a lot of exploration required along with careful analysis that determines the direction the next step that the work will take, and the ever-present possibility that the experiment will not work. The attributes of a good research

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scientist (in this article termed a research mindset) include things like: persistence, resilience, ability to keep in mind the 'end goal', consistency, thoroughness and good analytical skills. The development of analytical skills, and a research mind set in individuals is highly valued by employers and academic research groups as it means group research capabilities can be advanced (for example in Shuman, Besterfield-Scare, & McGourty, 2005).

Work-integrated learning placements, where students are positioned in professional science institutions, may offer different opportunities for tertiary students to develop these highly sought after skills. This paper examines the views of placement and non-placement undergraduate and graduate students and examines how the findings may be used to inform practice in tertiary courses. In the work presented here, we focus on the development of these skills through the use of academic tools common in both tertiary science teaching and the science workplace. The tools described in this research (laboratory books, technical reports and a literature review) need to be used effectively by science students in order to become a working professional in the science arena, and the focus in this work is on the gaining of skills and development of learning, rather than on the tools themselves.

SOCIOCULTURAL LEARNING THEORY

Traditional higher education teaching is generally reported to be a uni-directional transmission of knowledge where one lecturer presents material to many students (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Putnam & Borko, 2009; Wenger, 1998) and is focused on individual competencies (Wenger, 1998). There is a constant tension between the need to pass on facts and concepts to many students and the need to stimulate thought, enhance cognitive performance and to personalize and internalize knowledge for individuals (Huxham, 2005). Sociocultural theory suggests that learning is enhanced when it is not uni-directional (from one lecturer to many students with minimal interaction) but is situated within a community of practice, has some social scaffolding and is supported and mediated by workplace tools and artifacts (Pea, 1993; Putnam & Borko, 2009; Resnick, Saljo, Pontecorvo, & Burge, 1997; Wertsch, 1993) such as basic written instructions. The transmission of knowledge in this way is no longer 'listen, absorb and regurgitate' but becomes a process of learning that is personalized, collaborative and reflective, and promotes problem solving and analysis (Collins, Brown, & Newman, 1989; Wenger, 1998). However, this may be difficult to implement within a traditional system.

New understandings of learning and development were offered when Vygotsky's social development theory was published and had a major influence on modern educational theories and principles (Billett, 2001; Bockarie, 2002; McVee, Kailonnie, & Gavelek, 2005). Among his theories about learning and development, Vygotsky postulates that learning takes place not only individually, but also socially; in other words, we learn from, and with, others (Guile, 2006). Learning and development is influenced by association with groups, society and the culture, norms and 'tools' used by those groups and societies (Billett, 2001; Resnick, Pontecorvo, & Saljo, 1997). Vygotsky theorizes that learning does not necessarily follow a strict path; development then learning, but that the process is more fluid (Guile, 2006) and that using tools, such as language, facilitates learning and enculturates the learner into a 'community'. He also discusses this area of learning as a metaphorical zone, the zone of proximal development, where individuals learn, especially by imitation, "patterns of behavior, vocabulary and ideas which exceed their present level of development" (Smith, 2001). It naturally follows that as students learn and master skills, the tools that mediate

learning also change. Taking vocabulary as an example, the words learned and in daily use as children are vastly different from those in common use at university. Extending the idea of mediating learning and fostering a ‘community’, vocabulary used in science is different from other subject areas creating inclusion in a community as well as exclusion of those who do not use the language tools (Billett, 2001; Wenger, 1998).

Problem solving tools can be technical (e.g. hammer, pipette, software program), psychological or symbolic (signs) such as language and numerical systems, but they are purposeful in mediating both internal and external learning for individuals (Billett, 2001; Rogoff, 1995; Scribner, 1985). Wells (1995) suggests that tools extend human capabilities and can outlive their inventors commonly seen in mechanical inventions, but also in linguistics and numerical systems. Often cultural knowledge and processes extend around tool use, and participation in learning the use and purpose of tools “enables a learner to appropriate that knowledge, transform, and internalize it” (Guile, 2006; Lave, 1991). Billet (2001) suggests that deep learning and enculturation of students utilizes applied tools and the application or the tools themselves may evolve as learning progresses.

DEFINING THE RESEARCH PROCESS

Hodson and Hodson (1998) suggest that scientific enquiry follows five phases: initiation, design and planning, performance, interpretation and finally, reporting and communication.

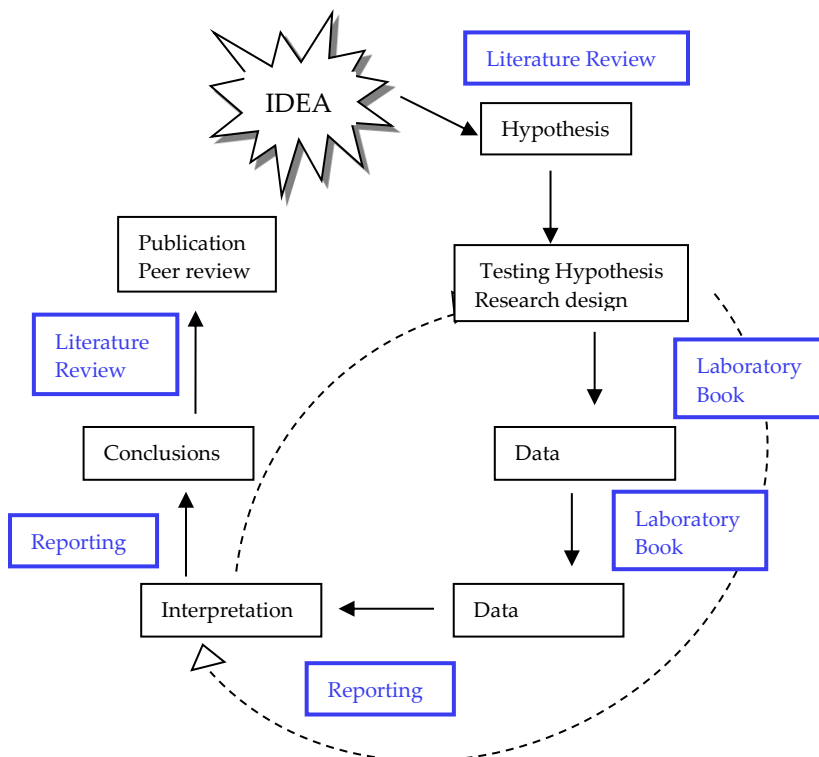


FIGURE 1: Outline of a generic science research process indicating where science tools are used.

An initial idea is followed by the development of an hypothesis, a plan to investigate the question or test the hypothesis is then developed, data is collected and analysis undertaken. If the analysis supports the hypothesis and can be reproduced with the same results it is then able to be published and disseminated for peer review. If the analysis does not support the hypothesis (or supports the 'null' hypothesis), the process is repeated with modifications until a valid result is obtained. Throughout this process various tools and artifacts are used, for example specific language and terminology, and Figure 1 indicates where the tools common in science research (laboratory book, technical report and literature review) are utilized in the research process.

At the tertiary teaching level science students commonly use science tools; laboratory books, research reports and literature reviews, and the use of these tools is also common across the external science environment. WIL students are exposed to the use of these tools in both environments as they move from the tertiary learning community to become embedded within a professional community of practice (a science research group). Our research looks at the development of students' understanding of the use and purpose of these tools, their understanding of the research process, the development of analytical skills and a research mind set.

University studies that include work-integrated learning (WIL) may have placements embedded in the degree structure or running in tandem with traditional tertiary degrees (Zegwaard & Laslett, 2011) which provide an opportunity for students to experience learning from expert practitioners in a workplace (a sociocultural context) while completing a tertiary degree. WIL placements position students inside a community of practice, alongside 'experts' who model types of behavior, and pass on knowledge which is often mediated by the use of specialized tools and artifacts (Hodson & Hodson, 1998; Lave, 1991).

BACKGROUND: DEFINING THE SCIENCE OF TOOLS

Technical Report

A technical report is designed so that information can be extracted easily. A report should contain specific sections although these may be trimmed down or excluded depending on the style of report required. The sections generally included are a statement of the research questions, a review of the literature on the subject area, the methodology used, analysis of the data and conclusions (Hughes & Hayhoe, 2008; Silyn-Roberts, 2002).

Generally in science research, progress of projects is monitored by the researchers submitting reports and giving seminars to update the rest of the team or group. Reports are prepared for the group, management, and often other partners in the projects. Part of the research process is discussion of results and conclusions in seminars, at conferences and in journal publications. Publication in journals opens the research to scrutiny, initially by peer review, followed by the wider science community (Burnett, 2005).

Laboratory Book

Because a major part of studying science is about collecting data it is essential that effective recording systems are used, (i.e., a laboratory book). In order for there to be transparency and repeatability in experimental work it is vital that a good record is kept of the methodology, the actual experimental work, results and in some cases, a verified record for patent purposes. If hypotheses need to be refined or methods changed it is critical that clear

records are kept of changes in experimental protocols and methodology. All these data are recorded in what is commonly termed a laboratory book (Knisley, 2005; Silyn-Roberts, 2002).

Literature Review

When writing scientific reports or publishing science research a literature background is included, known as a literature review (Hart, 1998; Knisley, 2005). Reporting on previous literature relevant to the subject area gives the researcher a comprehensive knowledge of the subject area, and what research developments lead up to the current state of knowledge. Sometimes the literature provides a starting point for the development and refinement of methods for the current work (Hughes & Hayhoe, 2008).

RESEARCH QUESTIONS

Students' use and understanding of the science tools was used as an indication of the development of analytical skills and a research mind set in their users. The following questions were developed to frame the investigations.

1. What was the understanding students had of each of the science tools'?
2. Was their understanding influenced by WIL placements?
3. Have WIL placements had an impact on students' development of 'analytical skills' and a research mind set?
4. Have WIL placements had an impact on students' understanding of the research process?

METHODS

Interviews were around 45 – 60 minutes in length and were semi-structured, using a list of specified questions established before the interviews (Coll & Chapman, 2000; Wiersma & Jurs, 2005). The initial questions had specific wording that was used for each interview. Only after the preliminary interviewee responses was there further exploration of responses and comments (Guba & Lincoln, 1994). Students were asked to explain their 'understanding' of the various terms retrospectively and currently, that is, as undergraduates and pre-WIL-placement, and again as graduate students or post-WIL-placement. While it is noted that retrospective interviews are dismayingly inaccurate (Bernard, Killworth, Kronefeld, & Sailer, 1984; Henry, Moffitt, Caspi, Langley, & Silva, 1994) it was felt that by linking the questions to actual objects and tasks participants' recollections would be more reliable. This was supported by comments from the interviewees such as; 'where you filled in the gaps', 'the booklet to be handed in for a grade' suggest that tasks using laboratory books etc was so commonplace and extended over a long period (3 years minimum) that recollection of their use was likely to be accurate.

The interviews were recorded and then transcribed verbatim. Interviewees were sent a copy of their transcript and were encouraged to respond if they felt their input at the time of interview did not accurately reflect their views. It was also established at the time of interview that if any clarification of comments were needed, interviewees could be approached after the initial interviews. In order to preserve anonymity pseudonyms have been used in these results.

There are inherent difficulties of validity, objectivity and reliability in interpretive/qualitative studies such as the present work where the emphasis is on uncovering perceptions and

understandings of the interviewees (Boumer, 1996; Cohen, Manion, & Morrison, 2000). Although Lincoln and Guba (1985) and Guba (1981) observe that any study, positivist or interpretive has threats to quality, they propose criteria as guides to trustworthiness of qualitative research; *credibility*, *dependability*, and *transferability*.

Credibility is about the focus of the research and how well issues such as the context of the research, the selection of participants and the data collection methods fit with the research focus (Graneheim & Lundman, 2004). While in some studies it is appropriate to have a wide spread of participants, in the present study the participants were carefully selected to maintain sharp focus on the research questions. As a consequence a narrow range of participants were used - all within 2 years of completing an undergraduate degree or graduate degree, and all based at the same university where the same methods and science tools such as those mentioned in the study are used. The selection of participants did cover gender, age, and subject major so all disciplines within the Faculty were represented. In a positivist approach the researcher seeks to be 'outside' the research meaning the data is unencumbered or influenced by researcher involvement (Coll & Chapman, 2000; Healy & Perry, 2000). However, in the present work the researcher is a 'passionate participant' (Guba & Lincoln, 1994; Healy & Perry, 2000) and the principle threat is that of bias. This threat is mitigated here by the use of structure in the interviews and selection of participants described above, the use of participant verification of interview transcriptions, along with negative case analysis (see below). Further mitigation included sending interviewees a copy of their transcript for verification and accuracy of transcription.

Dependability concerns the consistency of data over time. When research extends over a long period of time variation can occur in collection methods, analysis and interpretation (Coll & Chapman, 2000; Graneheim & Lundman, 2004). This research was conducted over a comparatively short period of time (two months) and the research focus covers a single view or perception at that time. The data analysis and interpretation took some time providing opportunities for negative case analysis where the results have been re-analyzed after a lapse of time - attempting to see if initial themes or interpretations were confirmed or refuted by evidence in the data for contrary positions (Coll & Chapman, 2000; Morse, Barrett, Mayan, Olson, & Spiers, 2002). The lack of any evidence in the data for the contrary position (i.e., a negative case) is taken to add credence to the original interpretation. The researcher also sought to address the issue of inter-rater reliability by employing the qualitative equivalent; viz. the use of a disinterested peer who examined interview transcriptions alongside the researchers' interpretations (Guba & Lincoln, 1989). Any lack of convergence was negotiated. This allowed a more objective analysis of the responses and the interpretation in the text.

Transferability concerns 'the extent to which findings can be transferred to other settings or groups' (Polit & Hungler, 1999). Usually in quantitative studies this term is called 'generalizability', and refers to how well the information can be applied in other work - intrinsically linked to sample size and random sampling (Coll & Chapman, 2000). Transferability in qualitative work is linked with the context of the research, the depth and detail of description (a thick description) and methodology, and the depth of interpretation. The onus is then on the reader to decide if the information is applicable to their own circumstances (Coll & Chapman, 2000; Graneheim & Lundman, 2004). The context of the represented work is substantial and well defined with thoughtful description and interpretation of the findings.

Thematic analysis is deemed to be developed in two ways, inductive or deductive. Braun and Clarke (2006) describe inductive analysis as a “process of coding the data without trying to fit it into a pre-existing coding frame, or the researcher’s analytic preconceptions”. Alternatively, deductive analysis is deemed to be more closely linked to the researcher’s analytical interests. Braun and Clarke (2006) suggest that this type of coding, while providing a “less rich description of the data overall”, does provide more detailed analysis of the data. Because the interviews were conducted with semi-structured questions using specific wording, thematic analysis is deemed to be deductive. This enabled detailed and specific information to be extracted and interpreted.

LIMITATIONS OF RESEARCH

There are some limitations to this research that deserve a mention. This work is not claiming to represent all students, but does provide an insight from a relatively small group. We have used information from each discipline taught at the University of Waikato to try and capture the variation or continuity of methods. The work is also limited by time, in that it is not a longitudinal view, but a snapshot of a fairly brief period.

The study is also restricted in its breadth and we have focused on the student perceptions only. There is a wealth of opinion and views that could be explored from the others involved in educating both WIL and non-WIL students but these views have not been included in this work.

The places where most students were employed, Crown Research Institutes, all used written log books, but it is noted that in other companies students may use electronic log books for recording data. In some cases both are used. The electronic systems are more for simply recording data and data analysis, but lab books seem to be for smaller experiments and research projects. The rapid development of technology and electronic information systems means that systems may have changed since the research was conducted, however, this work is based on what was in place in these institutions and companies at the time.

CONTEXT

The research was carried out within the School of Science and Engineering at the University of Waikato. The School of Science and Engineering offer three undergraduate degrees, a 3-year Bachelor of Science [BSc], a 4-year Bachelor of Science (Technology) [BSc(Tech)], and a 4-year Bachelor of Engineering [BE]. The latter two degrees have at least two compulsory work placements in the degree structure; from 9 months up to 12 months for the BSc(Tech) and six months for the BE. At the time of the interviews the BE degree was relatively new at the University of Waikato with a limited number of graduates therefore, interviews were conducted with graduates from the BSc and BSc(Tech) degrees only.

At the time of this research University of Waikato did not make a one year honours degree available. In other institutions this graduate degree is commonly available after students have completed an undergraduate degree and is often considered a bridge between undergraduate work and further study or employment. Graduate students at the University of Waikato may undertake a MSc or MSc(Tech), which is a two year non-WIL Masters degree consisting of academic papers, comprehensive research project and write up. Students who choose to carry on with studies after a Masters degree, can undertake a PhD degree, a pure research degree with a final thesis and oral defense, typically taking about 3 – 5 years.

The WIL experience is split into two placements, one being 3-months beginning at the end of the second year of study, and the second being 6 to 9-month placement at the end of the third year. The WIL placements are embedded in the BSc(Tech) degree and the experience and subsequent assessment must meet the same academic criteria as any other course at undergraduate level. Work placements are varied as students major in different areas and have a range of academic competencies. Placements are typically with government funded research institutions, multinational companies and local government agencies. Less frequently the experience may be based within the university; however it is preferred that students undertake their experience outside of the University. Placement coordinators source the WIL opportunities for students and ensure that the experiences are applicable to their area of study and are appropriately structured to advance student learning.

PARTICIPANTS

The participants used in this research consisted of 18 science students (8 males & 10 females) enrolled in either an MSc or a PhD degree, one having recently completed a Masters degree and working full-time (Table 1).

TABLE 1: Participant characteristics, duration of work placements, and level of current study.

Pseudonym	Gender	1 st placement duration (months)	2 nd placement duration (months)	Discipline ¹	Level of study at time of interviews	Type of employer or institution
Adam	M	3	3	Earth sciences	MSc	Private Company
Warren	M	3	9	Biology	PhD	CRI
Jack	M	3	9	Biology	MSc	Dairy Cooperative
Emma	F	3	3	Biology	PhD	CRI
Karla	F	3	3	Earth sciences	MSc	Australian University
Sophia	F	3	9	Earth sciences	MSc	CRI
Donna	F	3	9	Earth sciences	MSc	CRI
Silvia	F	3	-	Biochemistry	MSc	CRI
Jim	M	3	9	Biochemistry	PhD	CRI
Eleanor	F	3	3	Biology	PhD	CRI
Margaret	F	3	9	MAPE ²	PhD	Public Company
Jacob	M	3	3	Earth sciences	MSc	Public Company
David ⁴	M	-	-	Biology	PhD	University
Nathan ⁴	M	-	-	Biochemistry	MSc	University
Alison ⁴	F	-	-	Biology	MSc	University
Nigel ⁴	M	-	-	Chemistry	PhD	University
Shelley ⁴	F	-	-	Chemistry	MSc	University
Linda ^{3,4}	F	-	-	Chemistry	MSc ³	University

¹ All participants majored in science with either a BSc or BSc(Tech) degree

² Materials and Process Engineering

³ Participant had recently completed her Masters degree and had begun full-time employment.

⁴Participants are non-WIL students undertaking graduate degrees as shown at a tertiary teaching institution.

All of the participants had completed an undergraduate science degree (either a BSc of 3 years duration or BSc(Tech) of four years duration at The University of Waikato and none have undertaken an Honours degree. Twelve of the participants had done placements of varying durations (WIL participants) while six did not have work placements as part of their undergraduate degree (non-WIL participants). The majority (7 out of 12) of WIL students undertook their placements at Crown Research Institutes (CRI). Two students were placed with large national public companies, one with a large private company, one with a large Dairy Cooperative and one with a research unit at an Australian University. All students were at varying stages of completion in their graduate or postgraduate study.

FINDINGS

Technical Report: Pre-placement or Undergraduate Level

All students had a limited idea of what a technical report constituted; format, size, content and value. Most students referred to undergraduate laboratory reports “very short piece of work ... usually to do with lab experiments maybe,” (Sophia) or “might just be questions with answers” (Alison) or simply a piece of work done as a course requirement for assessment “it was something that I had to do in order to complete that task” (Warren).

None of the students mentioned that they had knowledge of a ‘structure’ for a technical report except where this knowledge had been discovered by themselves “I came across a good crib sheet for how to set (technical reports) out and ever since then I’ve stuck to that style as far as what to put in: the abstract, introduction...” (Jacob). Some students were aware that they would be required to write a substantial report based on their placement, described as “some big scary thing that I was going to have to write” (Donna).

Technical Report: Post-Placement and Graduate Level

WIL students had a greater understanding of what a technical report could be. Most described a specified layout but they also realized that technical reports could differ depending on the audience and level of information required “What I wrote was a BSc(Tech) placement report, not something for a manager. You have to write it differently if it’s for a manager than you would if you were just writing a scientific report.” (Jacob). For graduate students who had not undertaken a work placement the understanding of a technical report appears less developed, described by one student; “basically [a report is] just saying what you’ve done, what you’re going to do” (Jim). This rather basic view is likely the response to reporting requirements for funding agencies and external supervisors, “now, I just write the 6 month report – just telling them what I’ve done and what I’m going to do. Like, I keep track of progress as opposed to an actual communication of results” (Shelley).

Technical reports were also seen to overlap with scientific papers, particularly in organizations where a lot of research used to be presented as technical reports rather than published as journal articles: “we quite often used them for looking at what other research papers had been done because we’ve got a lot of the DSIR (a former government research organization – the Department of Scientific and Industrial Research), old reports, that were in the library” (Sylvia).

WIL students commented that the practice of technical report writing through the placements developed important skills for the workplace or graduate degrees: “It set me up pretty well for report writing (for my Masters and PhD)” (Margaret) and provided basic skills and framework for research after placement “I used [my placement report] as a

template and a guide on how to do it. [Otherwise] I would not have been able to really write a report. I would have been quite stuck" (Warren).

For non-WIL students, the development of report writing skills was delayed until near the end of their second year of their Masters (year 6 at university) when the thesis is written "I'm not too experienced in reports. I haven't started writing anything yet, so I guess it will probably be my first test when I start writing my thesis" (Shelley) Understanding of report writing deepens as students progressed through their Masters degree and on to doctoral degrees, "My perception what makes a *complete and good* [original emphasis] report has changed in the sense of content and what parts go where and how they fit together" (David – also year 6 of university) indicating that a fuller understanding of technical report writing still occurs, just later compared to WIL students.

Technical Report: Discussion

Technical report writing for non-WIL students appeared to be poorly understood at undergraduate level. Several circumstances may contribute to this attitude. Firstly, reports are generally short pieces of work (1-5 pages) related to specific academic and laboratory based topics. They are part of the assessment process, and appear to be not recognized by students as technical reports. Secondly, although report writing is taught as part of a specific writing course at this university (and offered at others), not all science students take this course. Thirdly, tutorials are offered on report writing, but are included in the teaching program only when faculty identify a need.

Involvement with non-university stakeholders broadens placement students' report writing experience. Their understanding of the report scope and potential variations in style and content depending on audience requirements is greater than non-WIL graduate students, even those students at PhD level. The results demonstrate that this experience makes students better prepared for participation as responsible professionals in a research environment, and well-prepared for graduate study.

Laboratory Book: Pre-Placement or Undergraduate Level

In a university setting a laboratory book has to fulfill more than one role at an undergraduate level - that of a manual, a teaching and learning tool, and for recording data and scientific experiments. All students expressed similar ideas from their undergraduate years on what a laboratory book was, with the most common response describing it as a book with pages where you "filled in the gaps" (David, Warren, Linda, Eleanor) or a "recipe for doing an experiment" (Margaret) that required little personal input from the student other than recording some results. A laboratory book was also thought to be something "neat and tidy for handing in (for marking)" (Donna) and nine students identified it as requiring some structure such as aims, methods, results and conclusions, along with five students that specified a lab book as used in chemistry undergraduate laboratory exercises University of Waikato (2009). While the role a laboratory book at this level is limited and quite prescribed "taking away a lot of the self-thinking side of learning" (David), it was recognized as a study resource.

Laboratory Book: Post-Placement and Graduate Level

During placements students developed different ideas of what a laboratory book is. The emphasis was no longer on neatness or gaining marks, but on recording often large amounts of data; "Not written up so to speak, it's just basically written down" (Adam). All students

spoke as if the responsibility for the structure within the lab book, determining what information went into it, how much, how often and at what standard rested with them "You've got to decide everything yourself and it's not so well laid out for you any more" (Eleanor).

Several participants reported they had discovered 'the hard way' that recording information accurately, thoroughly and in a timely fashion was invaluable as with the passing of time vital information becomes lost to memory and irretrievable if not well recorded. "You do not remember some of the details in particular so you have the ability to go back to a laboratory book of some kind so that you can retrieve that information accurately and write it up" (Warren). It was also reported by several students (Donna, Warren, Karla, Jacob and Silvia) that it became critical to be organized and the lab book was an excellent tool for this "I'd write the name of the spreadsheet [I'd been using] and where I'd put it in my lab book because there was nothing worse than going through all your files trying to find one little file that you couldn't even remember what you named it" (Donna) and "write everything in your laboratory book because you will forget or you will lose little bits of paper and it's good to have it all in one place when you go to look for them." (Donna).

WIL students also experienced different methods of data recording, that may not have been an actual book, such as, shared computer databases and spreadsheets "There was my lab book, I used to write down lots of stuff in there and then I'd go and access B's huge database and enter more information in there, and then I had another couple of smaller databases on my computer in my office" (Silvia). Although they may not have been using what is commonly understood as a lab book students developed a solid understanding of the importance of good recording "I don't think necessarily I gained any more information about a laboratory book but I did recognize the importance of documenting processes" (Warren).

The development of the laboratory book into something described by participants as "the Bible" (Donna), "my brain" (Eleanor), and "it's my whole life" (Warren) is notable in students who had undertaken a longer placement (usually about 9 months) and had been working on a research project that included analysis and write up.

Well, it's pretty much everything that you do, or think, and it's much more. Obviously if you're doing proper work there might be patents and stuff. It's much more important to be real clear about when you do things, how you do them, exactly what you've done. Especially if you have to go back after a year and start writing it up. (Silvia)

These comments are in contrast to students who did not do research projects during their placements. These students were involved in collecting data, but not involved in the analysis and write up of the results, they "wrote down stuff" (Sophia) but had no real idea how or when the information was used by their employers. Often this is common when students work in routine positions, such as in testing laboratories, where several tests are repeated on every sample that comes in. They are not involved in developing tests, and as students, not involved in interpreting results.

Students who had research based placements, and those at second year Masters level and higher, mention that the lab book was not only for recording data, but their thoughts, ideas and plans:

[I wrote] my thoughts, the possible tacks I would take in approaching a problem, it would always come together with an hypothesis or ideas that needed to be tested,

some methodology, reference to the methodology and then the preliminary results and things like that so I – it was more like a diary, as opposed being strictly following [a layout], just a gathering of results in the lab. It gave a fuller picture (David).

Students also mentioned that research itself evolves, and the lab book can become a tool for reflection, leading to the development of the research aims, "...writing down well enough and precisely enough what I thought I was doing and why I thought I was doing it, but going back and reviewing it all it's not quite what I'm doing any more. So I think a lab book's probably quite important" (Jack).

Laboratory Book: Discussion

Brown, Collins and Duguid (1989) state that it is the "community and its viewpoint, as much as the tool itself, that determines how a tool is used", and this is demonstrated in this research where what is known as a laboratory book at university is a very different thing from a laboratory book in the science research arena. Laboratory books, as shown in this work, developed into a deeply significant tool for all research students, often becoming reflective journals to develop complex research ideas and directions as well as the link between 'raw data' and data recording to analysis and writing. Research students had laboratory books that often evolved into very personal and personalized books. While the process occurred earlier in the career for WIL research students, while on placement (usually Year 4 of university) rather than at graduate level (Years 6 onwards) for non-WIL students there is a clear indication that students' understanding of the research process and the development of real research skills had occurred during their active involvement with science research communities of practice.

Literature Review: Pre-Placement or Undergraduate Level

The understanding of a literature review varies among the interviewees at undergraduate level; most (8 students) knew nothing at all about a 'lit review' while others (6 students) thought they had some idea of what a literature review was. Nigel, Shelley, Margaret and Eleanor described doing background reading for essays where references were primarily textbooks, "we had to write an essay and we had to go and look at books for an earth science essay, but a literature search to me didn't mean searching scientific publications, it meant searching books in the library" (Eleanor), and "I might have once used a paper that I found online or something in an assignment" (Margaret) Nathan, Margaret and Karla thought that a literature review was a review of popular reading books and magazines.

Literature Review: Post-Placement and Graduate Level

Even after placement some students (Adam and Jacob in particular) had not undertaken a substantial literature review as part of their placement report, so were not certain of what it entailed or what the purpose of a literature review was. Others felt that while they had done what they considered was a good literature review at the time, they later realized there was room for further development, "I thought I did a real proper literature review for my report at the time, but I think hindsight and further experience just tells you [it could have been more extensive]" (Jack). Such a realization suggests that further experience within the graduate degree increased their understanding of what a literature review required.

Those that had done a literature review on their placement, and also second year Masters students and PhD students had a very comprehensive understanding of how to go about producing a literature review and what should be included: "if you want to be clued up with

the current scientific knowledge in your particular field you would have to go and read all the papers to know what people have done ... it really just grounds you theoretically... " (Jack) even if what that required may have been slightly exaggerated "reading hundreds and hundreds of journal articles..." (Silvia). The increase in understanding is also shown by the sources used for literature reviews, no longer are the students limited to textbooks, but current relevant knowledge is displayed by the use of journals. Eleanor, in particular, demonstrates a very highly developed use of accessing wider resources and a professional attitude to acquiring knowledge:

It's on-going. You've just got to keep up with it all the time. [I access] all the different journals. I probably set aside half a day a week and just take all the latest journals out. Then a lot of people also email me relevant articles..."

Students also demonstrate increasing awareness of the purpose of a literature review, for example, what is happening in a specific scientific arena "in other areas you get a whole lot of debates so it sort of really brings you up to par with where current scientific understanding and what the debate is in that field at the moment." (Jack)

Literature Review: Discussion

The ability to undertake a literature review appears to have been developed with time and experience, and students' confidence in their knowledge and understanding was directly linked to experience. Pre-WIL students demonstrated, by their use of textbooks as primary literature sources, that there was little understanding of the broader concept behind a literature review, that is, being able to position the current research within the larger, most up to date body of work, yet this understanding of a critical concept of the science research process was comprehensively shown by WIL students who had engaged in research, and most graduates. WIL students have gained the skills prior to graduation and are therefore generally better prepared for graduate studies or moving into a professional science arena.

DISCUSSION AND CONCLUSIONS

The primary role of tertiary institutions is to educate students. This can extend knowledge and understanding for its own sake and perhaps the betterment of society. Tertiary education can also give students a comprehensive knowledge of theory and principles which can be applied in the workplace. It seems from this research, work periods in science research institutions contribute to students work skills, research skills, professionalism and the ease with which they can move into a science working environment.

Grounded in sociocultural and constructivist theory, much research has been done on how to give science students access to authentic activities that enhances their formal education (Brown et al., 1989; McGinn & Roth, 1999). Often this research is specifically for laboratory practices and experiments aimed at secondary school level (Putnam & Borko, 2009), but as can be seen in this work, more is involved than practical work in a science workplace. Many researchers theorize that students learn different skills and learn to use tools differently (Brown et al., 1989; Driver et al., 1994; Hodson & Hodson, 1998) when they become enculturated into a genuine community of practice, and our research lends support to those theories.

Students become enculturated into a community by learning the norms, jargon, and values of that community (Hodson & Hodson, 1998; Lave, 1991; Wells, 1995) and particularly by the use of the tools in common use within that community. In the science community the use of

tools specific to a science workplace such as a technical report, laboratory book and literature review by students demonstrated the development of a research mind set among students and understanding of the research process. From this research it is apparent that there is a disjunction between tool use at university and the workplace. The students interviewed demonstrate that although the tools can be acquired at university undergraduate level, unless they are actively involved in a research community, they are only able to utilize the tools in a limited way (Brown et al., 1989).

Ackerman (1993) challenges the assumption that “writing inevitably leads to learning”, and information gathered about the writing component from this study indicates that students do not develop a deep understanding of science research or the science process from writing within the university system at undergraduate level. The development of these skills is most evident when students have been involved in research projects, and more specifically in the writing up of the research. It is postulated (Broadhead, 1999; Carter, Ferzli, & Wiebe, 2007) that learning is enhanced by writing within a discipline, as would be expected when writing up research projects for placement assessment, and gives students additional benefits. Students are more engaged in the experience of science, they also appear to understand concepts and scientific thinking better (Broadhead, 1999; Carter et al., 2007).

Carter, Ferzli et al.(2007) also link this development of skills and comprehension to the differences between traditional higher education methods and workplace methods. Traditional teaching is often described as teacher-focused, decontextualized and disconnected from ‘doing’, and is seen as not favoring writing within a discipline. Whereas, when in a workplace, teaching and learning is student centered, tasks are in context with what students are doing, and writing becomes a crucial link between theory and action (Broadhead, 1999; Carter et al., 2007). Our study shows that students who had written up research projects as undergraduate placements gained the research skills earlier in their science career, prior to embarking on graduate degrees.

It is worth noting that it is also clear that when students have not specifically undertaken a task, such as a literature review, or been involved with the writing up of a research project no matter what their level of contribution, they tend to have a poor understanding of the task and concepts. Therefore, it is important that when setting learning tasks and assessment items within work placements, these critical skills are included.

It is our contention that experience within a science research culture exposes students to the practice of ‘professional’ science, science researchers and provides an opportunity for students to develop a deeper understanding of the research process and encourages them to develop analytical research skills and a research mind set themselves. This learning is not confined specifically to the workplace, but provides them with skills to move into graduate research and academic careers as well.

It is planned that this, and further research will be used to inform university practices that may minimize the gap between study and work for undergraduate students. A review of what report writing is expected (not necessarily taught) at each level of undergraduate study will provide the base from which a writing program can be developed. Alongside this review a report writing module is being developed. Offered over two years it is planned that the report writing module will itself develop and will build on skills that students have gained in the first level. Thus learning will be more structured, relevant and more closely

aligned to entry-level professional science requirements. Future plans may include a similar study looking at literature reviews and the laboratory book requirements.

The challenges that remain include creating teaching modules that are transferable to other universities and WIL programs. For others, the challenge will be identifying the science tools relevant to a range of workplaces and tailoring degree programs and WIL programs to develop skills that are more closely aligned to those required by non-tertiary organizations.

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