

Writing critically about science: a curriculum structure for animal scientists

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Introduction

Critical scientific writing skills are important generic or transferable skills that are effectively developed in well designed university undergraduate science programs. Preparation and oral defense of a research thesis form a capstone element of degrees that offer an integrated honours program, such as the Bachelor of Animal and Veterinary Biosciences (BAnVetBioSc) offered at The University of Sydney. Recent research shows that the best way to achieve these high quality learning outcomes is through a research-led curriculum. This does more than simply engage students as an audience for research; rather they are active participants, synthesising knowledge as part of a research community (Brew 2006).

The point of departure for planning such a research-led curriculum is to start with the end in mind. This means starting with a clear statement of the learning outcomes, the disciplinary knowledge, personal attributes and generic skills in scientific communication which graduates must reliably demonstrate in a range of different contexts (Biggs and Tang 2007). Students actively construct the necessary knowledge, skills and attitudes (graduate attributes) through active engagement in learning about the discipline. Learning is optimised when students are immersed in authentic, meaningful learning activities that are closely aligned to the tasks they will face after graduation (Ramsden 2003) and where they are guided by timely, constructive feedback and reflection on their progress. Designing learning and assessment tasks that create this environment is a challenge for curriculum co-ordinators and teachers. Implementation is tricky in the large classes of Australian universities (Ramsden 2003) as many authentic research-based learning activities are too staff and resource costly to run. The framework used to guide students into productive learning activity is the key to overcoming these constraints. Students need clarity on where they are heading with their learning, to feel some personal commitment to the goals and sustain steady work on challenging tasks, with staff and peer support (Biggs and Tang 2007). These are the conditions that support conceptual change and deep, lasting learning (Prosser and Trigwell 1999).

Undergraduate students vary in their written communication quality and many require considerable guided practice over several years to develop clear, accurate, scientific writing skills. Consequently, designing a curriculum to develop critical scientific writing means engaging students in writing and reflecting on scientific writing early and often and being clear on the standard of achievement required. Students benefit from a well planned scaffold of learning activities, aligned to learning outcomes and graduate attributes, with teaching support that can be gradually removed as they gain independence (Biggs and Tang 2007). Planning development of critical writing skills can be challenging in a four year degree program that offers subject choice. A semesterised, packed program makes it unlikely that every unit of study will have the time and resources needed to develop scientific writing along with the range of other disciplinary and generic skills that are required. Therefore, whole-of-degree strategies and careful oversight are needed to be certain that no student fails to meet the required standards for critical scientific writing.

This study evaluates the impact of an aligned series of peer assessed tasks in Year 1 to Year 3 on BAnVetBioSc students' experience of learning and readiness for fourth year research projects.



The Faculty context for enhancing students' generic skills in scientific writing

The Faculty of Veterinary Science initiated a program of graduate attribute review and development in animal science following stakeholder feedback and analysis of future career opportunities for graduates in 1999-2001. External stakeholders (employers, graduates and industry) identified concerns about the quality of students' scientific communication and critical writing. Internal stakeholders (staff and students) were concerned about the wide variation in students' preparedness for research thesis writing and presentation in their final year. Unit of Study Evaluations identified that the teaching, goals, generic skills development, workload and assessment were major areas of student concern, consistent with poor perceptions of the learning environment. A previous action research project found that animal science students who perceived that assessment rewarded recall were more likely to adopt surface approaches to learning, with poor quality learning outcomes (Taylor and Hyde 2000). This was consistent with research findings in other university student groups (Prosser and Trigwell 1999) and provided a compelling impetus to curriculum change.

The curriculum has undergone continuous redevelopment since 2000 to better meet the needs of stakeholders and graduates. The aim of the BAnVetBioSc program is to develop graduates with the range of knowledge, skills and attitudes required to contribute to animal production, health and welfare. A strong emphasis has been placed on graduate attribute development, particularly of research related skills because a high proportion of students find employment or further study in research. One of the Graduate Attributes in critical scientific writing is: 'Exercise critical thinking to analyse, evaluate and apply existing information or knowledge, and to synthesise new knowledge within the field of animal science with an awareness of the provisional and constantly developing nature of scientific knowledge'. Learning activities and assessment tasks were designed to support acquisition, sequential development and reflection on research capabilities throughout the curriculum (Table 1 and 2). Much of the responsibility for skill development in writing was placed with the core units undertaken in the first two years, particularly Animal Structure and Function 3A (ASF3A), which is discussed in detail below. Given the central role that assessment and feedback plays in driving the quality and timeliness of student learning effort (Gibbs and Simpson 2005), the written and oral assessments are increasingly complex tasks which require peer assessment and reflection through the program (Table 2), with in-depth development in core units (Table 3).

Staff development was required to ensure that graduate attributes were explicit and thoroughly embedded in teaching, learning and assessment activities. Externally facilitated workshops, curriculum planning and targeted support for writing learning outcomes and grade descriptors helped the teachers to develop new methods for teaching, assessment and grading, based on research in higher education. A wider range of learning activities and assessments was planned, including peer assessment (changes in Animal Science 2 described in Ramsden 2003). Workload for staff and students was managed with faculty policy limiting assessment to 3 items or less with a maximum of 3-6,000 words or 3 hours of testing time in each unit.

Peer assessment was included throughout the course (Table 2) because it adds value and impact to assessment tasks. It is most effective when students are engaged actively as participants in planning, defining criteria and providing feedback on assessment (Falchikov 2006). It can be transparent, fair, accepted and easy to manage if implemented well (Lui and Carless 2006). Peer feedback was introduced in one unit to engage students at a more professional level in evaluating the quality of their own and other's work (changes in ASF3A outlined in Biggs and Tang, 2007) and has since been adapted to other units with wide acceptance by staff and students. It has been argued that student engagement with peers in the assessment process can occur at three levels; first, students check knowledge and skill against a teacher prepared model answer, second, students discuss and negotiate assessment criteria and apply these standards to assess peer work and third, students are given greater ownership in the design of the task, criteria and process of assessment (Brew 2006). Prompt, high quality feedback, from staff, peers, self and early remediation of writing flaws is

important in preparing students for writing a thesis. Experience of assessing work against clear rubrics helps students develop these skills. The criteria used in planning tasks that involve peer assessment of critical scientific writing and communication are outlined (Table 1).

Table 1. Criteria for design of critical writing activities with peer assessment

<ul style="list-style-type: none"> • Students learn to write critically by practising critical writing to learn • Graduate attributes in scientific communication are developed sequentially • Tasks constructively align to achieve writing skills required for honours thesis • Explicitly identify the structure and purpose of research communications • Support practice in identifying and applying the features of good scientific writing • Authentic tasks are situated within a research context • Encourage creative inquiry and pursuit of areas of interest • Extend and provide depth in key areas of discipline content • Staff and student collaboration to negotiate assessment criteria • Graded by staff and students on a rubric based on SOLO taxonomy • Timely, constructive feedback provided on learning • Discourage academic dishonesty • Enhance skills in self monitoring and correction • Provide skills and experience in evaluation and support of peer learning

Table 2. Learning outcomes, activities and assessments to develop critical writing skills in the degree program

Unit of study and year and semester	Intended learning outcomes	Teaching and learning activity	Assessment value and marking process	Peer assessment process
AFNR1001 The Rural Environment	Academic Honesty	On line modules on referencing, citation, what is plagiarism, group work	No marks, but compulsory completion prior to first assessable task	No
Animal Science 2 – Year 1 Semester 2	Communicate complex scientific issues effectively to a general audience	Short critical talk and article and newspaper article on current issue of controversy in animal industries	10% Average of student and staff mark	Yes – in class Using agreed criteria
Animal Structure and Function 3A – Year 2 Semester 1	Critically analyze applied animal physiology research articles	Critical analysis of literature on pain in animal husbandry	20% Staff review of draft, feedback, final paper Staff mark final paper	Yes – 1 week prior to submission Feedback using agreed criteria
Animal Welfare and Behaviour Science – Year 3 Semester 1	Present a clear, evidence-based argument on animal use in research	Debate on critical ethical and scientific issues in an animal research study	20% Average of student and staff marks	Yes – in class Using negotiated criteria
Animal Biotechnology – Year 3 Semester 1	Critical analysis and oral communication of a current research study	Oral conference style presentation of a recent research paper on gene transfer to animals	10% Average of student and staff marks	Yes – in class Using negotiated criteria
Animal Genetics or Production research project proposal – Year 4 Semester 1	Critically analyse, evaluate and communicate existing animal science knowledge	Literature review and research proposal in style suitable for publication	10% Average of two staff markers on final paper	Yes – 1 week prior to submission Using agreed criteria
Animal Genetics or Production research project – Year 4 Semester 2	Critically analyse, synthesize, evaluate and communicate new knowledge in animal science	Honours research thesis and 10 minute conference style research paper	40% Average of two staff markers on final paper 10% staff and peer assessment of research talk	Yes – in class Using agreed criteria



Units of study were designed using these criteria to help students sequentially develop their scientific criticism and writing (Table 2). Structured learning and assessment tasks were implemented for first, second and third year students which included; a brief talk and newspaper article on a current area of controversy in animal science (Year 1); a peer-reviewed critical analysis of current literature on painful practices in animal husbandry (Year 2); a debate on animal ethical issues, a cutting edge journal article presentation and literature review in biotechnology (all Year 3), culminating in a literature review and honours thesis in Year 4. The tasks met workload guidelines. Peer assessment and feedback was provided formatively (2 tasks) and summatively (4 tasks).

Intensive development of critical writing skills in a core unit of the program

During a core Year 2 unit students develop skills immediately before these are applied to their first major critical review (Table 3). These add to skills gained in Year 1 in finding scientific literature (library tour) and communicating complex scientific controversies (Table 2). They are introduced to how scientists write and how to interrogate the published literature by the University library and learning support staff (Table 3). This is followed by several interactive tutorials and online activities on the structure, function, strengths and weaknesses of research articles. The articles' topics (e.g. endocrinology) are chosen to ensure they directly relate to the unit's curriculum, so students perceive the relevance of the content while they develop skills through practice in scientific writing. Students progress to the next stages of becoming knowledge-builders rather than just consumers of research (Brew 2006) which increases their motivation and ownership of their learning. They choose a topic of personal interest within a broad range (pain in animal husbandry) and are challenged to compare two different recent approaches to an important research question, how to measure pain in animals. This challenges students' conceptions of science as 'fixed' knowledge because there is a great deal of disagreement among scientists about methods for measuring pain.

Table 3. Curriculum to develop critical writing skills in the Animal Structure and Function 3A unit of study

Teaching and Learning Activities undertaken by students	Time and task
Introduction to scientific writing – University Learning Centre	1 hour tutorial
Literature search strategy for assignment topic and reference management software training online- supported by librarian	1 hour practical
The “Write site” – online scientific writing activities completed in pairs to identify and practice different writing techniques	Online learning in self-paced tutorial- 0.5 hour
Staged “dissection” of a scientific paper to understand the purpose and structure in a tutorial. Students analyze and rewrite some sections of a simple research paper with identifying information deleted (title, conclusions etc)	Group discussion and pair writing – 1.5 hour tutorial
Online learning activities- analysis of colour-coded, annotated examples of strong and weak student literature reviews. Task uses question and answer to highlight the structure of critical review and features of writing style	Independent learning – 1 hour online
Students select broad topics and then narrow selection of two recent papers for critical review. Papers should adopt different methodologies to investigate pain in livestock undergoing animal husbandry procedures	0.5 hour class – papers selected in consultation and approved 4 weeks prior to final submission
Critical review of two current papers – draft prepared and submitted online	3 weeks to prepare 1,500 word critical review, agree on assessment criteria
Peer assessment against grading criteria, provision of feedback. Papers returned with opportunity for reflection and revision before final submission	1 week prior to final submission- papers allocated – 3 days for feedback online or on printed version
Students receive staff assessment of final submission against grading criteria Constructive feedback provided on improvement between draft and final. Feedback and stimulus for reflection on learning from peer review	Staff return marks, feedback online (<i>WebCT</i>) within 2 weeks

Impact of intensive critical writing development on students' experience of learning

The program to develop critical writing skills in ASF3A has evolved, starting with a group research talk (2000-2002). Further changes were made (2003-7) because many Year 4 students simply described research with a lack of critical evaluation in their fourth year research projects. In 2003 the critical review of scientific literature was introduced, followed by library and writing training (2004),

online activities and peer review (2005) and research article tutorials (2007). Students' experience of learning improved, along with satisfaction (90-100%), despite the student numbers increasing by 200% during this period (Table 4). The perception of development of generic skills and clear goals remained high (over 80% students agreed) despite concerns about workload. The experience in ASF3A was more positive than in other units undertaken by the same students and students reported increased enjoyment and interest (Table 5). The critical writing task was the most challenging (Figure 1) when the grades, based on SOLO grading criteria, are compared.

Table 4. Students experience of learning – evaluation of ASF 3A

Scale 1-5; * Reversed item, SA/A% - strongly agree and agree. Critical task introduced in 2003.

Year	Clear Goals [#]	Good Teaching [#]	Generic skills [#]	Appropriate workload ^{#*}	Appropriate assessment [#]	Satisfaction SA/A%
1997	2.8	2.7	3.0	2.5	3.2	38
1999	3.3	3.0	3.3	2.5	3.3	54
2001	3.9	3.8	3.7	2.9	3.4	94
2003	4.2	4.3	3.9	3.6	3.2	100
2005	4.1	4.1	4.1	2.4	3.6	96
2007	4.2	4.0	4.1	2.6	3.5	90
<i>2007 mean for other units</i>	<i>3.6</i>	<i>3.7</i>	<i>3.8</i>	<i>2.9</i>	<i>3.6</i>	<i>80</i>

Table 5. Student evaluations – open comments on generic skills development in ASF3A

<ol style="list-style-type: none"> 1. A valuable learning activity – for content and skill ST 1: 'It was more of a learning experience than just demonstrating what we had learnt' ST 2: 'I learnt how to examine a paper and at the same time about the subject of the paper' 2. Constructive in its impact on students' learning strategies ST 3: 'Written assignments made us think laterally and critically' In a 2008 survey 39% students volunteered that these assessment tasks stimulated deeper learning. 3. Developed broad variety of graduate attributes ST 4: 'It was very focused on research skills as well as communication' ST 3: 'I was learning skills I will use in later years of this course' In 2008 43% year 3 and 67% of year students identified the oral presentations to be the most valuable task for developing their generic skills in scientific communication. 4. Allowed students to demonstrate their learning ST 5: 'Critical review allowed us to apply our communication, research and inquiry skills' 5. Enhanced learner interest ST 6: 'Allowed further research in areas of interest' 39% students volunteered that the choice of topic increased their motivation. 6. Positive impact of peer review and feedback ST 7: 'The critical review was a good particularly the peer feedback on areas which I needed to improve' 7. Negative comments on assessment task ST 8: 'The assessments were more focused on research papers and understanding them as opposed to the other material we were taught in the unit'
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One strong positive effect of the critical review task in ASF3A is a change in students' conceptions of the disciplinary content. Students discover, as they research pain in their chosen species, that imperfections in the measurement methods available make it difficult to reliably monitor the intensity of an animal's experience of pain. Given the high degree of importance that animal scientists place on preventing and alleviating pain in animals, the conflicts in the research make this a compelling topic for inquiry and ethics debate. Many students deepen their conceptions of pain alleviation, gaining a realisation of the complexities in interpretation and application of research. Students report confidence in tackling the animal welfare ethics debate (Year 3) and animal research ethics (Year 4 projects) following this Year 2 task, providing evidence that their learning is enduring and transferable to a new context. Through these tasks students perceive the many opportunities to make a contribution to research through refining the measurement methods, experimental design and analysis. Several students have become interested and pursued research careers in this area.

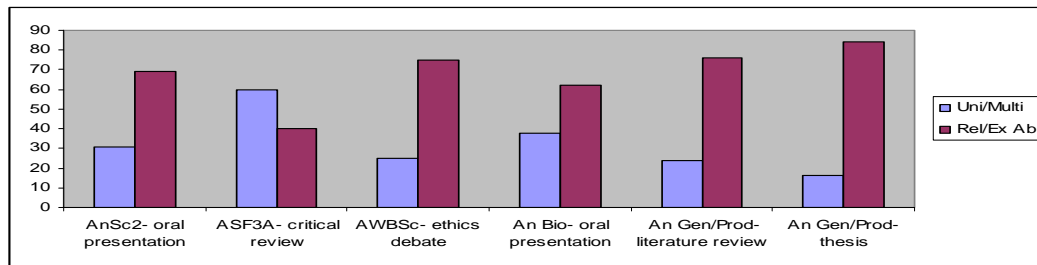


Figure 1. Staff and student assessment of achievement of intended learning outcomes graded on SOLO taxonomy (unistructural/multistructural and relational/extended abstract). Fail results were < 5% and were excluded.

Impact of critical writing program on students' skills and readiness for honours research

A progression in individual students' development of scientific writing and presentation skills is apparent to staff and students across the BAnVetBioSc program. After completion of the critical writing and communication tasks, coordinated across five units, most students entering Year 4 research projects (Honours) were able to write a clear, focused grant-style research proposal, a well structured literature review and present their work orally to their peers, and provided constructive peer feedback. Final year research presentations are now of a consistently higher standard than in the past, with students reporting far greater confidence in tackling tasks such as writing a literature review and presenting a research talk. The percentage of students gaining Honours 1 in Year 4 has increased.

Conclusions and steps for successful application of this research

Constructively aligned development of scientific graduate attributes is challenging but achievable. The long term impact on graduates' skills is difficult to discern with certainty due to the range of changes in the curriculum. However evaluation of graduate, employer and staff perceptions of the quality of graduate outcomes is planned to provide evidence for further improvement of these activities to support students' development of these important skills. The development of critical scientific writing and communication themes across a degree can be enhanced by; a) recognition of curriculum deficits arising from ad hoc development based on teacher preferences; b) development and articulation of Graduate Attributes for the degree; c) feedback from stakeholders on the skills required for future graduates to meet industry needs; d) research into student perceptions of their learning experience; e) Faculty support for curriculum renewal; f) targeted development to support staff in designing new assessment and learning tasks; g) collection and use of evidence on student learning to guide reflection; h) a commitment to ongoing curriculum change; i) engaging students as partners in learning and assessment: and j) clearly articulating the importance and benefits to students of well developed critical scientific writing and communication skills.

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