

Effective Assessment Practices in an Inquiry-Based Science and Technology Education Course in an Australian Teacher Education Program

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Abstract: Poor quality and limited numbers of dedicated science teachers in schools has been the subject of recent attention in the Australian media and science education community. Despite significant attention to improving science teaching with practicing teachers and schools, the quality of science education in pre-service teacher education programs has been largely ignored. Yet pre-service programs provide the perfect opportunity to excite and empower future teachers and their students to ensure high quality and highly motivated science and technology teaching in schools in the future. This paper describes how an inquiry-based science and technology subject used innovative assessment approaches to inspire and motivate 186 2nd year undergraduate students in the teaching and learning of science and technology across two USQ campuses in Queensland.

Introduction:

In Australia, the decline in students progressing to university from high schools to pursue science-based careers has troubled federal and state governments over the past decade. This is further exacerbated by the '*brain drain*' of top Australian scientific researchers to European and North American institutions. Consequently, Australian governments have provided substantial support for improving the quality of science teaching in both primary and secondary schools, for additional resources to assist science education in schools and for the provision of professional development opportunities to assist existing science teachers.

However, it is my contention that one of the most significant aspects where government support would have the greatest influence in the uptake of science-based careers in the future are the current pre-service teacher educators. Poor pre-service teacher attitudes to the teaching of science is likely to lead to less-effective, less-vibrant and shallow teaching and learning experiences in science by these future educators which will ultimately diminish the love and joy of science in the students that they teach. There is considerable research and anecdotal evidence documenting the negative perceptions of many pre-service teachers to key learning areas such as science and mathematics.

Pre-service teachers have reported a range of personal experiences that have biased their perceptions of science and the teaching of science including:

- Limited or no exposure to science in their past whilst at school
- Science teaching that they experienced was very didactic
- Teachers were very uninspiring and uninteresting
- Limited student engagement and limited student-centred science learning
- Limited connections or relevance of the classroom science teaching to real-world applications and contexts
- Science teaching was geared more to the boys than the girls in the class.

Breaking down the negative stigma of pre-service teacher educators to teaching science will go a long way to improving future prospects for increased interest in science-based careers in their students in the future. This paper describes how a science-based subject within the Bachelor of Education (Primary and Middle Schooling) program in the Faculty of Education at University of Southern Queensland (USQ) entitled *Educating the Inquiring Person*, used innovative teaching and assessment practices to inspire and motivate 186, 2nd year undergraduate

students across 2 campuses (Toowoomba and Wide Bay, Qld) in the teaching and learning of science and technology.

The Bachelor of Education (Primary and Middle Schooling) story

In 2004, a new 4-year 32-credit point Bachelor of Education (Primary and Middle Schooling) [BPMU] degree at USQ was established to replace the standard 4-year Bachelor of Education (Primary) program. The new degree was innovative in the sense that there is:

- strong consideration of the developmental nature of pre-service teachers
- integration of curriculum and pedagogy
- infusion of ICTs in cross-curricular approaches by staff modelling of ICTs as a normal part of their teaching repertoire
- internships in the final year of the program to allow smoother transition from university life to the workplace to help to reduce early teacher burnout
- a range of subject specialisation/majors to maximise student strengths and improve their employability in at least Year 1-9 contexts.

The BPMU is also offered on 3 campuses in Queensland: Toowoomba, Wide Bay and the new Springfield campus commenced in 2006. Each year there are about 350 students enrolled in the BPMU across the campuses. The first graduates will emerge from the new program at the end of 2008. Further details about the program can be obtained from the USQ web site at: <http://www.usq.edu.au/courses/BPMU/>.

Course Details - Educating the Inquiring Person (PRT2201)

This is a 2nd year 2 credit point course that is the first of the integrated pedagogy and curriculum courses in the BPMU. It integrates the key learning areas of science and technology and infuses inquiry-based approaches that are utilised in a 10-day professional experience component. The course design involved engaging students by blending together both content and pedagogy using constructivist principles. However, it was made clear that **inquiry** is not the exclusive domain of the science and technology curriculum areas alone. PRT2201 is taught over 13 weeks and the content of the course is delivered in a variety of modes and approaches including WebCT Vista discussion groups, online chats, f2f lectures, workshops, laboratory sessions and guest lectures. The flexibility of content delivery is largely due to the increasing recognition at USQ that university students have many commitments whilst attending university such as part-time jobs and family commitments with an ever-growing mature age student cohort. USQ is also world-renown for its distance and online education programs and this expertise has been utilised in this course.

Some students feedback includes: “... *I had to complete the course early, due to responsibilities that took me overseas prior to the end of semester. I could not, therefore, afford the time that would, and has in the past, been wasted by chasing up lack of clarity about objectives, concepts, relevance of content, technical support, etc. The mix here more than met my needs -- even with the lecturer needing to take some personal time off. I continue to be positively impressed with the intersection of theory and practice in USQ's flexible delivery platform - and am happy to talk to others about it whenever occasion arises. Whatever my final grade is, despite my time constraints, it will be fair. Thanks to USQ for meeting me where I live!*”

Switching Students On to Science

The prime objective of my teaching in the inquiry-based course (*PRT2201: Educating the Inquiring Person*) is to ignite a passion for learning science and technology in students. However, there is NO point in promoting science and technology education IF students have an inherent fear or resistance to this/these subject area/s. This may help explain the current shortage of ‘switched on’ science teachers due to poor experiences with science in their past. It is critically important to unpack prior experiences and to ‘switch them back on’ to the fun, enjoyment and fascination that IS science. If I can empower and support these pre-service teachers, then it is highly likely that they will return, inspire their own students in their classrooms leading to more committed and empowered science teachers in the future and hopefully more students considering careers in science.

Consequently, early in the course, time is devoted via the electronic discussion areas and on-campus classes to share and unpack the ‘*baggage*’ of past experiences and poor perceptions of science and technology. By doing this, pre-service teachers have a far more accepting view of science and are more willing and open to engage with the subject matter. Some unsolicited student comments include: “*I have found this course has made me less frightened of science and technology and how I was ever going to teach it.*” “*You have made it fun by adding your “humour” in the lectures each week, showing us examples of experiments and then letting us do some hands on work in tutorials. And its helped me realise that science and technology isn’t all boring experiments where you have to write up aims, conclusions etc etc.*” “*By far the best thing about this course would have to be the way it is taught - being Science and Technology ‘hands on, minds on’- I love how we are actually taught in the manner which we should learn to teach. So, in learning to teach from an inquiry/interactive approach, we are actually being taught the content in this method also. It’s just great! Thanks very much.*”

The **key features** of the PRT2201 course include:

- Development of a Talking Book (audio-enhanced PowerPoint designed to help correct scientific misconceptions in students in Yr 1-9 range) using a Design-Make-Appraise procedure
- Microteaching (pedagogical content knowledge and development and use of ‘*hands-on, minds-on*’ science and technology activities)
- Workshops (development of pedagogical skills associated with inquiry-based teaching and planning)
- “*Learning Examination*” (student-created examination where students use their research skills to locate possible examination question bank which are then narrowed down for the exam)
- Lectures (used primarily for information-sharing rather than specific science-technology content coverage)
- Professional Experience (apart from providing students with their first real taste of school-based teaching, it provides them with the opportunity to undertake some inquiry-based team-teaching with their mentor teacher)
- USQ *StudyDesk* (a critically important component of the course in that this electronic environment was used to good effect to demonstrate to students, through experiential learning, how to and how not to use discussion areas in educational and information sharing contexts. This was demonstrated to great effect in the exam creation process (Figure 1)).

The screenshot displays the 'Discussions' section of a WebCT Vista course. At the top, there is a search bar and a note: 'Students can access all available components below because the tool has been added to the Course ToolBar.' Below this are buttons for 'Create Topic', 'Create Category', and 'Reorder Categories'. A summary table shows 'All Topics' with 1319 Messages and 'All My Posts' with 223 Messages. The main content is a list of discussion categories, each with a title, a description, a message count, an 'Available' status, and an 'options' menu. The categories include:

- PRT2201 - Workshops and Professional Experience Discussions**: Issues related to the Pedagogical Workshops and also the 2-week professional experience later in s1 can be discussed here.
 - Interest in Observations: 54 Messages, Available: Yes
 - Pre-Professional Experience Questions: 183 Messages, Available: Yes
 - Talking about Pedagogical: 16 Messages, Available: Yes
 - Help or Advice Needed: 28 Messages, Available: Yes
- PRT2201 - Exam Questions - Development Area**: This is where each of your randomly-assigned groups can discuss the exam question development for the PRT2201 examination. Questions will be a combination of multiple choice and short answer questions. Further details will be provided in the Workshops.
 - Issuey 1 - Earth and Beyond: 57 Messages, Available: Yes
 - Issuey 2 - Natural and Processed Materials: 95 Messages, Available: Yes
 - Issuey 3 - Life and Living: 72 Messages, Available: Yes
 - Issuey 4 - Forces and Changes: 157 Messages, Available: Yes
 - Issuey 5 - Substances - Technology Strand: 74 Messages, Available: Yes
 - Issuey 6 - Materials - Technology Strand: 83 Messages, Available: Yes
 - Issuey 7 - Systems - Technology Strand: 145 Messages, Available: Yes
- PRT2201 - Main Discussion Area**: This is where you access the many other asynchronous discussion areas for the PRT2201 course. Come on in...
 - PRT2201 General Discussion: 250 Messages, Available: Yes
 - Science and Technology Web Resources: 11 Messages, Available: Yes
 - What?!! - Please explain those demonstrations: 24 Messages, Available: Yes
 - Scientific and other forms of Wacky Humour: 20 Messages, Available: Yes
- PRT2201 - Content-related Discussion**: Let's engage with some of the ideas and readings that are being discussed in the Lectures and Laboratory (Hands On, Minds On sessions).
 - Phobias about Science and Technology: 12 Messages, Available: Yes
 - Good and Bad Science and Technology role models: 26 Messages, Available: Yes

Figure 1: WebCT Vista Discussion Forum area of PRT2201 showing the layout, structure and activity in the Discussion Categories especially within the *Examination Question* forums.

Talking Book Creation Using a *Design-Make-Appraise* Process:

The Talking Book are creative learning tools (audio-enhanced animated and graphically-rich PowerPoint slides) and teaching resources designed to challenge and correct scientific misconceptions in Yr 1-9 students. Students develop:

- (a) **Design Proposal:** Students provide details of the planned story, appropriate audience, links to the Queensland Science and Technology syllabi, details about the misconception and the correct concept and the science behind the concept. Staff feedback and advice was provided to help guide students in the development of their Talking Book.
- (b) **Creation of Talking Book:** Physical creation of the story using the advice in (a) and applying them into PowerPoint.
- (c) **Appraisals:** Peer assessment and critical review of 2 other Talking Books in computer labs on USQ campus. Provides students with skills in rating/assessing a Talking Book using criterion-based assessment sheet. Course staff compare the assessment of the Talking Books against the Appraisals provided by students to observe the thinking and justification that the students use in rating other Talking Books.

The student teachers use a story genre of their own choosing to: (a) correct a misconception of a scientific concept, (b) provide the 'correct' science, (c) use a '*hands-on, minds-on*' approach where school students are directed to create a product that helps to unpack the misconception, (d) use and apply appropriate scientific literacy, and (e) developing an age-appropriate and creative story that guides the students from misconception through to correct concept. The open-ended nature of this exercise, using a constructivist approach to the development of the Talking Book, allowed students to engage with scientific and technological course materials in very creative ways. The Talking Books are also incredibly valuable educational resources for use in future classrooms. Student comments included "... *I liked the Talking Book task as it provided me with a lot of relevant technological knowledge and information*" and "... *The Talking Book at first I did not like but once I got into [it] I really enjoyed making it. It will be a good resource for [me] in the future.*"

Laboratory Sessions

They are exposed to '*hands-on, minds-on*' activities to enable students to actively engage in knowledge creation with the science and technology content rather than being passive recipients of knowledge. As future teachers, these students need to be prepared to work alongside their classroom students and to even be challenged by them.

Workshops

Focussed upon the pedagogical development of the students by preparing them for their 1st professional placement. As part of the BPMU '*pedagogical scope and sequence*', this initial professional experience in PRT2201 largely focused upon lesson planning single and multiple lessons over a 2-week (10-day) period. In addition, they worked upon questioning techniques and strategies associated with inquiry-based teaching, which they undertook as a single team-teaching episode during their professional placement. The teaching strategies learnt in the workshops were also utilised in the Microteaching lessons.

Feedback from students include: "... *I liked that in the workshops we were taught practical classroom strategies, which assisted me while I was on prac, and will continue to throughout my professional teaching career*"; "... *I enjoyed the fact that the content is related back to hands on experience[s]. Fun and interesting. I learn by doing so that was good for me*" and "... *Lecturer was able to interact with student's at their level allowing for easier understanding of topics.*"

Microteaching

The primary focus was upon pedagogical content knowledge where students constructively researched the relevant content knowledge in the science, technology and other relevant key learning areas in preparation for their microteaching lesson. Thereby, the students were able to teach *themselves* a large portion of the relevant content in the science and technology syllabus across a Year 1-9 audience.

The microteaching process involved groups of students (3-5 students) randomly assigned/selected core-learning outcomes from the science syllabus across Year's 1-9. They then apply their pedagogical skills developed from the Workshops for the content knowledge to develop a lesson plan and teach it to their peers in the Laboratory Sessions within a 1-hour timeslot. These episodes were peer-reviewed and feedback was openly shared with all participants. The ideas, teaching approaches and lesson planning displayed were a very useful way of having the students *teach each other* the breadth and depth of the science and technology content over the Years 1-9 range by highlighting relevant pedagogical content knowledge.

Developing Authentic Uses for Examinations

In a 13-week course, it was considered impossible to effectively teach **ALL** the relevant science and technology content to students using traditional approaches of lectures and tutorials. Consequently, a more creative approach was required. The *student-created exam* was devised as a useful tool for students to generate long-term learning in science and technology content. In addition this concept also:

- (a) demonstrated and modelled a pedagogically-appropriate use for an examination
- (b) allowed students to take responsibility for their own learning by allowing them to democratically decide upon the most significant content for the exam
- (c) raised awareness about the development of appropriate exam questions.

The process involved the random assignment of ~26 students from across Toowoomba and Wide Bay classes into 7 groups with each group being assigned to a strand from either the Queensland science or technology syllabus. Each group was charged with the creation of 12 potential exam questions (6 multiple choice and 6 short answer questions) **BUT NO** answers were to be provided or shared in the Discussion Forums. Each group was assigned a private discussion area in WebCT where they posted their questions (refer to Figure 1). Questions were geared towards important content that future Year 1-9 teachers teaching in science-technology would need to know.

All groups ended up creating a wealth of questions (some more than 30 questions/strand group) and then they used their own negotiation, democratic and leadership skills in these electronic forums to decide upon the final 12 questions (Figure 2). Teaching staff simply monitored the process, identified any problematic questions and ensured that any questions were addressed promptly. The process of generating the final 12 questions was where the bulk of the learning took place in each of the forums. Clearly, by having students argue and negotiate the final 12 questions then they would clearly be learning, as they would be discussing the virtues and reasons for inclusion from an informed and researched position.

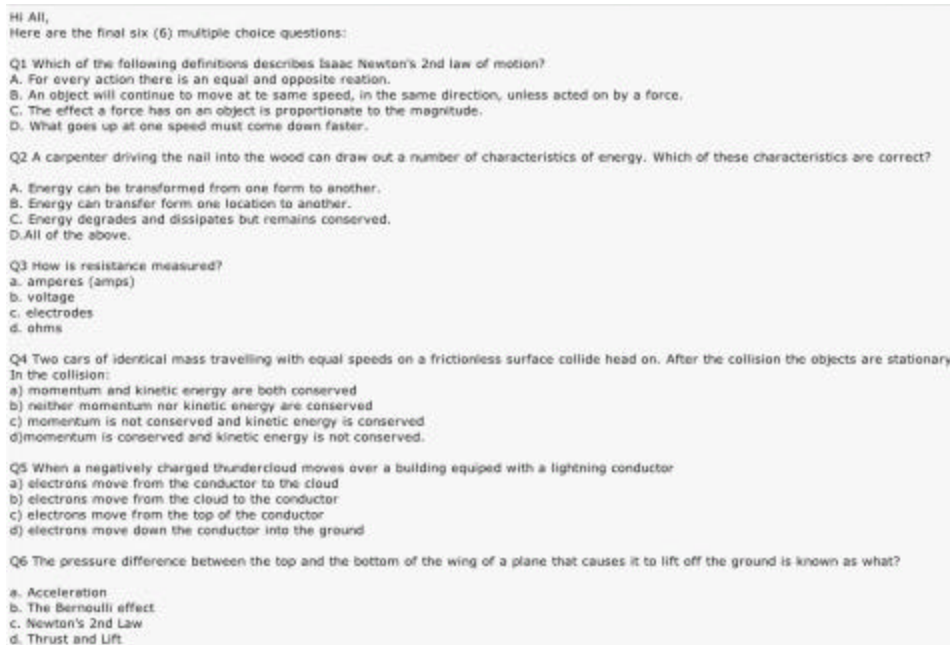


Figure 2: Screen Grab from the *Energy and Change* Discussion Forum showing a sample of the questions produced from the group for the 6 multiple-choice questions.

All 7 groups (total of 84 questions) were then given access to **ALL** of the 84 questions. Students knew that the final exam would involve a total of 60 questions drawn from the bank of 84 questions created BUT they had no idea which 60 would be involved. Students would then go and find the answers themselves to all 84 questions. Samples of the final exam paper are presented in Figures 3 and 4. Students learnt a great deal about science and technology content simply by constructively arguing and actively debating with their peers in the WebCT discussion area about why one question was more important or relevant than another. As noted earlier, the student-created exam and the Talking Book development represent constructive, authentic tasks for these 2nd year learners. The student learning of science and technology content that took place during the process was incredible.

- Section A (Multiple Choice):**
PLACE THE CORRECT RESPONSE ON THE SHEET PROVIDED:
1. Which of these organs produce insulin?
(a) liver
(b) pancreas
(c) spleen
(d) brain
 2. Why do we always see the same side of the moon from earth?
(a) The moon revolves around the earth once every 28 days, and rotates once on it's axis every 28 days.
(b) The moon revolves around the earth one a month.
(c) The earth revolves around the moon.
(d) Only the earth rotates on it's axis.
 3. What does DNA stand for?
(a) Deoxyribose Nitrogen Acid
(b) Deoxyribonucleic Acid
(c) Deoxynucleotides Adenine
(d) Deoxyribose Nucleic Acetate
 4. Which is **NOT** a group of elements represented on the Periodic Table?
(a) metalloids
(b) metals
(c) non-metals
(d) moltens
 5. Which of the following definitions describes Isaac Newton's 2nd law of motion?
(a) For every action there is an equal and opposite reaction.
(b) An object will continue to move at the same speed, in the same direction, unless acted on by a force.
(c) The effect a force has on an object is proportionate to the magnitude.
(d) What goes up at one speed must come down faster.

Figure 3: PRT2201 Final Exam paper showing a sample of the multiple-choice question format.

The Strategic Use of Humour

I also appreciate the pressure and weight of expectation on many higher education students. Therefore, another important aspect of my teaching is the regular use of *humour* in all my courses. Subjecting students to my (quirky) sense of humour is an attempt to (a) show students that you can have an occasional laugh whilst you learn, (b) it also shows students that I am a 'real' person, and (c) it helps to make students feel less-intimidated by me and/or the course and thereby encourages more open and frequent dialogue. These points are especially important in my online teaching when face-to-face opportunities to know more about me are simply not possible. Therefore, humour has been a very successful strategy to personalise the teacher and the teaching no matter what mode of delivery. I also inject some humour into the examination paper as well.

Student comments included: "... *Jerry has a great sense of humour and so tutorials with him were always made interesting*"; "... *Jerry seems to want to make the course fun*" and a backhanded complement was "... *maybe not crack so many jokes, although it does ease the tension in the classroom*" and "... *I think the element of fun was more evident in this than any other course I've completed thus far. While this may not be a particularly deep observation, the fact that a serious, important subject could be approached with so much good-natured, friendly banter between participants added significantly to the building of a sense of learning in community with colleagues - not something for which distance learning is yet noted. I think Jerry Maroulis is to be congratulated for his affable*

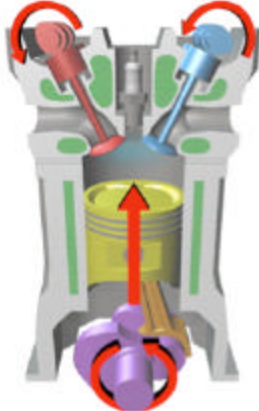
and personable approach in teaching. I also found that the manner of assessment was most helpful and realistic to my personal circumstances -- far more than, say, formal examinations. Along the same lines, assignments were sufficiently realistic to my workplace environment that two of them are becoming real-world applications. This is of tremendous value."

18. What causes a tsunami?

19. Explain the difference between series and parallel circuits?

20. What is the purpose of the motherboard?

21. Using the following diagram of a typical 4-stroke internal combustion engine, identify the **key components** and **explain** how this engine works.



22. What are the **THREE** classifications of rocks?

23. What is the first law of thermodynamic systems?

Figure 4: PRT2201 Final Exam paper showing a sample of the short answer questions.

Conclusion

The lack of competent and high quality science teachers has recently been the subject of much national media and Federal Government interest, with blame being levelled at the claimed inability of undergraduate teacher education programs to adequately prepare high quality science teachers for primary and secondary schools in Australia. However, exposing pre-service teachers to more science content and expecting them to be more enthused and excited about their teaching of science in schools is at best naïve.

This paper outlines how constructivist principles were successfully used to develop assessment pieces and teaching and learning approaches in the 2nd year inquiry-based science and technology course (*PRT2201*) in USQ's Bachelor of Education (Primary and Middle Schooling) program that are:

- relevant to the future 'real' work of the pre-service teachers in a Year 1-9 context;
- model teaching approaches that demonstrate effective uses of ICTs to communicate with fellow students in solving real issues;
- fun and enjoyable for both staff and students with the goal being to demystifying and remove the negative perceptions of science teaching and to show that science can really be fun for everyone;
- showing innovative examination process in achieving both science and technology-content coverage and the development of effective student research skills in finding answers to potential exam questions;
- peer assessment of pedagogical content knowledge in lab sessions that builds upon and informs the content knowledge created for the examination;

- applying pedagogical knowledge and skills developed in workshops into the inquiry-based teaching in their 10-day professional experience placements;
- utilising/modelling the *Design-Make-Appraise* process with the pre-service teachers in developing the Talking Book which:
 - addresses scientific misconceptions
 - develops appropriate ICT skills and
 - develops appropriate scientific literacy skills in both the student teacher and the intended audience for the Talking Book.

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