The Free Energy Interviews: Scientists and Journalists Collaborate in a Cross-Disciplinary Research Journey

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Keywords: science careers; student interviewers; working scientists; interview technique

International Journal of Innovation in Science and Mathematics Education, *22*(5), 61-75, 2014.

Abstract

Many students in high schools and universities view science and scientists as "other". Students have few mechanisms that they can use to access information about "who" a real scientist is, and "what" they do all day. In 2010 we began a project to address this information gap by (i) producing a series of recorded interviews with working science graduates and (ii) supplying these to undergraduate students in a large mixed-interest biochemistry class. We named the project "Free Energy". Initially a science academic interviewed other scientists alone, however in the second iteration we included student interviewers as well. To obtain course credit these students, who are all co-authors on this paper, used Free Energy as the basis for their Summer Undergraduate Research Experiences. We present a description of the development and delivery of Free Energy and explain how we used it as the subject of student research projects in a Science faculty. We also explain what we as academics and student interviewers have learned from the process of interviewing science graduates in a working radio studio and delivering these recorded interviews to large groups of undergraduate students.

Introduction

"What is it like to be a scientist?"
"How do I build a career in science?"
"I don't want to be a researcher, so what can I do with a science degree?"

Anyone who has taught tertiary science students will have been asked important questions like these. The problem is the answers are long, complex, and often very personal. How can we help our students with these important issues?

In 2010 authors SLR and JH began a cross-disciplinary collaboration in an attempt to help our students address their questions and concerns about their futures in science. The project consisted of a series of interviews in which we asked working science graduates about their lives and their careers. We planned to provide these interviews to undergraduate students enrolled in generalist, introductory, second-year biochemistry class. We named the project "Free Energy", both for the description of "available energy" by Josiah Willard Gibbs (Gibbs, 1873), and for the idea that students could be energised by listening to the interviews.

This paper describes the development, implementation, and iterative improvement of Free Energy. We provide a discussion of the challenges and solutions associated with the project, including a discussion of interview production and delivery to the students. We have collected research data from the activity, using it as the basis for four Science Undergraduate Research Experiences; we will briefly describe the types of data we are collecting and how the student participants created an individual research project from Free Energy. Finally, we reflect on the profound learning opportunity that Free Energy has provided for the student interviewers and for author SLR in the project.

Justification for the project

Worldwide, young people have low expectations of the careers and pay rates available to scientists, and they possess little information about the daily activities of scientists, or how scientists build their career (OECD, 2006). Although some students enter science with realistic ideas about a career in science, many drift into the discipline with an interest in science, but little idea of the skills or the future a science degree can confer (Rodrigues *et al.*, 2007).

Since science is a generalist degree, the lack of a specific "job" at the end of training can weigh heavily on the minds of some students. Before beginning university, many school students have the perception that research and teaching are the only career pathways after a science degree, and are put off by this prospect. A study with Australian school students showed "the features least likely to encourage student entry [to a science degree] are that the degree leads you to become a science researcher, work in a laboratory, or become a science teacher" (Tytler and Symington, 2006). These students also indicated that if they were able to work together with other people they would be more interested in science as a career (Tytler and Symington, 2006). In addition, it has been shown that undergraduate science students have low awareness of the communal nature of the scientific effort (Ryder *et al.*, 1999).

Students' fear of what a future in science holds is not unreasonable, and it is important they have readily accessible and up-to-date career information (DeHaan, 2005, Ryder *et al.*, 1999). The need for this information is especially acute now, when financial restraints, extant grant funding models, and tertiary policy development are hindering both the career progression and stable employment of scientists in academic and research positions (Gascoigne, 2012; Science is Vital, 2011; Stephan, 2012). In a recent survey Australian graduate students, post-doctoral fellows, and early career researchers cited (i) increased mentoring and guidance, (ii) a clearly defined career pathway and (iii) further training, amongst the most important improvements they wanted to see for the research community (Gascoigne, 2012). A similar study conducted in the UK (Science is Vital, 2011) yielded very similar results – people working in scientific research careers cited funding restrictions, career fragmentation, and a lack of career advice as factors that contributed to poor morale amongst their ranks.

Disillusionment about career pathways may contribute to a migration of trained scientists away from research science. In Australia around 40% of science graduates are employed in positions outside their specialised discipline (McInnis *et al.*, 2000). This should not be considered a failure of science or scientists, in fact it makes sense, as science- and technology-trained professionals are increasingly needed to sustain a technologically-driven future (Tytler, 2007).

Consequently, it is important that science students know about alternative, non-research careers that allow them to indulge their enthusiasm for science and use the skills they obtain from their science degree. It is also important that they have realistic expectations of what a career in science entails, as well as early guidance on how to build and navigate that career. Perhaps most crucially, we suggest students will benefit from the opportunity to connect personally with scientists in a low-pressure forum that allows them to engage as legitimate peripheral participants on the edge of the scientific community (Lave and Wenger, 1991). Each of these factors influenced our plan for the Free Energy project.

The Genesis of Free Energy

Authors SLR and JH first developed the idea for Free Energy in 2009. JH had an established record of helping science academics implement media-based teaching innovations, while SLR had not worked in a cross-disciplinary capacity before.

Our mutual goal was to produce a library of interviews with science graduates; we felt that undergraduate science students could use this to hear, first-hand, how science graduates live and work. There is increasing interest in preserving and accessing the stories of important scientific advances (British Library, 2014; CHF, 2014), however our approach was not focused on these exceptional events, because few science graduates will achieve this level of success. Instead, we aimed to conduct interviews with 'normal', relatable science graduates who were successfully *employed,* because employment was and is a key concern for our student audience.

Live broadcast or taped, edited online release?

The University of Queensland (UQ) School of Journalism and Communication (JAC) has a state-of-the-art radio studio (JACradio). Initially we felt a live radio broadcast would be the ideal way to engage SLR's students, however we quickly realised this was not feasible. The availability of members of the team (and of the interviewees) meant that we would be unable to broadcast live at the same time each week. Author SLR's inexperience as an interviewer meant multiple takes might be necessary. We also felt some interviewees may inadvertently make comments that they did not want released. Finally, we realised that our students have busy lives, and they are not always able to listen to a program at a particular time. Therefore, we decided to pre-record the interviews in the studio, edit them for length and content, and then release them to students online using a password-protected link. This mode of production has remained consistent throughout the project.

Free Energy Series 1 (2010)

The interviewees

We began production of Free Energy in 2010, with eight interviews featuring eleven interviewees from a variety of backgrounds. Interviewees included senior, mid and early career science academics and research students, a science graduate working in occupational health and safety, a networking expert, and a human resources manager who spoke about interview technique. The interviewees (or "talent" as they are termed by Journalists) were sourced by SLR through personal connections or direct contact using publicly-available email addresses. The addresses were taken from online profiles of interviewees, usually on the websites of research institutes, universities, or companies. Occasionally contact details were sourced from a CV or personal page that the individual had placed online. All interviewees contacted were willing to participate with the understanding that the interview would be edited for content and released to a select group of students. They were not remunerated for their participation. We did not obtain ethics approval or collect informed consent for analysis of the interview material. No analysis of the material is presented here.

The interview process

The interviews took place in the JACradio studios. Author CLES acted as the producer, using Adobe Audition to record and edit the interviews (CLES was an undergraduate student and JACradio manager at the time). Author JH attended the first five interviews to provide coaching to SLR and the interviewees.

Interviews were conducted as unstructured discussions. We focused on material that (i) drew on the expertise and experience of each interviewee and (ii) we felt would be useful to our student audience. The intended audience was a mixed-interest class of second-year biochemistry students (BIOC2000). We asked about relevant science and also discussed topics like networking, job interviews, how to get an internship in a laboratory or workplace, and the work histories of the talent.

Although SLR (a scientist) had previously completed a two-day media skills course at her workplace, JH and CLES (both journalism professionals) were able to teach her a large number of additional skills. For the benefit of potential new implementers the most significant insights from this process for SLR are reported and discussed in Table 1.

Table 1: Insights gained during the production of Free Energy.

Writing for radio
Writing for radio is different to writing for a paper or a lecture. Audio content must be short, focused, and personal. • Introductions of talent can use a biographical sketch, but published biographies are unsuitable. All material must be rewritten for a *listening* audience using active voice and a less formal, more conversational style. • The search term "writing for the ear" can be used to locate helpful online resources. A useful book is Frangi (2012). • Before recording, test the material by reading aloud. If it is hard to read out, rewrite it.
Speaking for radio
Listen to your recorded voice before you enter the professional studio. This allows identification and remediation of annoying sounds and habits. *Maintaining consistency of volume and projection is important.*

• Keep a consistent distance between the mouth and the microphone (about the distance of a hand with the thumb and little finger outstretched). Closer contact amplifies breath sounds. A greater distance introduces a hollow tone. • Maintain the same orientation of the mouth and microphone at all times. This is particularly difficult with more than one interviewee. Learn to look at the interviewees with your eyes only, rather than turning your whole head. • Use the deeper register of your voice (particularly for women). Most microphones pick up deeper tones (lower frequencies) better, so working in the lower register helps keep quality consistent and makes you sound more authoritative. • Support your voice adequately with air. A voice wavers and is thin if it is not given enough abdominal support. Work with your voice coming from the belly rather than the head or chest. This habit also increases the low tones in your voice. *Vocal tics and mouth sounds are very apparent on a recording* • Smile while you speak. Smiling moves your facial muscles into a position that promotes a happy-sounding voice. It also keeps your lips apart, which reduces lip and tongue sounds (e.g., lip popping and saliva noises). • Loud laughter is annoying to the listener. Avoid laughing if possible. Saying “Ha!” with a smile is better. This sounds happy on a recording and encourages the talent to keep speaking. • Speak clearly, but normally. It is obviously important to speak clearly, pronounce words properly, and not hurry over words or sentences. There is no need to speak more slowly than usual; this sounds ponderous on a recording.
Interview technique
Most scientists have no media training, so while the interviewer can moderate their own technique, managing the scientist talent is a different task. Interviewees are often nervous and unfamiliar with the recording environment. *Listen carefully to your talent and pursue particular lines of conversation with further questions.* • An interview in which the host and the talent have a real conversation is more entertaining and accessible than one driven by a list of prepared questions. • Pursuit and encouragement of relevant lines of conversation calms your talent and reduces the amount of material you need to remove in your final edit. *Don’t get excited as an interviewer and keep the audience in mind at all times.* • An animated conversation is fun in person, but listeners can feel excluded if the people on the recording sound too friendly. • Animated conversations result in people talking over one another. This material is difficult to understand on a recording and difficult to edit. • Do not include content in the interview that draws on your personal relationship or past knowledge of the talent. Exceptions can be made if the content is prefaced with “I want our audience to know…” *Hand gestures are invaluable in the studio.* • Media professionals use idiosyncratic hand gestures, facial expressions, and breath patterns to communicate semi-silently in the studio. Train your talent in these gestures before recording

begins (but be aware they don't always heed the signals).
- Do not respond audibly to your talent too often during the interview. Repeated statements ("Yes", "Uh huh", "Mm") quickly become annoying on recorded material. Instead, open your eyes widely, nod, smile, and gesture with your hand for your talent to continue speaking.

Don't be afraid to ask for a re-take.
- Talent do not always respond to signals for "Please wind it up now", or "Please don't talk about that". If this happens, don't be afraid to ask for a re-take. Give a short explanation of what you and the prospective audience are looking for in the audio. If necessary, explain why you will have to edit out a comment they have made (e.g., they criticised someone or used inappropriate language).
- When doing a re-take, leave a short (~1 second) break between the end of what you said previously and the new audio so there is space to edit.

Processing and delivery of interviews

CLES was enrolled in a dual Science/Journalism degree program at the time of interview production. Consequently, he edited the interviews using his professional judgment to retain material of 'value' for the BIOC2000 audience, and remove material that was deemed inappropriate or redundant by either the talent or the interview team. Inappropriate material included (but was not limited to) instances of technical coaching, repeated questions due to technical hitches, criticism of a person or location that was identifiable, and swearing. The sound files were edited using Adobe Audition to improve audio quality (e.g., removal of popping and hissing). The edited sound files were between 20 and 40 minutes long. They were made available to BIOC2000 students using a password-protected link on the JACradio website. Each interview had the name of the interviewee and a short descriptor associated with it so the students could easily tell which interview might interest them (Table 3). Listening to the interviews was not mandatory or assessed as part of BIOC2000 in 2010, but the interviews were heavily advertised to the students using lecture slides, online announcements, and email.

Student use of interviews in 2010

The student use of Free Energy in the first year of implementation was extremely disappointing. The BIOC2000 cohort (n=473) were surveyed to determine how many of them had engaged with the program. Only 96 students responded to the survey. Of these, seven indicated they had listened to half or more of the shows. Thirteen said they had listened to one show, and another thirteen said they had listened to part of one show. The remainder (65.5%) did not listen to any of the shows.

Student use of interviews in 2011-2012

After this response, no further interviews were recorded during 2011. Instead, SLR implemented a new assessment item in the 2011 and 2012 iterations of BIOC2000 that required students to listen to one program and write a half-page, free reflection. At the beginning of 2011 SLR obtained ethics clearance through the UQ Human Research Ethics committee to analyse the student responses. During 2011-2012, 778 students submitted a reflection, with 704 providing informed consent.

The responses were remarkable. They will be described more fully in a separate publication, but a brief summary is provided here. Although many students indicated that they had initially been reluctant to spend time on the mandatory assignment, the vast majority indicated that they enjoyed the interviews and found them interesting. Students frequently indicated that their view of scientists and science careers had been changed by the interviews. They also showed a distinct preference for some interviewees over others (Table 3).

Table 3: Student preferences for different interviewees

Pseudonym[a] and description of talent used on the Website[b]	**# Students Submitting Responses**
Nel, Matti, Elias: 3 post-doctoral scientists on lab politics, travel, and pay scales.	211
Angela: A senior female researcher who works on obesity.	186
Jamie: A female student about to graduate from a PhD in cancer research.	130
Arthur and Ravi: Two male PhD students on "what's involved in doing a PhD".	72
Gillian: An HR expert discussing interview tips and "how to get a job".	60
Daniel: A senior male researcher who works on cone snails, venom, and pain.	47
Patrick: A senior male researcher on Zellweger Syndrome.	27
Tricia: A networking expert discussing networking methods in science.	24
David: A male ex-research scientist who runs OH&S for a research institute.	21
Total	**778**

[a]The actual names of the talent were provided to students.
[b]These descriptions were given to the students online alongside the link to the interview.

These results indicate that students preferred to listen to interviews from talent who are

(i) similar to them in age
(ii) just a little ahead of them in their educational pathway
(iii) talking about money, travel, and the lab environment
(iv) talking about well-known diseases.

In contrast, our cohorts showed very little interest in listening to a networking expert or a senior researcher who worked on a disease with which they were not familiar. Perhaps most pointedly, students enrolled in a Science program had almost no interest in listening to an OH&S officer. Almost all the respondents for this talent were enrolled in an OH&S Bachelor's program.

Student suggestions for improvement of Free Energy

We examined the 704 responses for areas that students felt we could improve. Some wanted us to add video content (n=17), transcripts (n=8), or photos, diagrams, additional web links, and reflections from the scientists themselves (n=6). The feedback was fairly evenly split between requests to make the interviews longer (n=8) or shorter and easier to navigate (n=13). One of the most consistent requests was that we include more opportunities for student interactions with the talent (n=30). The suggestions included requests for a live broadcast with phone and online chat facilities so students could ask questions, a meet and greet with the talent, a pre-interview question submission and, most commonly, students as the interviewers. We had previously decided that live broadcasts were not feasible. SLR had also tried and failed twice to elicit pre-interview question submissions. We felt, however, that it would be possible and desirable to include students as interviewers. Subsequently, SLR advertised Free Energy as a Summer Undergraduate Research Experience (URE) and invited students to become involved as co-hosts.

Free Energy Series 2 and 3 (2012 and 2013)
The Free Energy URE
SLR devised a research project in which each student host would interview six subjects and examine their career pathways. Particular emphasis would be placed on the factors that influenced career decisions. The research question was "What are the personal characteristics and circumstantial factors that drive the career pathways taken by science graduates?" The data analysis methods used during the project are described below. An extended ethics approval for the student research projects was sought and granted through the UQ Human Research Ethics committee.

The student interviewers
Student interviewers (authors AD, KTKG, MTNI and CBGW) approached author SLR requesting to participate in the Free Energy URE and act as interview co-hosts. All four students conducted the interviews at the end of the second year of their undergraduate degrees.

Preparation for interviews
Students identified potential talent and contacted them directly using email addresses sourced as described for Series 1. The talent response rate was variable, and was largely dependent on whether the person approached already knew the student or SLR. Those with a personal connection were usually available to be interviewed, while those who were 'cold-called' usually did not respond to the email contact. Some interviewees were also recruited personally while they were visiting our university.

In order for the student interviewer to prepare, each interviewee provided a curriculum vitae (CV) that allowed the student to draw up a career timeline diagram. The students provided the talent with information about the interview location, the questions to be asked, and the ethics approval for the project (including the rights of the interviewee to listen to and approve the interview before it was released to the undergraduate student audience). The talent had access to the informed consent documents in advance of the interview date.

The interviewees
In all, 22 interviewees were recruited. They were from six countries (Australia, USA, England, Denmark, France, India) and included 14 males and eight females. Their occupations included Science Faculty academic (n=6), research fellow (n=4), PhD student (n=4), science communicator (n=3), patent attorney (n=2), consultant (n=2), science journalist (n=1), and senior administrator (n=1). n=23 because one interviewee had two jobs.

Interviews

Each of the interviews was conducted by SLR in conjunction with one of the students as follows: AD (Harry, Hugo, Gavin, Ian, Marco, Polly), KTKG (Candice, Divya, Lotte, Michael, Yves), MTNI (Bruce, Carson, Darren, Janice, Lara, Marie), and CBGW (Aaron, Basil, Cole, Hamish, Steph). JH attended some interviews to provide technical coaching. Each interview lasted from 25-40 minutes and was recorded as described for Series 1. The student interviewers conducted a semi-structured interview using pre-written questions. The interviewees were allowed to digress from the structured path whenever they wished. All interviewers also used improvised questions pertaining to the individual participant and the topic of discussion.

Both the improvised and scripted questions addressed

- (i) the interviewee's current work or study,
- (ii) their daily activities at work or study,
- (iii) the educational and career path they had followed,
- (iv) how and why they had made each of their educational and career choices,
- (v) their best and worst scientific moments,
- (vi) the skills they had obtained from their education and their work.

Processing, transcription, and online delivery of interviews

Post-interview the student interviewer transcribed the audio files. They then annotated the transcripts with comments related to speakers' contributions and their emotive gestures. These transcriptions were used for interview analysis. After transcription, interviews were 'edited' on paper (with directions as to which parts of the interview should be re-ordered or removed from the final edited product). These edited transcripts were made available to the talent for review and approval. After approval of the textual edits the sound files were edited using Adobe Soundbooth CS5 (by KTKG) or Adobe Audition (by CLES) to improve audio quality and to remove material that was deemed inappropriate or redundant by either the talent or the interview team. This material was also removed from the written transcripts before release.

The edited sound files were made available to BIOC2000 students through a Dropbox share link. The transcripts were made available to students by email upon request (e.g., for students with a hearing disability). BIOC2000 students wrote a reflection on an interview as an assessable item.

Inductive analysis of interviews

The student interviewers performed an inductive narrative analysis using the Grounded Theory Method (Glaser and Strauss, 1967). This is a non-mathematical, qualitative method of data analysis, with the primary aim of generating a theorem that is inherently 'grounded' in (having been derived from) the data. We aimed to develop: (i) an understanding of the personality characteristics of 'successful' science graduates and (ii) a framework for examining the drivers (motivations) in play as science graduates make career decisions. SLR performed the analysis in parallel with one student participant for each interview. Inter-rater reliability was established through discussion and iterative analysis of interview transcripts and audio files.

Student presentations of results

The students wrote a report on their findings that included maps of the graduate's careers, the results of their Grounded Theory analysis and a word cloud for each interviewee. They presented this work to a scientific audience at the Summer student colloquium. These results will be reported in a separate paper. The work was well accepted by the audience and the marking panel; all four students obtained high grades for their projects.

Student interviewer reflections

This project was of particular interest to author SLR because it had the potential to influence the attitudes and understandings of the student interviewers.

Each student interviewer (AD, KTKG, MTNI, and CBGW) wrote a short reflection at the end of their Summer project. (Table 5). They were also asked to provide another short reflection (Table 6) and respond to a short series of open-ended questions (Table 7) a minimum of one year after they interviewed the scientists, with three of the four student authors contributing.

All of the reflections suggest that participating as a Free Energy interviewer and undergraduate researcher was a high-impact educational experience (Kuh, 2008) The students experienced significant personal and professional growth as a result of their participation; they reported changes in their time-management skills, their confidence, their willingness to engage with peers and professionals, and their openness to new opportunities. They reassessed their conceptions of scientists and science careers. In three out of four cases they changed their attitudes and behaviours to better enable opportunities for a broader set of career options. Excerpts from reflections (lightly edited for spelling and grammar) are shown below.

Table 5: Reflections of the student interviewers immediately after the project was complete

Student 1
This project has made me learn a lot about my perception of my own career path. The different comments made by the interviewees really helped get me more organized, aware and prepared for what may come my way. The interviewees chosen for this project had helpful opinions. They have taught me that not everything will go my way. I should have a backup plan. It was very interesting to be able to have a conversation with real-life scientists. They gave us insight into what they have gone through, the good as well as the bad; that was very good for me. I can be ready for whatever may come my way. *Note:* This author subsequently completed a research Honours year in Biomedical Science.
Student 2
The project has been both an eye opener and a learning curve for me. The highlight was the transformation of my perspectives on academia and industry. My perspective of an academic was transformed from one of a boring life lecturing and spending lonely time in the lab to one of a colorful world of challenges, competition, and fun teaching. I realise that there are secure and highly-valued positions in the faculty as well as exciting, collaborative lab research, travel to conferences, and network building. My perspective on the biotech industry was also "myth-busted". It changed from my idea of the perfect, high-earning, exciting job (which is what the media portrays) to a highly volatile and harshly competitive world. I now think it is best suited for people who are willing to take huge risks and face the consequences.

Student 3
While I was aware of some of the major requirements and the effort in an undertaking as a PhD, I was not aware of the possible creativity and freedom that is associated. I have discovered the role that a supervisor plays in a successful PhD and the importance of developing and maintaining the relationship. Furthermore, to my surprise, I found that doing a PhD was more than earning the title of "Doctor". It's about developing a range of practical, transferable skills. Looking ahead, to what potentially is my future career, I now feel more confident that I could possibly arise to the challenge of completing a PhD.
Student 4
These interviews gave new meaning to my studies and commitment to further research. Although I do not want to become a researcher at the moment, I have learnt how important it is to keep doors open and try new fields. After re-assessing my interests, values and career options, I have learnt that I should: (i) do an honours year, (ii) talk to people working in a field that interests me, (iii) follow my interests, (iv) improve skills I am not yet proficient in, (v) be open minded and willing to take risks.

Table 6: Reflections of the student interviewers one to two years after their project involvement

Student 2 ***Reflection two years after project involvement***
This project helped me realize that the world of research is not dull, rather, it is highly competitive. The scientists who make it to the top are really passionate about their work, which reinforced my respect for them. What I have learned from the different interviewees is this: no matter how focused or how unsure you are, always use every occasion as a learning opportunity. Different learning experiences will prepare you with a diverse set of skills to stand out! You never know when you might get lucky and an opportunity comes along that would require your unique set of skills. Like they say, "Luck is what happens when preparation meets opportunity." I started to get a glimpse of the variety of pathways that are available for a science student apart from the ordinary, standard academia pathway. This project definitely helped me to stay open-minded about looking beyond a traditional career; and now, after this project, I have become involved in various student clubs that connect students to industry. The project helped me to hone my interviewing skills and build my confidence to such a degree that I decided to take up a similar project for my honours research. I designed my own questions and used these to quiz individuals to access process implementation within a corporate setting.
Student 3 ***Reflection one year after project involvement***
My involvement with the FEP taught me that scientists are just 'normal people', they're not there to be raised up onto pedestals, away from the general public with their discoveries streaming down. They put their blood, sweat and tears into hours of painstaking work, which doesn't always earn them high acclaim (and that's often not what they want). Often the joy they get from

learning drives them forward – they are always seeking out new answers. Most importantly, scientists want to share their work, often eagerly and with much enthusiasm, but an audience that understands it is increasingly hard to find.

I have learned that no-one plans their career in science. It kinda just happens…Sure expectations are laid out, goals set and interests discovered, but they often change and need to change. Sadly, many scientists get stuck in a 'dying' field and begin to be disregarded by their peers. Therefore, it is important to be dynamic and learn a variety of skills. This improves employability, and also broadens the applications of your study. Also, it's not always great, there are frustrating days!

When I started the project I just wanted to enter medicine or industry. I saw no future for myself in research and academia. By the end of the project I had a totally different outlook on what work and future I wanted. I was exposed to another side of what research actually is – self-determined, self-driven work on a project that interests me. I then used the valuable advice from my interviewees to seek out a potential supervisor who would accept me into their laboratory. Interestingly, this process was similar to what was outlined by Ben Barres in his recent publication (Barres, 2013). Currently, I am looking forward to completing my honours year and starting a PhD project.

Student 4 ***Reflection one year after project involvement***

This was my first research project. I learnt a lot about how I work independently. I found that my time management skills were lacking and I had to work to be more organised. This project helped me confirm that I like working with people. Doing the interviews themselves was when I felt most comfortable. I also learnt that I need to prepare a lot to make an interview work.

I learnt that scientists are a diverse group of people! It was good to see both women and men achieving academically and professionally. It was made clear to me that science careers don't always start with a set goal or have a defined path. Because of that it's important to try new areas if you have different interests or you are dissatisfied with your current position.

Scientists have a passion for their work and follow it wherever it goes. As result, it seems their hard work is often rewarded and they are happy with a challenge. This project has taught me a lot about what I want to get from a career in science – it's made me think about what kind of career I want to have. The idea of working in a field where I can use science but not be in a wet lab is appealing. At the moment I am taking an introductory communications course and have been in contact with a potential honours supervisor who is researching student learning in tertiary science degree programs.

Table 7: Student interviewers' reflections about professional practice and communication

What have you learnt about professional practice from your experience?
Student 2: This project has taught me the value of keeping up with deadlines, respecting other people's time and conducting myself in a professional manner. **Student 3:** I learnt about building and maintaining professional relationships with my interviewees, supervisor and associated staff. I learnt about the requirement for confidentiality and how to sensitively discuss topics which might cause some discomfort with my interviewees, but were vital to my project. And I learnt that preparation is key. **Student 4:** I learnt that there are a lot of skills taught in a science degree that are applicable to different environments. Being disciplined, performing background research, constructing a research plan and performing detailed analysis were all skills I was able to practice. I also appreciated the opportunity to establish new networks in a variety of fields.
What have you learned about communication from your experience?
Student 2: I had always recognized communications skills to be my weakness but I was never challenged me enough to make conscious efforts to improve. However, this project moved me to start making conscious efforts to improve. Good communication is more than something that helps you get good grades at university. Good communication gets grants, good papers, and the right investors to commercialize work. This project definitely proved to be a stepping stone in terms of my personal communication skills. I started to learn the skill of listening and asking questions. **Student 3:** I learnt that many different forms of media are necessary for scientists to effectively convey their work to their peers and the general public. Specifically, a lack of information seems to deter undergraduates and/or high-school students from seeking out and undertaking research higher degree (RHD) programs. **Student 4:** Before doing the interviews I wasn't aware of the importance of communication in science. Being able to express complex terms in colloquial language and create meaning in a dialogue are a great skills to have and really are necessary. This can be from tutoring students, talking to a lecturer or even when I'm writing my lecture notes.

Discussion and Conclusions

The working science graduates interviewed for Free Energy have provided a valuable resource for us as researchers, and for the thousands of students who have had the opportunity to listen to their stories. Their narratives offer a window into the vibrant, competitive, and exploratory world of a working science graduate. They allow us to see what motivates them in their careers, and perhaps more importantly, what kinds of people they are.

This information is powerful. The student interviewers experienced profound changes in their perceptions of scientists and science careers as they participated in Free Energy. We also know, from data that will be presented later, that the many undergraduates who listen to a Free Energy podcast also gain a far more detailed and realistic understanding of what it means to be a working science graduate.

We hope the BIOC2000 students will use Free Energy to evaluate their sense of self-efficacy through vicarious experience (Bandura, 1977) in the same way that the student interviewers have done. Since the effectiveness of vicarious learning depends on the similarity of the model to the audience (Bandura, 1977) we have interviewed a diverse range of people (in terms of age, gender, profession, and career stage). Not all of these interviewees will provide similar models for all listeners, however students should find some commonalities with the talent. We also hope the student interviewers will provide a relatable model of engaged, authoritative student behaviour. Whether the BIOC2000 students appreciate this, and whether they accept that the interviewers are still learning and refining their technique, remains to be seen.

The scientists interviewed for Free Energy revealed their humanity and their complex pathways to success as they spoke. It was gratifying to see the power of these stories and to bring them to undergraduate students. The student interviewers engaged with the narratives, grew as people, and reconstructed their identities and goals. We hope to see a similar effect for undergraduate students who listen to and reflect on a Free Energy podcast.

Acknowledgements

We thank the interviewees for speaking with us during the course of this study. We also thank the JAC Radio staff who gave us access to the JAC studio and taught us how to use the equipment. Kay Colthorpe generously provided critical reading of the manuscript.

References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioural change, *Psychological Review*, 84(2), 191-215.

Barres, B. (2013). How to pick a graduate advisor, *Neuron*, *80*(2), 275-279.

CHF. (2014). The Center for Oral History. Retrieved September 3, 2014 from http://www.chemheritage.org/research/policy-center/oral-history-program/index.aspx

DeHaan, R. L. (2005). The impending revolution in undergraduate science education., *Journal of Science Education and Technology*, *14*(2), 253-269.

Gascoigne, T. (2012). *Career Support for Researchers: Understanding Needs and Providing a Best Practice Approach*, Australian Council of Learned Academies Secretariat Ltd. Retrieved August 1, 2014 from http://www.tossgascoigne.com.au/docs/CareerSupportForResearchers.pdf.

Gibbs, J. W. (1873). *A Method of Geometrical Representation of the Thermodynamic Properties of Substances by Means of Surfaces*. New Haven, Connecticut Academy of Arts and Sciences.

Glaser, B. G. and Strauss, A. L. (1967). *The discovery of Grounded Theory: Strategies for qualitative research*. Chicago; Aldine Publishing Company.

JAC Radio (2014). Retrieved August 1, 2014 from http://jacradio.com.au.

Kuh, G., (2008), *High-Impact Educational Practices: What They Are, Who Has Access to Them, and Why They Matter.* Washington, D.C.; AAC&U.

Lave, J. and Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge; Cambridge University Press.

British Library. (2014). *Oral History of British Science.* Retrieved September 3, 2014 from http://www.bl.uk/historyofscience.

McInnis, C., Hartley, R., and Anderson, M. (2000). *What Did You Do With Your Science Degree? A national study of employment outcomes for Science degree holders 1990-2000*, Centre for the Study of Higher Education: University of Melbourne.

OECD. (2006). *Evolution of Student Interest in Science and Technology Studies: Policy report.* Organisation for Economic Co-operation and Development Global Science Forum. Retrieved September 21, 2014 from http://www.oecd.org/science/sci-tech/36645825.pdf

Rodrigues, S., Tytler, R., Darby, L., Hubber, P., Symington, D., & Edwards, J. (2007). The usefulness of a science degree: The "lost voices" of science trained professionals. *International Journal of Science Education*, *29*(11), 1411-1433.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching*, *36*(2), 201-219.

Science is Vital. (2011). *Careering out of control: a crisis in the UK science profession? A report prepared by Science is Vital at the request of the Rt Hon David Willetts MP, Minister of State for Universities and Science*, Science is Vital.

Stephan, P. (2012). *How economics shapes science*. Cambridge, MA, USA; Harvard University Press.

Tytler, R. & Symington, D. (2006). *Boosting science learning - what will it take?* ACER Research Conference, 2006. Retrieved September 3, 2014 from http://research.acer.edu.au/research_conference_2006/16.

Tytler, R. (2007). *Re-imagining Science Education: Engaging students in science for Australia's future*, Victoria: ACER Press.