Peer review role-playing as a method of teaching senior undergraduate science

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Abstract: *We present a case study of the use of role-playing as a method of enhancing course delivery in senior undergraduate science courses. Specifically we examine the use of simulating peer review of scientific proposals for time on major international telescopes in a third year astrophysics course at the University of Tasmania. We find that 90% of participating students found the experience to be both enjoyable and a good method for learning and that 100% of students felt that the exercise had aided their understanding of the course material. Furthermore 80% of students felt that the role-playing had enhanced their understanding of scientific decision making while 70% believed that they had learnt to apply principles from the course in new situations.*

Keywords: Role-Playing; peer assessment; physics and astronomy; Generation Y.

Introduction

Role-playing is an extremely effective method for exploring the issues related to a particular complex social situation. The act of role-playing allows students not only to assimilate core knowledge but to learn and practice related skills, such as creative and rational thinking in a realistic situation. In addition, role-playing allows an iterative process of interaction, risk-taking, self-expression and feedback (Blatner 2002) that in turn re-enforces the skill set. Finally, participants tend to view the exercises as something other than traditional learning and thus are much more predisposed to acquire information than in more passive educational environments. Thus, role-playing plays a triple-pronged function in education, serving to motivate students, augment traditional curricular and develop generic skills.

Role-playing has long been known as an effective teaching tool and role-playing techniques have been successfully used to teach courses in humanities units for many years. Recently there has been an increase in the use of role-playing and other active learning techniques in science and mathematics courses. However, while much effort has gone into using role-playing scenarios to teach junior level courses including first year astronomy (Francis and Byrne 1999), little has been attempted at a senior level. We present an exercise aimed at using role-playing in the context of peer review of scientific proposals as a method of not only re-enforcing course content, but giving students valuable insight into modern scientific decision making and providing an active and effective method to enhance generic attributes such as critical thinking, data synthesis and communication.

Telescope proposals and the establishment of a Time Assignment Committee

All scientists will be familiar with the process of writing proposals to be reviewed by their peers. Be it funding requests, fellowships applications or requests for equipment and services, scientists spend a large amount of time justifying projects to their peers. Yet science graduates are often poorly prepared for this type of activity (Jagger, Davis, Lain, Sinclair and Sinclair 2001). Previous research indicates that students taught with conventional methods, even those who perform well in traditional assessment, often lack the ability to apply their knowledge in real-world situations (Francis and Byrne 1999). This tension between content-based knowledge and factual or practical knowledge (i.e. knowing versus doing) is commonplace in both the higher education sector and the business world. Whereas higher education has been less forward in addressing the integration of content-based and practically-based knowledge, still relying strongly on traditional content delivery (particularly in the physical sciences), the business sector has readily embraced techniques to enhance the links between the two.

Students were told that they would have to write a proposal to ask for time on a major international telescope at the start of the semester. The proposal would be based on an original scientific idea and the students would work in teams (similar to scientific collaborations) to work out what science drivers they wished to pursue and consequentially which instrument they should use. As a senior undergraduate class, most students had already taken at least two other units in astrophysics (each worth 12.5% of a year), so their exposure to the subject material was high. In addition, the lecture course was structured such that science done with current instruments was highlighted throughout the first half of the course before the proposal work began. Students were forewarned that though they would work in teams to come up with an idea they would write individual proposals. Finally, they were told that, like a real telescope proposal, their proposals would be (anonymously) assessed by their peers as part of a role-playing exercise based on a telescope Time Assignment Committee (TAC). Marks for the subject would be awarded for the proposal itself (as assessed by the academic in charge) and for participation in the time assignment committee exercise. The marks were split such that the proposal was worth 10% of the final grade and participation in the TAC was worth 5% of the total mark. Participation in the TAC exercise was made relative to a predefined set of criteria. Marks were given out of five and students obtained one mark for each of the following: attendance; reading the proposals prior to the meeting; providing at least one comment on each proposal; technical comments on those proposals which involved the same instruments which they themselves were proposing to use; and provision of detailed comments for a range of instruments/proposals beyond their own instrument.

The whole process ran for five weeks and was broken into six components:

- generating an idea;
- researching the idea;
- writing a proposal;
- reviewing proposals by other students;
- holding a time assignment committee meeting; and
- providing peer feedback.

The first three activities corresponded to the creation of proposals, while the last three formed part of the TAC role-playing exercise.

Generating an idea

Before the exercise commenced students were given an introductory lecture on applying for telescope time. This lecture discussed the way proposals are structured, how time is awarded, what reviewers are looking for and commonly made mistakes. The need for proposals in other scientific disciplines was also stressed. In addition students were given actual successful telescope proposals for some of the instruments that had been discussed in the lecture course to use as guides.

The exercise commenced with a tutorial session where students were divided into groups of four and asked to brainstorm a question or idea they were interested in researching. The tutorial was conducted by the lecturer who spent time with each group helping them formulate an idea and gently guiding them towards consensus on a testable hypothesis. Students were asked to pick a particular wavelength regime and hence instrument to focus on in order to test their questions. Science drivers ranged from searching for exo-planets with microlensing to examining the role environment plays in the generation of radio galaxies. All of the science drivers the students came up with were entirely plausible fields of cutting edge research.

Once groups had selected an instrument and science driver they were asked to come back to the lecturer in a couple of days and collect an information packet. The lecturer then provided three to four relevant research papers on each group's topic and the manual for the instrument the students intended to use. Students were asked to spend the next week reading the reference material before the next tutorial that addressed the finer points of how to apply for time.

Researching the idea and writing a proposal

At the second tutorial session students were again divided into groups and asked to discuss their proposals in detail, how they related to the most recent work in the field (as discussed in the research papers provided) and what issues relating to the instrument configuration were relevant. During this session the academic again spent time with each group answering technical questions about each project and the instruments in question.

At the end of the second tutorial all of the groups had a clear idea of what they wanted to do and how they could do it. They were then set a list of calculations to obtain the amount of telescope time they would need for each experiment. As each group had different science drivers and were using different instruments this was unique for each set of students. The groups were allowed a week to do the calculations and a week to write the proposal. During this period each group met again with the lecturer to discuss further details, receive help and correction with calculations and obtain writing tips.

Reviewing proposals by other students

The class was divided into two Time Assignment Committees to assess the final proposals. Each committee was comprised of half of the members from each student group. The proposals from each half of the class were then distributed anonymously to the other half of the class and students were given one week to read the proposals before the TAC meeting was convened. The students were asked to assume typical roles that are found on a Time Assignment Committee to inject realism into the exercise. This included a chair, secretary and technical experts for each TAC. Chairs were told that their role was to run the meeting, keep the discussion going and interpret the collective opinion of the members of the TAC. As in a real TAC students were only given a limited time (10 minutes) to consider each three-page proposal, thus it was extremely important that the chairs kept the meeting on track.

Secretaries were instructed to collate the comments of the TAC which would be provided (via the lecturer) to each of the proposers. This served the dual purpose of simulating the outcomes of a real telescope proposal and to give students the experience of constructing and receiving peer review. Technical experts were told that their role was to provide the other members of the TAC with information on the strengths and weaknesses of the proposals submitted by their former fellow group members. In addition, all students were asked to assess the scientific merits of each proposal and to rank each proposal. Specifically they were asked to consider the points relating to how well each proposal communicated the scientific goals and what the technical aspects of the request were. In particular they were asked to consider:

- Is it well written?
- Is there a clear, and more importantly, achievable scientific goal?
- Does the potential science justify the amount of time requested?
- Is it technically feasible?

Prior to this exercise students had only been exposed to their own idea and the telescope related to their own proposal, thus it was necessary to ask that before assessing the other proposals they obtained some background for the other telescopes that their peers were using. Abridged information on each instrument was thus provided by the lecturer when the proposals and TAC roles were assigned.

Holding a Time Assignment Committee meeting and providing peer feedback

Time assignment committee meetings were convened by each student chair at a mutually agreeable time about one week after the proposals and roles had been distributed. The TAC discussed each proposal in turn and then provided a score out of 10 and a percentage of time awarded. The lecturer sat in on the TAC meeting as an observer but did not interfere with the meeting.

The meetings were absolutely fascinating. The students all took their roles quite seriously and some went so far as to actually play the roles of busy astrophysicists claiming they had read the proposals on the plane flight to the TAC meetings and that they had other meetings to get to later in the day! About 90% of the students had come extremely well prepared to the meetings and had read all of the proposals and the background material. These students genuinely seemed to enjoy the exercise and did an outstanding job reviewing the proposals, often finding subtle flaws that could easily be missed. Not surprisingly, the students that had not prepared for the meeting were fairly obvious and did not seem to enjoy the experience as much as their more organized classmates.

Students quickly discovered the type of things that really make a difference to proposals, particularly when reviewing several proposals for the same experiment on an instrument. They also soon identified common mistakes that proposers make such as incorrectly calculating the time required for the observations as well as stylistic errors such as going over the page limit and failing to provide adequate abstracts or summaries, with one student commenting 'I really hate it when there is no abstract stating a clear objective, I don't have time to trawl through pages of text to find out what you want to do!'.

Another often heard comment from students was '*I don't have confidence in this proposal*.' Like a real TAC the students needed to be convinced that the authors actually understood the science behind their proposals and that they knew what to do with the data once it was taken. Several of them were surprised that this played an important role in scientific decision making but seemed genuinely satisfied that they had discovered this fact for themselves. The use of diagrams and figures was also particularly strongly criticised by students. 'What is the point of that figure? They don't even discuss it in the text. I just don't see how that is helping their argument.' was one response to which fellow TAC members concluded it was just filler to get to the page limit. At the end of the exercise one of them stated that he understood now that it was more important to be clear and concise than to waffle and fill up the space with useless text or figures.

When it came to assessment the students were surprisingly hard on their peers with an average score of only 4/10 given for the class. The maximum mark was only 6.5/10 and the minimum was 0.5/10. Nevertheless 36% of proposals were successful and were awarded some or all of the time they requested, which is similar to the real telescopes where somewhere between 15% and 50% of proposals obtain time.

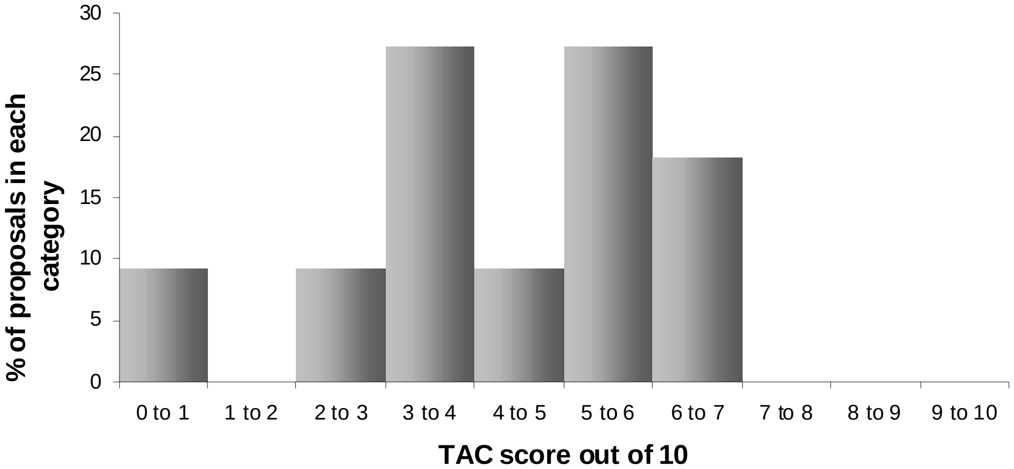

Figure 1. Distribution of marks generated by the peer assessment of telescope proposals

At the conclusion of the meeting the TAC secretaries wrote up comments which were passed back to their peers via the lecturer. Typical comments included:

- Need to explain how the data will be used to fulfil the science goals.
- The introduction goes round in circles and repeats itself.
- Demonstrates a good understanding of what the data will produce.
- Needs to summarise data found in previous studies.
- A detailed background should be provided for all primary goals.
- The issue of why X-ray [observations] must be used as opposed to radio [observations] should be addressed.
- Bias in the data needs to be further addressed.
- The proposal has good, clear aims.
- Haven't justified why so much time is needed – proposal is not feasible.
- Needs a better justification – specify how long and how many exposures will be expected?
- Apply again – overall a good proposal, just needs to be a bit more specific especially [about] time and which bit of the hardware you are going to put to use.

In addition to the comments the students were given a graph of the distribution of scores out of ten (Figure 1) so they could see how their proposal was placed in the overall class distribution. At a final wrap-up tutorial the statistics of the time assignment process were discussed and the students were afforded the opportunity to ask questions about the process. This was particularly important due to the severity of the marks of the TACs which, without being placed into context, would have caused some students to feel discouraged due to very low marks. At the conclusion of the tutorial most students were happy if they had achieved a mark of at least 2.5/10 as this was within one standard deviation of the mean of the distribution.

Baring the severity of the TAC comments, there was a reasonable correlation between the marks awarded by the academic and the students for each proposal with the students ranking each proposal in roughly the same order as the academic. The average mark awarded by the academic in charge was 6.6/10 and the lowest mark was 4/10 with the same standard deviation as the students (~1.5) meaning that on average students gave their peers roughly 60% of what the instructor awarded. Only 10% of scores differed wildly between the academics perceptions of the proposal and that of the students. In these cases the students assessed the proposals much less favourably. One reason that might account for this was that these tended to be proposals heavily laden with jargon which relied on the background of the reader more heavily, rather than setting out the goals clearly. This will be something that will need to be monitored in future.

Student feedback

The usefulness of the TAC exercise was assessed via a set of questions given to students at the end of the course as part of the University of Tasmania's standard 'Student Evaluation of Teaching & Learning' process. Students were asked a series of questions relating to their experiences in the TAC sessions, responses were of the form of agreeing or disagreeing with the proposed question or statement using scale of 1 to 5. Results of the questions concerning the usefulness of the TAC exercise as a method of enhancing the course (shown in Figure 2) were overwhelming positive.

The responses indicated that 90% of participating students enjoyed the activity and found the experience to be a productive method of learning and all students agreed that the exercise had aided their understanding of the course material (even the 10% who thought it was not a useful exercise still believed it had aided their understanding of the material).

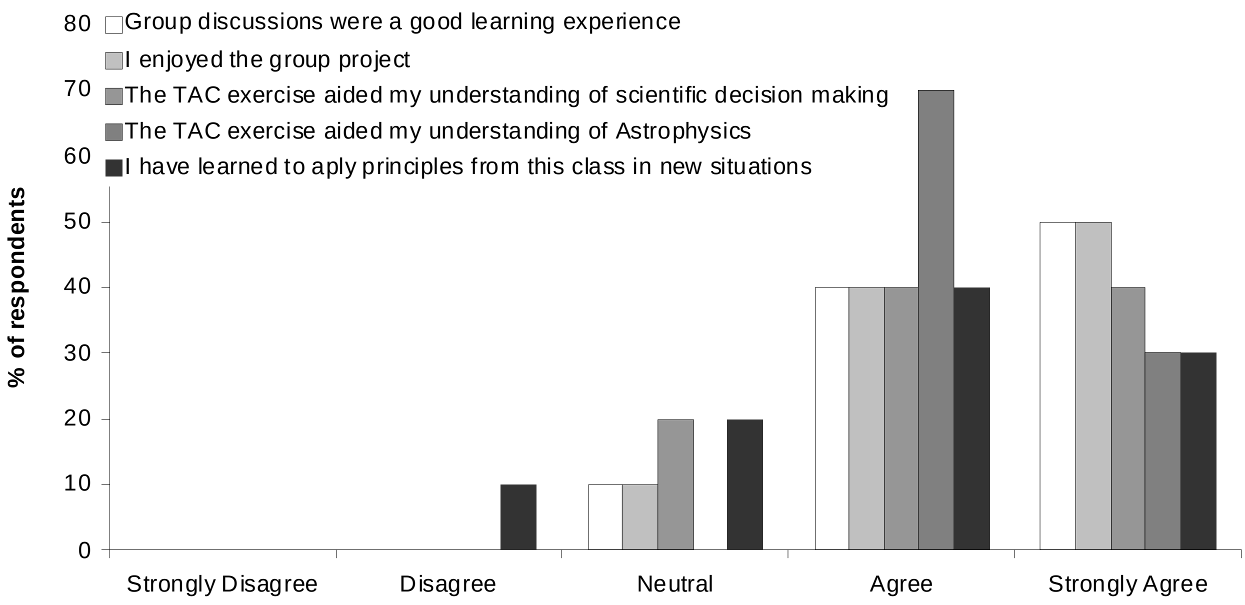

Figure 2. Results of the student feedback on the proposal writing and time assignment committee exercise. The columns represent the response students have to each of five questions relating to the teaching method.

Material assimilated in this exercise included: understanding the use of a radio interferometer; understanding the evolution of large-scale structure in the Universe; understanding X-ray emission processes in galaxy clusters; understanding properties of radio galaxies; and principles of optical astronomy, all of which formed part of a course which was delivered traditionally via lectures. In addition 80% of students felt that the role-playing had enhanced their understanding of scientific decision making while 70% believed that they had learnt transferable skills that they could apply in new situations.

In addition to specific comments regarding the exercise, students were also asked to comment on the level of effort expended compared to other units. 70% of students believed the workload to be appropriate and 30% responded that they were neutral about the issue of workload. No students thought the workload was inappropriate and no comments to this effect were received, suggesting the TAC exercise was considered an equal amount of work compared to the more traditional written assignments undertaken in other courses.

The TAC exercise was also consistently listed as the best aspect of the course by all students who chose to give written comments with statements such as 'The TAC stuff was an interesting exercise' and 'Real world applications, role-play and [the] TAC helped.' being typical.

Reflections and positive outcomes

During the course of this task we discovered several important results which will influence future activities of this type. The most obvious results were how best to make the students engage in the activity which primarily related to the size of each group, the way the activity was initiated and the interactions with the lecturer. However, there were also additional, more subtle positive results.

Francis and Bryne (1999) found that groups of two or three were optimal for first year based astronomy role-playing as otherwise less verbal students ceased to play an active role. However, in their exercise the students were much more junior to the ones we were teaching and students were not assessed on their participation. For this exercise we found that groups of four were most suitable because there needed to be sufficient students to really discuss the problem and because each student was assessed not only on their report but also on their participation there was sufficient incentive to actively engage in the exercise. In fact we found in previous years that groups of three lacked sufficient breadth to cover the topic actively and tended to fall behind while groups of five tended to be too large and loose focus and it was in these groups that less able students ceased to engage.

To improvise effectively students need a feeling of relative safety and at least some familiarity with their peers and the situation at hand. In order for role-playing exercises to be successful, this rapport should be cultivated first via a series of introductory exercises (Blatner 2002). The role of the initial tutorials and breaking the students up into groups and the informal group discussions before writing the proposals served to introduce students to their peers in an informal way and establish a pattern that allowed students to feel comfortable not only voicing their opinions but to see the opinions of their peers as constructive rather than hostile or negative. The group nature of the tutorials was an important part of the process which facilitated the speed of communication (DeBord 1989). The feeling of relative safety and rapport within the class was further enhanced by a group visit to two of the University's nearby telescopes followed by an informal question and answer session at a barbeque.

Even in an Australian cultural context, where students are generally reluctant to display lack of understanding or limited knowledge in front of their peers, the TAC meetings worked surprisingly well. This was attributed to the class having been properly de-sensitized to the process via the introductory tutorials.

In order to succeed such activities do require a fair amount of preparation. The academic involved must not only ensure that the initial activities serve as a successful spring board for further participation but must also go to some effort to assign roles and establish boundaries for the exercise if it is to be a success (DeBord 1989). It has been further suggested that without significant enthusiasm on the behalf of the academic the exercise, however well planned, may still fail (DeBord 1989). The process did require a significantly increased workload for the lecturer. In addition to the administrative increase of preparing background information, assigning roles, marking proposals and sitting in on TAC meetings, each group had to be given three to four research papers to read in addition to telescope manuals and associated documentation and the academic had to be familiar with all of this material. While this was relatively straightforward for telescopes and topics connected to our main research interests it did require quite a bit of additional high-level research in fields we were not experts in. The one-on-one meetings with groups during the proposal writing stage also added another eight to ten contact hours on to the course, which represents a 25% increase on the standard lecture load. Having said that, the workload is somewhat reduced every year the exercise is run so while the initial investment in set-up is quite high, repeated use comes at not too high a price.

In addition to the clear enhancement of the traditional curricula of the course as demonstrated by the fact that all students felt the exercise had helped them learn about astrophysics, the task also provided an opportunity to increase students' generic attributes. There is an increasing desire for improved generic skills in graduates from all sectors and particularly those in the physical sciences (Mendez, Mills, Pollard and Zealey 2005). Czujko (1997) shows that the top three skills required by private sector or government employers of physics graduates in the United States were generic problem solving, interpersonal skills and technical writing. In the UK postgraduate physics graduates who ranked highly on problem solving skills still exhibited poor communication and teamwork ability (Jagger et al. 2001) and the situation is likely to be similar in Australia. In Australia it seems that teamwork, flexibility to new situations, oral, and to a lesser extent, written communication skills of science graduates still fall short of employer expectations (McInnis, Hartley and Anderson

2000). The need to improve generic skills is clear and tasks such as the one described here could play a valuable part in redressing the perceived skills deficit in current graduates. Our example certainly allows students to work on the problem solving, interpersonal skills and technical writing desired by American employers and in addition enhances teamwork, flexibility and oral and written communication ability which are desired by Australian recruiters.

Another strong positive outcome of the program was the improvement of the teaching-research nexus. In a recent study about one quarter of all Australian Physics departments viewed the teaching-research nexus as a strength of their educational programs (Newbury and Sharma 2005). The University of Tasmania has a very strong research tradition in Astrophysics and courses on the topic are taught at all undergraduate year levels, however this is the first opportunity students have had to engage in a life-like research exercise based on the discipline. Several of the students that participated indicated at the conclusion of the course that this had cemented their choice to continue on to honours in astrophysics, thus, at least anecdotally, there has been a positive follow-on effect to the local research effort.

Finally, although role-playing as a technique is known for its ability to engage students we were struck by just how enthused the students were using this methodology over other group-based teaching programs that had been used on the same cohort of students. In fact every single student attended all of the tutorial sessions and meetings relating to the proposals and TAC tasks, which by comparison to other classes and group work conducted for the same cohort was nothing short of extraordinary. One explanation is that this particular educational tactic was more broadly appealing as it tapped into several of the key learning preferences of the students. Jonas-Dwyer and Pospisil (2004) list the following as being characteristics for Generation Y learning preferences:

- technology;
- entertainment and excitement;
- teamwork;
- structure (which activates and motivates); and
- experiential activities.

It would seem that the proposal writing and TAC exercise covers all of these learning preferences and that this is likely to account for the overwhelming success of the endeavour.

Conclusions

In order to most effectively teach physics to modern students, universities needed to adapt to changing social and economic conditions which include a changing student cohort, an employer driven value shift away from traditional discipline based knowledge to more generic skills in graduates and the emergence of new technologies. It was suggested in the recent report on the way Physics is taught in Australia commissioned by the Australian Universities Teaching Committee that one of the ways that universities could accomplish this was by ‘providing opportunities for group work, hands-on real world activities with clear goals and explicit assessment criteria’ (Low, Wilson and Zadnik 2005).

We have developed a six week teaching plan involving collaborative work, role-playing and peer review based on the real-life model of proposing for, and assessment of, time on international telescopes that fulfils this recommendation. The plan has been extremely successful at not only motivating the students and augmenting traditional curricular but also at developing highly desirable generic attributes. Thus, the teaching plan has provided a three-pronged success story for novel teaching and learning methodologies. In particular the teaching plan was able to actively engage all of the learning preferences of Generation Y students, thus giving the broadest possible appeal to today’s student cohort which is known to be much more diverse than previous generations (Low, Wilson and Zadnik 2005).

Undergraduate astronomy and astrophysics courses are currently offered at approximately 20 Australian universities (Johnston-Hollitt et al. 2005) with around 270 equivalent full-time student units (EFTSUs) per year credited to astronomy related courses in the period from 2000 to 2004 (Gibson, Maddison, Sim, Tzioumis and Webster 2005). Typically such courses represent a one eighth load and so this approximates to 2160 students annually (Johnston-Hollitt et al. 2005). While such courses tend to focus on first year astronomy which is too junior a level to adopt the teaching strategy described here, about 26% of all Australian Astronomy courses are pitched at 3rd and 4th year students for which the peer assessed role-playing methodology could be of value.

Additionally, although this methodology was developed originally for astrophysics, the concept is readily extendable to any science or even humanities field in which access to shared or distributed resources must be obtained via peer-reviewed proposals. We would therefore, recommend this methodology to other educators as a way to engage students, enhance core course content and provide realistic experiences of the complex social phenomena associated with modern academia.

Acknowledgements

The original idea for this application was first inspired after the author, who was at the time a student, attended a two hour postgraduate role-playing workshop based on TACs run by Paul Francis at the 1997 Harley Wood Winter School. In this workshop Paul provided students with TAC personas and fake telescope proposals to review. The following year she was fortunate to run the 1998 Harley Wood Winter School at which Paul gave another two hour postgraduate workshop using role-playing as a technique to examine funding of future telescopes (Francis and Byrne 1999). Paul’s original idea to have students discuss proposals sowed the seeds for this current work which has obviously been greatly expanded from a 2 hours session to a 6-week program about applying for time on existing instruments, nevertheless The author is indebted to Paul Francis for providing this inspiration so many years ago. The author would also like to acknowledge the comments and suggestions of anonymous referees which have added to the depth of this paper and will assist in future research of this kind.

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