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The SPIRIT Telescope initiative: Engaging students in contemporary astronomy

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Abstract

Now in its seventh year, the SPIRIT initiative remains unique in Australia as a robust web-enabled robotic telescope program funded for education and research. With multiple modes of operation including real time control, SPIRIT provides free access to contemporary astronomical tools for students and educators in Western Australia and beyond. The internet enabled telescope solution itself has proven an excellent model for low cost robotic telescope deployments, and the supporting education program has evolved over time to include a broad range of student engagement activities as well as opportunities to undertake authentic science. This paper summarises the technical solution and education program, and also examines the results from a recent Girls in STEM program of activities.

Keywords

robotic telescopes in education; internet enabled telescope; astronomy outreach; girls in STEM

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Introduction

The reality that modern observational astronomy is accomplished through the use of robotic telescopes is reflected in numerous initiatives that offer remote telescope access for education and outreach (Gomez and Fitzgerald, 2017). Located at The University of Western Australia (UWA), the SPIRIT Initiative has been in operation since 2010, providing educators and students in Western Australia free robotic telescope access (Luckas, 2017). The original design goals included:

- A robust technical design centred around the use of commercially available components.
- Access remotely via browser and suitable for low internet bandwidth regional schools.
- A flexible web-interface catering for a range of student abilities and goals.
- A solution that offers remote real-time and advanced unattended telescope control.
- A supporting education program that includes professional development opportunities and on-line resources.

The technical solution (Luckas, 2013) has remained essentially unmodified since this time and SPIRIT enjoys high participation rates—routinely booked for much of the first semester observing season. The education program has expanded over the past 7 years to include a range of engagement and knowledge-based experiences. Hundreds of students from dozens of schools throughout Western Australia have used SPIRIT to undertake authentic science in areas such as photometry and spectroscopy. In some cases, their achievements have been professionally accredited.

Technical solution

The SPIRIT telescopes are located on the roof of UWA's School of Physics, housed within fibreglass domes. Rotation and shutter control are fully automated, including redundant weather aware monitoring via cloud sensors. Both telescopes use commercial robotic telescope mounts that deliver accurate targeting and tracking error correction through integrated control software. Exposures of up to 300 seconds are easily achieved at all telescope orientations with stellar profiles exhibiting negligible trailing artefacts.

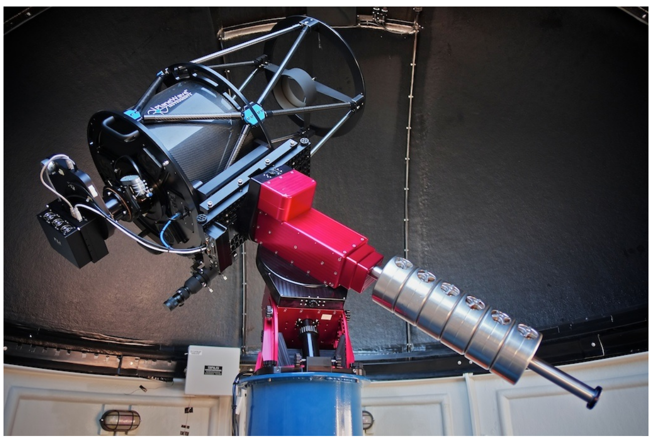

Figure 1. *The SPIRIT II Telescope*

SPIRIT I utilises a 0.35m f/11 Schmidt-Cassegrain telescope paired with a CCD camera providing a square field of view of 20 arc minutes. Commissioned in 2012, SPIRIT II includes a more sophisticated 0.43m f/6.8 Corrected Dall-Kirkham telescope and a larger CCD sensor providing a square field of view of 40 arc minutes. Both systems have been optimised to produce stellar profiles that meet a 2-3 pixel FWHM ideal under the comparatively poor skies of UWA.

The SPIRIT I and II imaging systems include software controlled filter wheels that provide access to both photographic and photometric filters. The image train on SPIRIT I is supported by a large temperature controlled focuser that maintains focus throughout the night via a temperature probe attached to the side of the aluminium telescope tube. The carbon fibre truss construction of the SPIRIT II telescope provides a thermally stable support for the optics negating the need for nightly focus adjustments.

Using stacking techniques, student measurements of a magnitude 19.5 minor planet were achieved with the 0.35m SPIRIT I telescope and successfully submitted to the Minor Planet Centre in 2011. Photometric studies by students of brighter than magnitude 16 stars with exposures of 180 seconds or less routinely yield software determined magnitude errors of around 0.03 or better for targets whose brightness is above sky background and read noise levels.

A single server model is employed in each of the SPIRIT observatories with device control centred around ASCOM compliancy (ASCOM, 2017). Web-enabled access is achieved using ACP Observatory Control Software (Denny, 2006) and users are able to access and control the SPIRIT telescopes using any modern browser on both desktop and mobile platforms.

Spectroscopy

SPIRIT II includes a web-enabled spectroscope mounted to the top of SPIRIT II comprised of an 80mm refracting telescope, a 100 lines/mm transmission grating and a video camera. It produces a real time, low resolution spectral image of bright targets with a spectral dispersion of approximately 10 Angstroms per pixel. The entire visible spectrum—from ultraviolet to infrared—is contained on a single image taken by the camera. Spectral profiles are viewed on the web interface in real time and users can also download data for subsequent analysis. Students are able to interactively learn about the temperature profiles and chemical signatures of stars, reproducing the foundational work of those such as Edward Pickering and his team at Harvard in the early 20th century.

Access and use

The SPIRIT initiative is hosted by the International Centre for Radio Astronomy Research (ICRAR) and funded as part of outreach and education. As remote telescopes, SPIRIT I & II also service student and research requirements as UWA's campus observatory. Access is provided through the SPIRIT web site (http://spirit.icrar.org) which contains a description of the program, access to guides, activities, image galleries and a news blog. The telescope access page includes links to current weather information, as well as the calendar and booking form.

Modes of Operation

The telescope web interface offers a choice of operating modes that provide a pathway for students to develop their skills. 'Mode 1' allows novice students to control the telescope in real time, acquiring images with different filter and exposure combinations as they monitor operations through the browser interface.

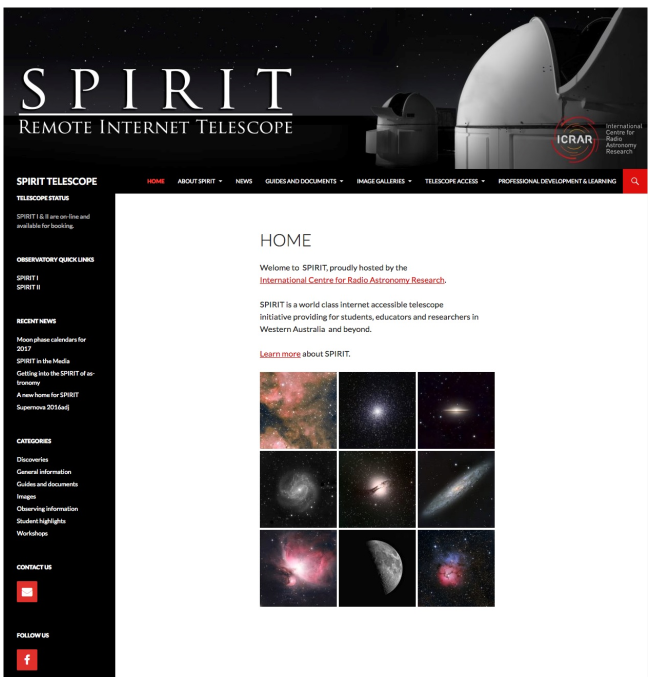

Figure 2. *The SPIRIT initiative's home page at http://spirit.icrar.org/.*

A web cam inside the observatory provides additional visual feedback of dome and telescope operations. Fixed and moving object databases accessible through the imaging interface negate the need for novice users to have knowledge of the celestial coordinate system or moving object ephemerides. 'Mode 2' allows more experienced users to undertake multi-target imaging using a range of exposure and filter combinations. Using an intuitive directive-based format, sophisticated text based observing plans can be uploaded and run at the time of booking. This mode is typically used by students undertaking long term monitoring of variable stars, minor planet astrometry and survey work. It also provides an efficient means of servicing collaborative work, where many students submit observation requests coordinated by a teacher or group leader.

For the vast majority of students, mode 1 offers a reliable method of acquiring images, engaging them in a fun and intuitive way. Mode 2 allows advanced students to undertake astronomical data collection in an identical way to professional astronomers.

Both RAW and calibrated FITS files can be downloaded directly from within the web interface or via FTP. High quality JPEG versions of each image are also automatically generated at the completion of each target, providing students with 'instant satisfaction' and a means to monitor image quality in real time. JPEG versions have also proven sufficient for basic student engagement activities including colour astrophotography.

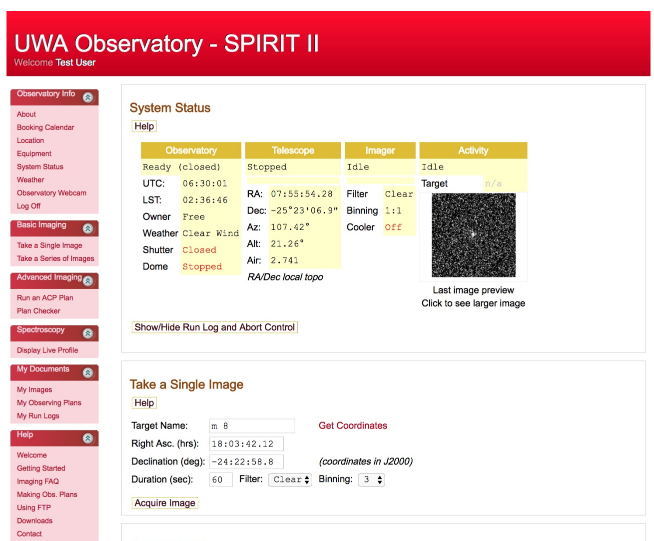

Figure 3. *The SPIRIT II telescope web interface.*

Education Support

Student-centred workshops are offered at no cost to metropolitan schools for groups embarking on school-based programs. These usually start with an engagement cycle of activities, where students are introduced to the mechanics of the night sky, learn how to remotely access and use the SPIRIT telescopes, acquire images and undertake basic image processing. Packaged as “SPIRIT 101”, these activities provide an engaging way for students to learn about contemporary observational astronomy before embarking on more challenging activities. With the completion of SPIRIT 101, a number of advanced activities become available, including:

- Targeting and imaging asteroids with SPIRIT. Students learn how to target and observe minor planets using the SPIRIT telescopes.
- Astrophotography with SPIRIT. A workshop covering both basic and advanced image processing techniques, enabling students to create stunning colour images of astronomical objects.
- Advanced astrometry with SPIRIT. An advanced minor planet workshop with students submitting observations to the Minor Planet Centre for publication.
- Variable star photometry with SPIRIT. Students undertake photometric observations of short period variable stars with an option to submit observations to the American Association of Variable Star Observers (AAVSO) database (AAVSO, 2017).

Advanced activities often form a component of existing academic extension programs in what is an astronomy-poor state and federal science curriculum in Australia. Remote and regional schools are uniquely positioned to take advantage of SPIRIT’s web-enabled interface and tailored learning programs are available to service regional schools at a small cost.

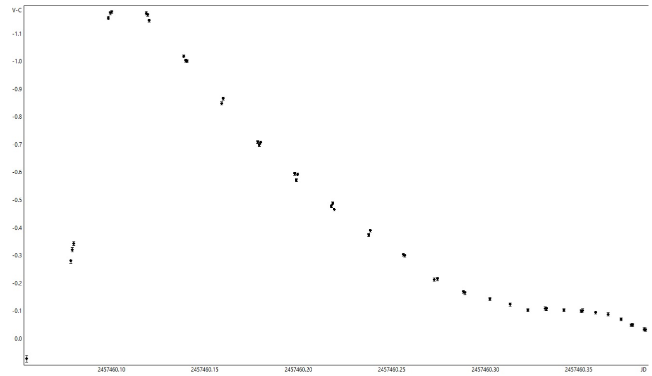

Figure 4. *Student light curve data of the RR Lyrae variable star FX Hya submitted to the AAVSO (Victoria Wong, 2016).*

Girls in STEM

The last few years have witnessed an increasing recognition of the need to encourage more girls to study science (Australian Government, 2017). During 2015 – 2017, pilot projects involving students from a local girl’s school in Perth were initiated as part of Girls in STEM outreach activities using SPIRIT. The project forms part of the school’s science extension program for selected Year 9 and 10 students. The Year 9 project runs for a term, introducing students to remote observational astronomy using SPIRIT in the form of an astrophotography project, where students create photobooks showcasing their work, image processing techniques and basic explanation on the astrophysics of the objects that they observed. In Year 10, these same students undertake a photometry project. Running for approximately one term, these students undertake planning and observation of selected short period variable stars, analyse and create light curves of their results, write up their work and submit observations to the AAVSO. The 2017 program included a post project survey. Although initially designed as a feedback mechanism for informing the SPIRIT program, the survey results provide the impetus to investigate a more formal and long term research project incorporating SPIRIT use and student perceptions.

Survey Design

Surveys were designed primarily as an outreach feedback mechanism for each of the two activities;

the Year 9 (14-15 years of age) astro-imaging activity, and the Year 10 (15-16 years of age) light curve photometry activity. Of note, the Year 10 students had undertaken the Year 9 activity in the previous year, though no feedback survey was undertaken at that time. Both surveys were anonymous, polling students for their general impressions, what they enjoyed the most and what they found difficult. Where students were given a choice of answers, rather than the opportunity for an open ended response, choices were displayed in a random order to each participant. Functional feedback questions were aligned to tasks within each activity. Extended questions on different elements of each program as well as their relative importance were also included. In the case of the Year 10 survey, additional questions were included to rank elements of the photometry activity by importance as well as a question on whether the activity might influence their choices about future study. Copies of both the Year 9 and Year 10 feedback surveys are included in the appendices.

Year 9 Results

The sample size was 15 with a 100% response rate. In general, students ranked the program as 'Interesting' rather than 'Boring', with all responses ranked above 'OK' (question 1). The average was 6.13/7 with one third of students ranking the activity at the maximum value of 7.

The majority of students agreed that they would like to use SPIRIT again, with 7 of 15 students assigning a maximum value of 7 for question 5.

In question 6, students rated the relative difficulty of three tasks:

- Ease of booking and accessing SPIRIT
- Operating SPIRIT / Acquiring images
- Processing images

Using SPIRIT to acquire images, as well as processing those images showed a large spread across all difficulties (except 'very hard'), with fairly even numbers across all responses. Booking the telescopes was reported as the easiest task to accomplish.

Student Comments

Student comments were generally very positive. 12 out of 15 respondents said their favourite part of the project was seeing the final images of the objects (question 2). "Beautiful", "amazing" and "successful" were common descriptions.

Some comments reflected a sense of privilege in gaining access to use SPIRIT:

> "I liked that it isn't a common thing for students to do and that only professional scientists and us are able to use SPIRIT."

Three broad themes appear to emerge from the responses to question 4 - "What was the most important part of this project for you?"

- Learning a new skill/new area (5/12 respondents)
- Taking the images themselves (5/12 respondents)
- Discovering that something which had seemed difficult at first was achievable (2/12 respondents)

One student responded with:

> "Being able to take pictures of the sky easily and knowing that something that had seemed so difficult and mysterious was actually quite easy and fun."

Year 10 results

The sample size was 14 with a 100% response rate. In general, students ranked the program as 'Interesting' rather than 'Boring', with all responses ranked above 'OK' (question 1). The average was 6.14/7 with 5 of the 14 students ranking the activity at the maximum value of 7, an almost identical result to the Year 9 responses.

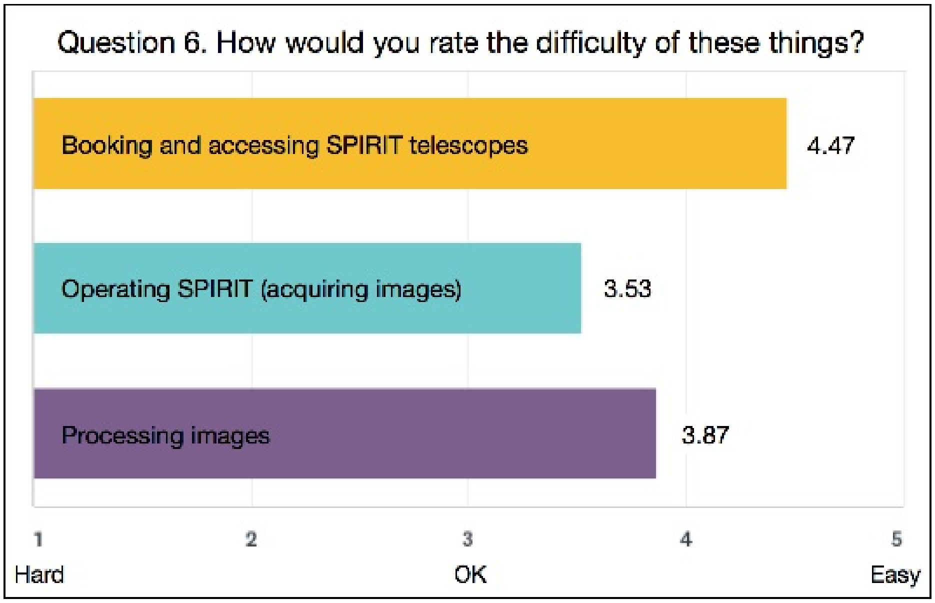

Figure 5. *Student rankings on the relative difficulty of three different tasks in the Year 9 activity. Responses range from 1 (very hard) to 5 (very easy). The average score is also shown.*

When asked about using SPIRIT again in the future (question 5) the average score of 6.07/7 indicating that the significant majority of students would value such an opportunity (7/14 students assigned this a maximum value of 7).

In question 6, students rated the relative difficulty of three tasks:

- Ease of booking and accessing SPIRIT.
- Operating SPIRIT (acquiring data).
- Undertaking photometry measurement and analysis.

Operating the SPIRIT telescopes to acquire data and booking the telescopes were generally reported as easy tasks (averages of 3.93/5 and 4.21/5 respectively). Of note, while the booking processes is identical for both Year 9 and 10 activities, the Year 10 data acquisition process is a significant step up, and includes mode 2 unattended and scripted data collection. Completing the photometry measurement and analysis was seen as the hardest task, with an average response of 3.07/5, with the majority of students rating the difficulty as 'OK' (rather than 'Hard' or 'Easy').

In question 7, students were asked to select their favourite of three principle elements; observing, analysis and research. 10 of the 14 students marked 'Observing with SPIRIT' as their favourite, with the remaining 4 respondents selecting the 'analysis' component.

Perceived Importance

Students were asked to rank five different aspects of the photometry program with respect to 'importance' (question 8). The majority of students ranked 'Getting to control the SPIRIT telescope yourself' highest, with 'Being able to use your own data in science' most commonly ranking second. 'Learning about modern observational astronomy' and 'Learning about variable stars' were least valued. Only one student ranked 'Submitting data to the AAVSO for professional credit' as highly important.

When asked to rank the degree to which using SPIRIT had influenced their decision to study science (question 11), only 4 students indicated that SPIRIT had significantly influenced their decision about future study in science, with three ranking the likelihood as 5/7 and one at 6/7. The average response was less than 'Maybe' with one student ranking the likelihood as 'Not at all'.

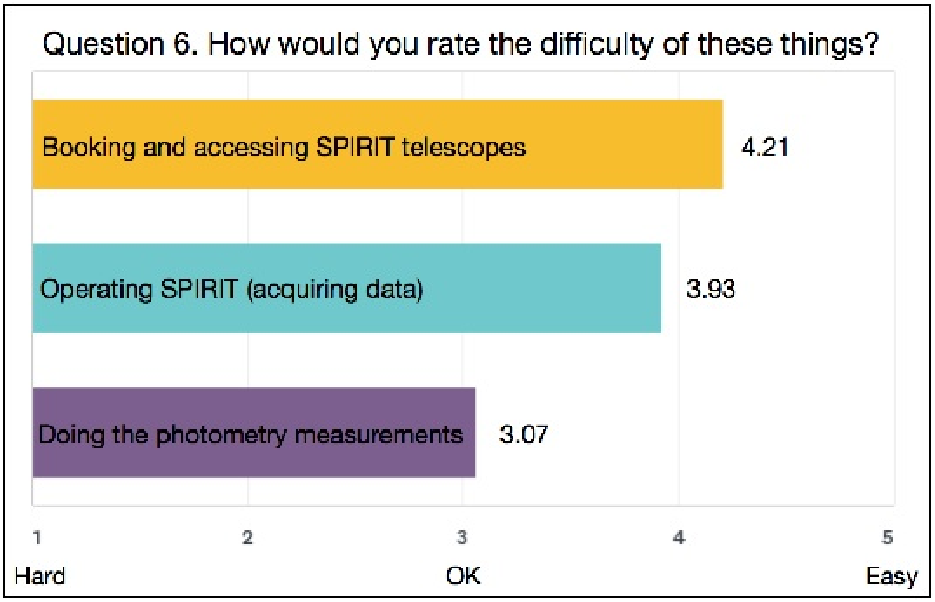

Figure 6. *Student rankings on the relative difficulty of three different tasks in the Year 10 activity. Responses range from 1 (very hard) to 5 (very easy). The average score is shown adjacent to each measure.*

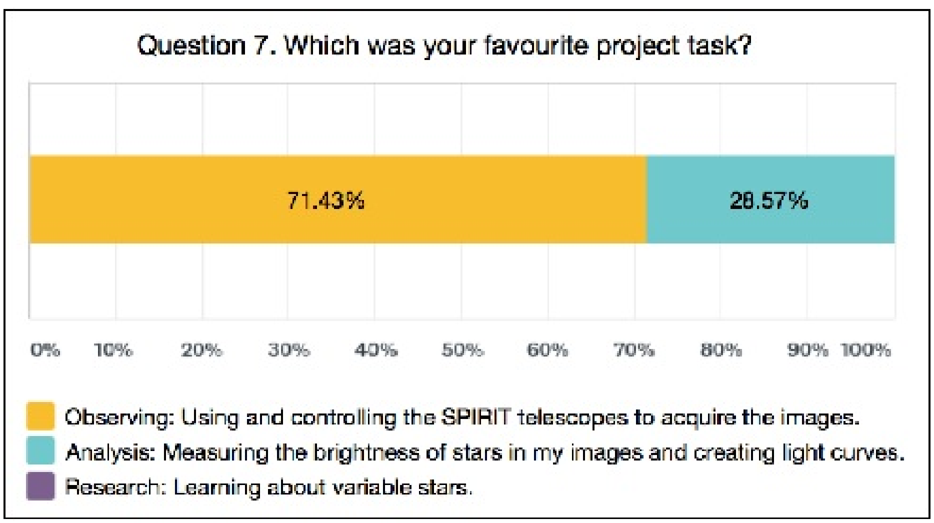

Figure 7. *Year 10 student responses when asked to select their favourite of three tasks. No students selected 'Research: learning about variable stars' as their favourite component.*

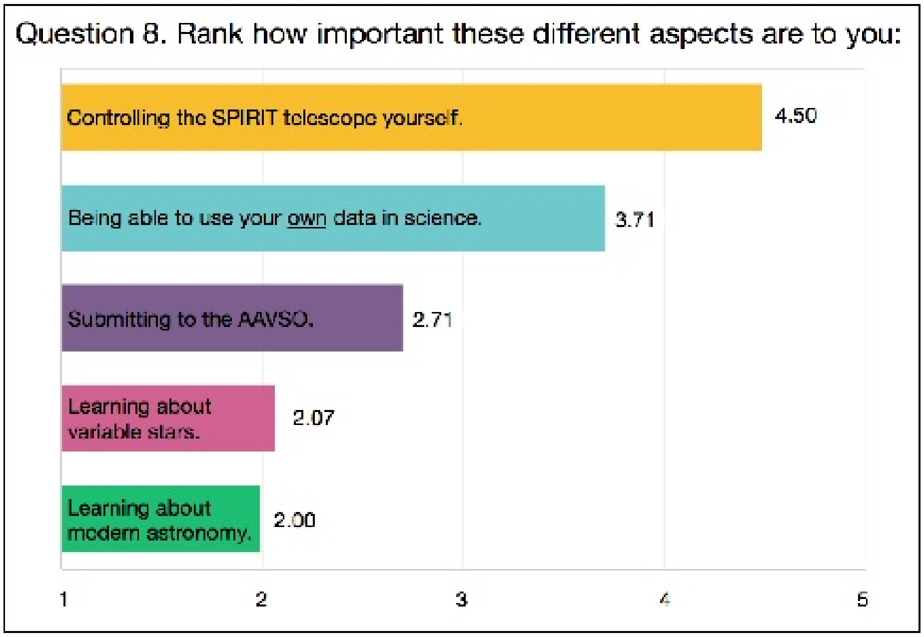

Figure 8. *Student rankings for each of 5 different aspects of the Year 10 project. A higher average value indicates more students ranked this aspect more favorably.*

Student Comments

Students were generally very positive in their feedback about the extended Year 10 activity, with many comments highlighting the value of undertaking their own research:

> "Being able to use the telescope without assistance and creating our own light curve." "The fact that we acquired data and learnt how to make a light curve, going through a process which professional scientists would do."

Students also highlighted the uniqueness of this initiative:

> "Being able to use my own data and learning something new that you can't or don't learn in a normal classroom."

> "Being able to learn these unique and interesting skills."

Discussion

Both the Year 9 and Year 10 groups appear to value the opportunity to use a research grade telescope, with both showing almost identical enthusiasm at the prospect of accessing SPIRIT again in the future. Student ranking on the level of interest in these activities was statistically the same for both groups, perhaps an indication of the level of maturity in delivery of the general SPIRIT program.

There is a predictable pattern in the perceived difficulty of different operational tasks, and it was pleasing to note that Year 10 students found it comparatively easy to operate SPIRIT in mode 2 despite the considerable leap in skills from simple mode 1 control.

Analysis of Year 9 student comments suggest that the chance to learn a new skill is seen as important, together with the opportunity to take their own images (ie, acquire their own data). As with Year 9, the Year 10 comments favour practical aspects of the activity, rather than analysis and measurement—perhaps no surprise given the novelty of controlling robotic telescopes in real time compared to the seemingly mundane aspects of routine classroom-based work. The Year 10 students indicated a level of increased difficulty when it came time to process their data, commensurate with the extended nature of the variable star activity compared to basic image processing in Year 9. Both groups reported similar levels of difficulty in undertaking the same tasks (e.g booking and access). These comments correlate well with students previously familiar with SPIRIT advancing to more challenging usage scenarios.

Year 10 students proffered a mixed response to the question on whether using SPIRIT had influenced any future decisions to study science. This may be due to the fact that many Year 10 students have already made subject choices. It might also indicate that the activity had no influence on their decisions. A pre-survey, intended for future activities, will likely help gauge this point more correctly.

The informal nature of this feedback survey together with the discrete and small sample sizes suggest a level of caution in drawing specific conclusions. However, some general and anecdotal information can be derived from the responses. It is clear that students appear to 'enjoy' the practical aspects of these activities, with a heavy inclination to rank interactivity and telescope control as their 'most favourite activity'. This raises important questions about what students truly value, versus our assumptions. At the very least, it suggests consideration of more rigorous approaches in determining student perceptions in order to inform robotic telescope implementations in education. For example, it is not clear that request based or scheduled telescopes offer the same level of student satisfaction and engagement when considering the prevalence of responses that seem to indicate that students value interactivity highly. Likewise, the degree to which program coordinators might perceive the relative importance of student participation in publishing is questioned. It is worth noting that the Year 10 students involved in the AAVSO activity were high achieving (gifted) students—nominally those that might value the opportunity to 'publish' above all else. As it turns out, however, they didn't. One Year 10 student who had been participated in both activities commented:

> "My favourite task was taking photos of Nebulas, Globular Clusters and Galaxies last year in Challenge Science. This year, I thought that the task of collecting and analysing data was a little too hard and not as interesting."

The student in question ranked telescope control as the most important element, and ranked submitting data for professional credit least important.

Conclusion

It must be re-emphasised that the nature of the survey used in this analysis provides, at best, anecdotal information. More rigorously designed survey mechanisms (including pre-surveys) together with a larger sample over longer periods are ideally required before any serious analysis of student perceptions or educational outcomes of the SPIRIT program can be attempted.

That said, the SPIRIT telescope has proven a successful model of its type, and remains a uniquely engaging educational initiative in many aspects. Within the current global community many assumptions about the nature of student engagement in robotic astronomy prevail and the educational value placed on their achievements is still yet to be fully established. The need to apply rigour in how the perceived success of these programs informs current and future robotic telescope implementations and their supporting programs remains an important educational objective for the years to come.

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Appendices

Year 9 Survey

SPIRIT Telescopes - Year 9 Project Survey

Thanks for using SPIRIT this year as part of year 9.
All the questions in this survey will help us improve SPIRIT and the activities we offer schools, so we would appreciate your honest answers.
All your responses will be anonymous, so we won't know who has said what, and there are no right or wrong answers to any of these questions.

* 1. Using the SPIRIT telescopes for this project was:

Boring			OK			Interesting
☆	☆	☆	☆	☆	☆	☆

2. What was your favourite part of using SPIRIT?

3. What do you think you'll remember most from this project?

4. What was the most important part of this project for you?

* 5. If given the opportunity would you like to use SPIRIT again?

Definitely not			Maybe			Definitely yes
☆	☆	☆	☆	☆	☆	☆

* 6. How would you rate the difficulty of these things:

	Very Hard		OK		Very Easy
Booking and accessing SPIRIT telescopes	○	○	○	○	○
Operating SPIRIT (acquiring images)	○	○	○	○	○
Processing images	○	○	○	○	○

Any comments?

* 7. Do you plan to study science in year 11 and 12?

Definitely not | Maybe | Yes I will

☆ ☆ ☆ ☆ ☆ ☆ ☆

* 8. Do you think you'll study science at university?

Definitely not | Maybe | Yes I will

☆ ☆ ☆ ☆ ☆ ☆ ☆

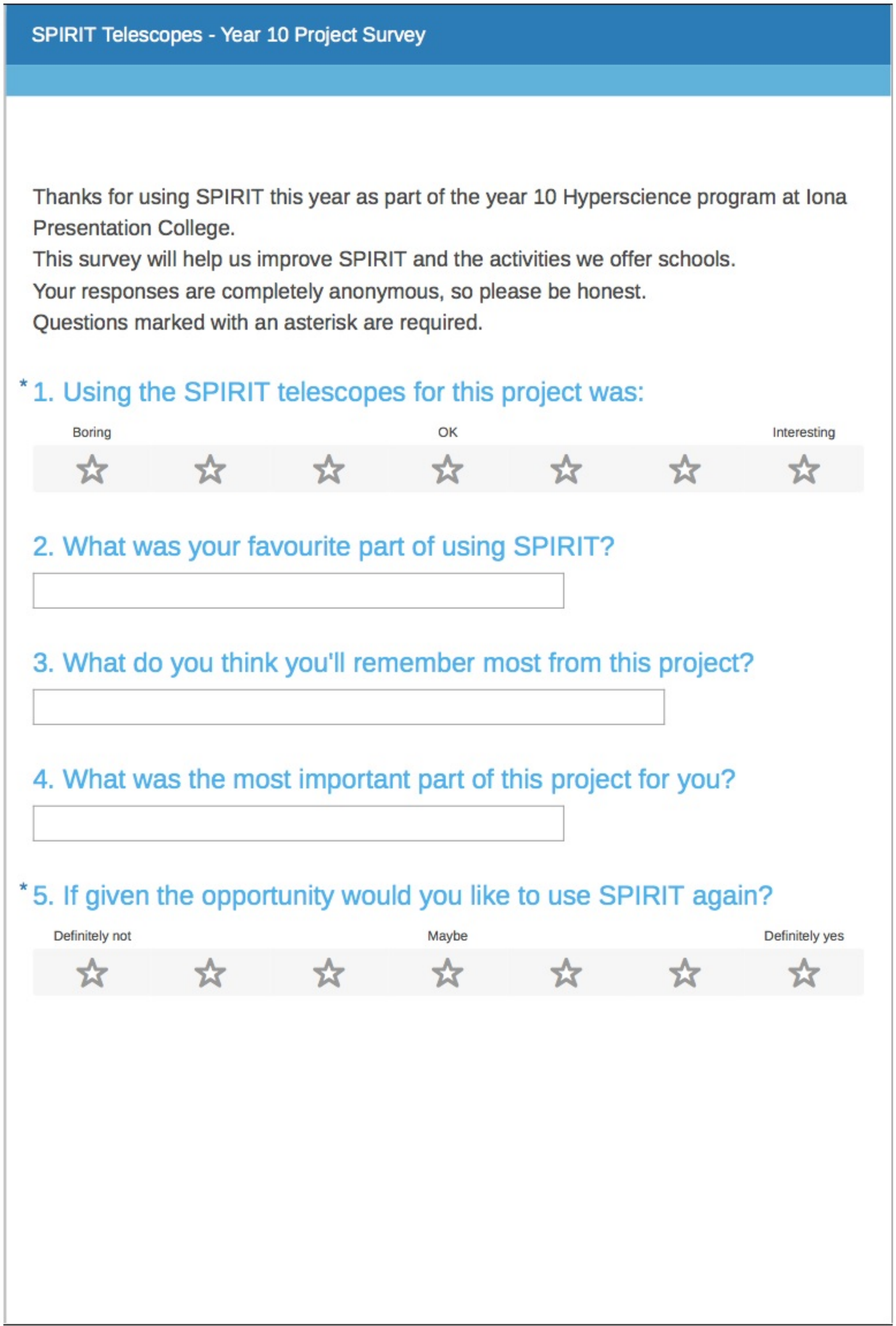
* 9. Have you heard of the Square Kilometre Array?

- Yes
- No
- Not sure

If yes, where?

10. Is there anything else you'd like us to know?

Year 10 Survey



SPIRIT Telescopes - Year 10 Project Survey

Thanks for using SPIRIT this year as part of the year 10 Hyperscience program at Iona Presentation College.
This survey will help us improve SPIRIT and the activities we offer schools.
Your responses are completely anonymous, so please be honest.
Questions marked with an asterisk are required.

* 1. Using the SPIRIT telescopes for this project was:

Boring — OK — Interesting

☆ ☆ ☆ ☆ ☆ ☆ ☆

2. What was your favourite part of using SPIRIT?

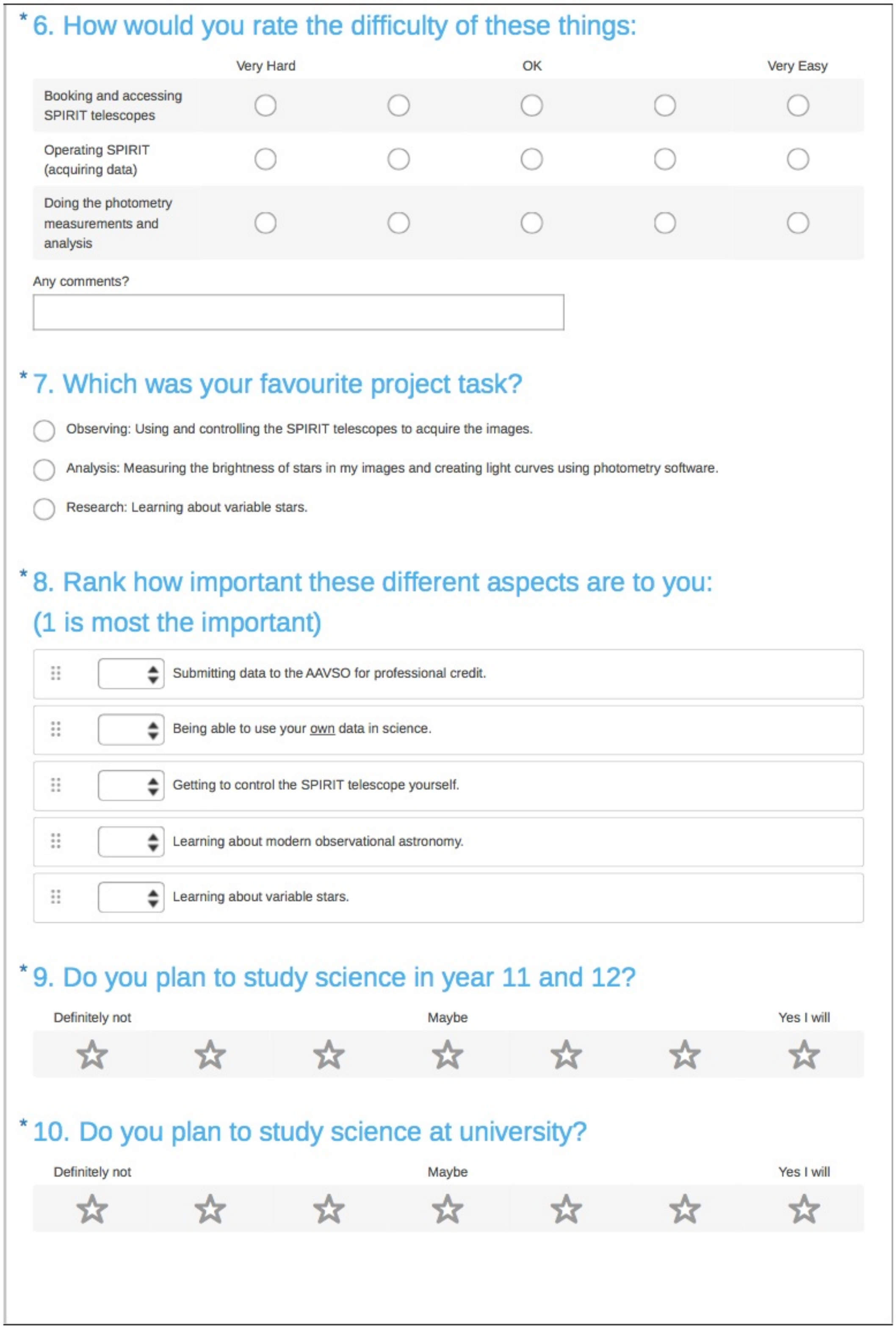
3. What do you think you'll remember most from this project?

4. What was the most important part of this project for you?

* 5. If given the opportunity would you like to use SPIRIT again?

Definitely not — Maybe — Definitely yes

☆ ☆ ☆ ☆ ☆ ☆ ☆



* 6. How would you rate the difficulty of these things:

	Very Hard		OK		Very Easy
Booking and accessing SPIRIT telescopes	○	○	○	○	○
Operating SPIRIT (acquiring data)	○	○	○	○	○
Doing the photometry measurements and analysis	○	○	○	○	○

Any comments?

* 7. Which was your favourite project task?

- ○ Observing: Using and controlling the SPIRIT telescopes to acquire the images.
- ○ Analysis: Measuring the brightness of stars in my images and creating light curves using photometry software.
- ○ Research: Learning about variable stars.

* 8. Rank how important these different aspects are to you: (1 is most the important)

- Submitting data to the AAVSO for professional credit.
- Being able to use your own data in science.
- Getting to control the SPIRIT telescope yourself.
- Learning about modern observational astronomy.
- Learning about variable stars.

* 9. Do you plan to study science in year 11 and 12?

Definitely not — Maybe — Yes I will

☆ ☆ ☆ ☆ ☆ ☆ ☆

* 10. Do you plan to study science at university?

Definitely not — Maybe — Yes I will

☆ ☆ ☆ ☆ ☆ ☆ ☆

* 11. Do you think using SPIRIT has influenced your decisions to study science later in school or at University?

Not at all			Maybe			Definitely
☆	☆	☆	☆	☆	☆	☆

* 12. Have you heard of the Square Kilometre Array?

- ○ Yes
- ○ No
- ○ Not sure

If yes, where?

13. Is there anything else you'd like us to know?