Internet Astronomy in schools using remotely controlled telescopes

David H. McKinnon and Helen Geissinger

Abstract-- The Charles Sturt University Remote Telescope Project makes available to primary and high school students and their teachers a simple-to-use telescope and electronic cameras over the Internet. Access to the telescope is supported by curriculum units of Astronomy activities. The telescope is not a robotic device. It is controllable in real time with images transferred to the user also in real time. This paper describes the project, the software control system and the related curriculum activities, and results obtained from interventions conducted with teachers and students. Discussion centres around how to ignite students’ and teachers’ interest in science and how projects such as this one may lead to more exciting coverage of important topics in the primary and secondary schools.

Index Terms-- Astronomy, Education, Educational programs, Telerobotics, Telescope

I. INTRODUCTION

The last 10 years have seen a small number of robotic and remote telescope facilities come on-line and which are accessible over the Internet or through modems. One of these, the Bradford Robotic Telescope [1], is a completely autonomous system that was available from 1993 to 1997 when it was destroyed by a lightning strike. The Bradford Robotic Telescope’s totally autonomous software system allowed users to open an account and receive an observer priority rating that enabled them to submit observation requests on-line. The software scheduled the request and the observer received an email telling them where to access the images when they had been taken. The public demonstrated its interest in 1997 when statistics revealed that if the telescope had 365 clear nights a year they had enough observation requests for the next 84 years [2]. In educational terms, this situation is rather less than satisfactory given the potential wait time. Other projects, the most notable of which is Telescopes in Hawaii. The ‘Faulkes’ telescopes are yet to be completed. Australian secondary school students will have access to these telescopes for 25% of the available observing time while UK schools will have access for the other 75%[5]. The telescopes will operate in both of the ways described above: autonomously and under remote control. The target audience at least in the early stages is senior high school science students. One research grade CCD camera with a robotic filter wheel will be used to deliver 50kbyte colour jpeg images to the user. The scientific data contained in the three black and white images each taken through a different coloured filter will be available to the students a few days later for downloading. Each image in its Flexible image transfer format will be of the order of 48 Megabytes in size. This will require a download to the school of 144 Megabytes of data before any science can be done on the images. One must question the sense of this approach.

It is against these large projects that the Charles Sturt University Remote Telescope Project is framed. The project takes elements from those described above and renders the technicalities of control at a level where primary age students and their teachers can easily use the system. Specifically, access to the telescope is achieved through the Internet rather than a modem link direct to the telescope somewhat like the Bradford Robotic Telescope and secondly, the telescope is controlled in real time rather like the TIE project.

This paper describes: the software and hardware systems; the educational materials written to support the project; and, the results of an investigation undertaken to evaluate the impact of the materials on students’ motivation and learning. The paper concludes with a brief discussion.

II. HARDWARE SET UP

The telescope is a commercially-available computer-controlled 12-inch Meade LX200 mounted equatorially. The telescope is normally fitted with an F/6.3 focal reducer but can operate at a number of other focal ratios: F/3.3, F/10, F/15 and F/30.
Two CCD cameras are mounted on the telescope: one at the prime focus of the telescope to give magnified images of the sky, and one piggy-backed with a 135mm telephoto lens to give wide angle views. Figure 1 shows the arrangement of the cameras.

The CCD cameras are produced by Starlight Xpress in the UK [6]. Both cameras are inter-line transfer parallel port devices enabling rapid download of the images. The prime focus camera is an SX version with 512x290 pixels each of 12.4 x 16.6 μm on a 6.4mm x 4.6 mm chip, and the wide-angle camera is an MX5 version with 500x290 pixels each of 9.8 x 12.6 μm on a 4.9mm x 3.6mm chip. Together with dark frames and flat fields for radiometric correction, good science can be done by students in both primary and high school. For example, students in primary school can take nice pictures and learn about the procedures involved in processing them. High school students can acquire images from which scientific data can be extracted such as supernova searches using the prime focus camera, photometric work on variable stars such as long period variables or Cepheid Variables, and asteroid and comet searches using the wide angle camera. Telescope focus is maintained and controlled remotely by a stepper motor arrangement.

The telescope and CCD cameras are driven by an IBM Netfinity 3000 file server called Black-Hole linked to Charles Sturt University by an SDSL link running at 768 kilobaud. Black-Hole has its own IP address on the University network. The file server is also networked to a local work-station at the first author’s home by an Ethernet link running at 100 Megabits/sec. This allows schools to be shadowed and supported when they take control of the system should they require any. The telescope, CCD cameras and robotic focuser are all controlled by software running on the file server. Figure 2 illustrates the hardware set up, the communication link to the University and the topology of the system.

The telescope is located in a custom built observatory with a roll-on-roll-off roof. The observatory building is a modified 2.3 metre square garden shed with metal louvres fitted to the North, South and East sides and to the roof. This arrangement maintains the internal temperature at no more than two degrees Celsius above the ambient air temperature. A thermostatically-controlled exhaust fan helps maintain temperature control during the day.

III. SOFTWARE SYSTEM

The underlying principle for the software system and web page development has been ‘keep it as simple and as intuitive as possible’. Our target audience, in many instances, consists of teachers and students who have had limited computer or Internet experience. This situation, however, continues to change.

The software used to control access to the telescope and cameras is Windows NT Terminal Server and running Citrix Metaframe. Users who access the telescope have installed Citrix Thin Client software on their computer. This is downloaded from the telescope web site at the University [7]. The Windows NT Terminal Server Edition platform allows us to maintain an up-to-date software system without troubling the user. The Citrix software allows clients to use the Internet to access Black-Hole and run the control software as if it were on their own desktop. Indeed, the Citrix Metaframe software produces a local screen image that is exactly like a Windows 95, 98 or NT screen. Citrix allows the user to control the telescope, the CCD cameras, and the robotic focuser. Images taken by the cameras are displayed on the user’s computer within a few seconds (typically < 3 seconds for broadband connections and < 20 seconds for ISDN or 56Kbaud modem connections). The images can be saved immediately to the file server’s hard disk, and downloaded later in a batch process for later off-line image processing at school or home by the students using the Starlight Xpress image processing software. If the school has a broadband link then the image can be saved directly to their own computer.

All the software needed to locate objects in the sky, slew the telescope, and capture CCD images reside on the file server. From here, the NT environment and applications are emulated to user workstations. That is, all of the processing
takes place on the file server with only the screen pictures being transmitted over the Internet. By centralising the applications in this way, any upgrades or reinstalls are completely localised and the results immediately available to users. There are many educational advantages to this approach, especially the invisibility of the hardware and software mix. The user has a telescope to point and a couple of cameras to use; the system at the conceptual level is thus delightfully simple.

Control over the telescope is effected by using a planetarium software package that also controls the telescope. The package is a point-and-click application and presents a view of the sky as seen above the observatory at that instant in time. Users click on an object (one of the 19 million in the database) and then tell the telescope to slew to that object. Software limits stop the telescope pointing to trees or other obstructions. In addition, a telescope-pointing model runs in the background ensuring that when the user tells the telescope to go to a particular object, it will be near the centre of the field of view. Indeed, the telescope’s pointing accuracy is better than 1 arcminute while the field of view is 11x 9.5 arcminutes. Control over the cameras is effected using a software package developed in-house. The camera software is basic. It allows the user to set the exposure time (10 minutes – 1/1000 second), the camera to be used, and displays the image once the exposure is complete. Users then specify where they wish the image file to be stored (at the server or on their system). Post-processing of the image takes place at the user’s computer.

Web page design also uses the KISS philosophy. The public domain web page residing on the Charles Sturt University web server provides general information, a gallery of images, software, links and resources, contact information, weather conditions for Bathurst, and Quicktime movies of the telescope’s operation and technical specifications. The links and resources are regularly updated with users often supplying valuable links for inclusion.

This software mix minimises the fear and confusion often the lot of inexperienced users. It allows them to access and use a high-powered precision instrument far beyond the budget of any school.

IV. TAKING CONTROL

The educational package is constructed in such a way as to teach the primary age children about what astronomical objects are visible above the telescope at any time. Students make decisions about the objects they will image before getting online. This is done using the shareware SkyGlobe software. Students and their teacher then construct a bid for access to the telescope for a one-hour period at a time convenient to them. The bid is submitted and they are issued with a time-dependent logon-id and password. At the appropriate time, the students access the Internet and come through the gateway to the telescope network. On launching the planetarium software they see what is visible at the zenith above the observatory at that time. Software controls that users have no need to access are disabled. Students can control the telescope within the prescribed pointing limits set in the software and direct the Telescope to the objects they wish to image.

The CCD camera software is started in the same way so users can issue the necessary commands to take an image. The time that it takes for the image to appear on their screen depends on the Internet. The file size generated by the cameras is 290kbytes. Download times from the cameras to Black-Hole are normally less than two seconds. Users generally save the images at the file server computer for later downloading and processing.

Warnings are issued at 5 minutes and 2 minutes before the end of the observing session so that the user can tell the telescope to park and logoff.

Recognising that teachers may be somewhat afraid of all this technology, the developer provides on-line support throughout the 10 weeks of the program. Teachers can contact him via email to seek clarifications, obtain advice, or discuss learning approaches. In addition, when the class come ‘on-line’ to take control of the system and conduct their observations, a technician is available who ‘shadows’ the session and from whom advice may be sought at any time simply by opening a simple text processor and typing at the computer. This has been most effective in dealing with any problems that have arisen. One problem is cloud causing an exposure to ‘grey out’ and a simple ‘try again’ or ‘cloud in that part of the sky’ can help allay the users’ fears that they have done ‘something wrong’.

V. EDUCATIONAL MATERIALS

The educational materials are supplied in a Teachers’ Guide entitled A Journey through Space and Time [8] and a CD-Rom. The guide provides an extensive set of lesson plans covering such topics as: taking control of the telescope and cameras; image processing; finding objects in the sky; the solar system; stars and galaxies; poetry; space travel; constellation myths. The learning materials for primary schools are integrated across all curriculum areas while for high schools the materials are targeted directly at science and technology. In the primary school, the materials are designed to engage the students for 4 hours/day, 4 days/week for the 10 weeks of a school term. The web site described above also provides an extensive list of resources available on the Internet. Teachers commented that it became their ‘homepage’ for all Internet-based educational activity.

VI. EVALUATION OF STUDENTS’ LEARNING

A. Participants

In 2001, four classes of children in Primary Years 5 and 6 learned about Astronomy during a 10-week period at the four rural schools in which they were enrolled. Two of the classes were Year 5 while the other two were Year 5/6 composites. Their teachers had agreed to participate in the evaluation of the educational materials and in investigating the impact on students’ motivation and learning. The impact on students’ alternative conceptions was undertaken by a fourth-year Honours student as part of her thesis requirements.
One of the classes had studied Astronomy in a previous unit, while the other three had not. The three class teachers agreed to undertake the teaching of the materials over a full school term. The remaining teacher agreed to focus solely on the activities required for the students to understand how to control the telescope, process images and how to find what was 'up there' when they were to take control. Of the 105 children involved, data for both the pre- and post-tests were obtained from 74 pupils.

B. Instruments

The tests employed to tap students' tacit knowledge about astronomy were of two kinds: one required students to read questions, indicate whether they agreed, disagreed or did not know, and to supply evidence where possible for their opinion [9]. The second test required them to draw a picture to illustrate a given situation, such as the phases of the Moon, and to provide a written explanation for their diagram [10]. The two questionnaires comprised both the pre- and post-tests. Thus four scales were generated with good to very good reliabilities (Cronbach α range 0.65 – 0.83).

The findings broadly support Dunlop’s [10] postulate that drawings elicit different and richer information from those that require syntactical determinations.

C. Method

A quasi-experimental pre-test, post-test design was used to evaluate the impact of the educational materials on students' learning. A pre-test that allowed them to express their general knowledge about Astronomy was followed by 10 weeks of social constructivist learning across the six key learning areas of the primary curriculum on various aspects of Astronomy using the materials supplied in the Teachers' Guide and on the CD-Rom. During weeks 5 and 6, the classes of students went on-line and took control of the telescope. The cycle was completed by a post-test that reiterated the questions originally asked. The test results were subjected to statistical analysis using analysis of variance procedures with repeated measures on the occasion of testing. In addition, qualitative data were gathered from all participants to demonstrate how the Journey through Space and Time program was received and used.

D. Results

The specific test results are reported in detail in publications by McKinnon, Geissinger and Danaia, [11, 12, 13]. For the purposes of this conference paper, only the highlights of the findings are given.

The quantitative results showed that all four classes had only a little general knowledge about Astronomy on the pre-test occasion. This appeared to be so even for the class who had studies astronomy (the earth in space – topics related to the solar system) during the first school term.

There was no significant main effect due to age of the students, class membership or to gender. That is, students of all ages and both sexes in all four classes did not differ significantly in their pre- and post-test results.

There was however, a significant main effect due to the occasion of testing. That is, the mean of the four scale scores for all of the classes was significantly higher on the post-test than on the pre-test (effect sizes ranged from 0.5 – 0.75). All classes showed an improvement in the sophistication of their explanations with one composite class markedly ahead of the others in this respect. They learned how to express their ideas better in both written and pictorial form.

There was however, a significant class x occasions interaction. Three of the classes demonstrated steep rises in the graphs that showed the learning effect, while the one class with prior experience of Astronomy did not. It should be remembered that this particular group did not engage with the learning materials devoted to concepts about the solar system and other astronomical phenomena, but instead concentrated on the technical aspects, such as telescope control and image-processing procedures.

One aspect of this research demonstrated whether change occurred in students who held 'naïve beliefs' before the study and those held after the work was completed. The class that concentrated mainly on the technical aspects showed little change in their alternative conceptions. Students in the other three groups demonstrated that a large number of them had substituted more scientific explanations for their previously held alternative conceptions.

VII. CONCLUSION

The researchers believe the students’ explorations of various scientific phenomena, coupled with peer discussion and verbal reworking of concepts, enabled the children to discard some of their naïve ideas. The technology that allows children to take control of a sophisticated telescope via the Internet is shown to be a great motivator that helps them learn about astronomical objects and their relative positions in space. The evidence of these tests supports the position that engaging with such concepts leads to more insightful learning than does a concentration on mere technical details. Another motivating factor was the children’s ability to take actual photographs, download them to their school computers, process the images, and display them for peers, parents and the general school community. The children were deeply interested in what they could see with the telescope and what they could show to demonstrate their new knowledge and skills.

In summary, the Journey through Space and Time program in the Primary Years (Grades) 5 and 6 has demonstrated good immediate learning outcomes. It remains to be seen whether the students will maintain their interest in the stars and add to their scientific and astronomical knowledge in the future. Their familiarity with the Internet as a source of updated Astronomy information plus their new-found ability to conduct email discussions with peers and experts will stand them in good stead. In addition, they can process digital images, a useful skill when working with the various kinds of digital cameras now available.

These are exciting times for Astronomy and Science Education where students can control sophisticated remote
devices over the Internet. The impact on students’ attitudes towards Astronomy in particular and science in general will be interesting to monitor. Access to such instruments on the Internet that students themselves use to take pictures and acquire scientific data appears to be highly motivating. Such an impact in the science classroom is a very real possibility that needs to be monitored and evaluated. When these approaches are contrasted with the more normal ‘go to the library and do some research’ methods employed by many primary school teachers, and even science teachers in the high school, they are motivating, rewarding, interesting and exciting.

The results from the one class who concentrated on the control aspects of the project serves as a salutary lesson for teachers and curriculum developers. It is not the technology per se that teaches the students about their universe even though they have to understand, at least in part, some aspects of it. Rather, it is the mindful engagement with the scientific ideas and their naïve conceptions over a period of time that is made possible by the motivating influence of their interactions with the technology and the fact that they want to ‘take a picture all by themselves’. These they show with great pride to their parents. An example is provided in Figure 3 showing a picture taken by a 10-year old. The reason that the student gave for wanting to take this image was: “I have seen pictures of this galaxy on the Internet. It is beautiful but I want one all of my own”.

For the students, the process of taking the picture and processing it with the image-processing program supplied on CD-Rom is only the tip of the iceberg of conceptual change and educational development. When the students are motivated and interested, engaging them with the educational materials over a long period of time presents the teacher with opportunities to deliver significant educational outcomes. The results demonstrate this.

VIII. PUBLICATION

Dr David H. McKinnon and Dr Helen Geissinger have collaborated in the production of this paper and give their full agreement for its publication.

REFERENCES

[5] Personal communication with Dr Richard Cole, Faulkes Telescope Project Director.