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Helping Them Understand: Astronomy for Grades 5 and 6

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This article reports on research into learning gains made by children aged 10-12 when they studied astronomy using learning activities in a constructivist environment consolidated by access through the Internet to a scientific-grade telescope. Young people often hold naïve or alternative ideas about scientific phenomena from early childhood. Since these ideas may be believed well into adulthood in spite of attempts to dislodge them, educators must address the problem actively from grade school onward. In the program reported in the article, a learning environment supported by peer interaction and access to exciting and credible Internet resources has lead to the discard of naïve ideas and acceptance of explanations based on scientific findings.

Astronomy can be an easy subject to teach in the sense that almost everyone is interested in stars in the night sky and eager to learn about space travel and phenomena such as comets, asteroids, and galaxies. Two reasons why many people do not take up astronomy as a lifelong interest have to do with their poor understanding of concepts such as scale and distance and with their reluctance to discard naïve ideas. Research showing that even science students hold naïve ideas about their field of study is seen as a serious barrier to learning. Consequently, educators at the secondary and tertiary levels now try to address the problem of students' alternative conceptions. Unfortunately, poor understanding of scientific facts and adherence to naive ideas stem from early childhood and may be compounded by exposure to primary schooling in which adults (especially teachers) hold naïve ideas (Skamp, 1994).

A science-teaching specialist at Charles Sturt University (CSU) in Australia has developed a social constructivist approach for children aged 10 to 12-years who want to study astronomy in primary school. The project, *A Journey Through Space and Time*, requires teachers to devote a 10-week period to astronomy using learning activities that "cross the curriculum," for example, address key learning areas in English, Mathematics, Human society in its environment, creative and practical arts and health and physical education, as well as science and technology. The learning project reported in this article was developed to interest children in investigating astronomy and engage them in scientific methods of work. New teaching/learning projects tend to be accepted by innovators but are seldom adopted by mainstream educators because they suspect the programs may not deliver the promised educational benefits. For this reason, research into the learning outcomes of *A Journey Through Space and Time* commenced as soon as school classes began enrolling in the program. Although interesting and credible findings have been made and are reported here, the research is ongoing and is conducted with every group.

PROJECT COMPONENTS AND TECHNOLOGIES

A Journey Through Space and Time consists of access by way of the Internet to a remote-controlled telescope and the guidance of educational materials: learning activities that address the key learning areas, a CD-ROM containing *PowerPoint*© slides showing step-by-step procedures, image processing software and a gallery of celestial images, plus a website for communications, (http://www.csu.edu.au/telescope) links to other astronomy resources and a showcase for the images taken by school children. The CSU Remote Telescope is a computer-controlled commercial 12-inch Schmidt-Cassegrain instrument. Two electronic cameras driven by software (written in-house) are attached to the telescope. One camera uses a 135mm telephoto lens to produce wide-angle images while the other looks through the telescope and produces highly-magnified images of the object(s) on which the telescope is focused. The software for the telescope and cameras is located on an observatory file server and consists of four control systems: (a) the file server and client interface, (b) the accurate pointing capability, (c) the focusing, and (d) the operation of the two electronic cameras. To make contact with the system, the teacher downloads a small client program from the telescope website that presents a “desktop” such as the usual Windows 95/98/NT interface seen on school computers but which, also supplies the icons that run the systems. This ease of use means that teachers do not need technical knowledge (beyond that required to gain access to the Internet) to command the telescope and use its capabilities. Since the CD-ROM contains instructions for all the technical procedures, teachers and students do not experience difficulty if they follow these in the recommended order.

PARTICIPANTS IN THE STUDY

The study was conducted from March to July 2001, with the consent of teachers and their 5th and 6th grade classes in several rural schools in New South Wales. (School names have been altered to protect the identity of participants.) To begin, the teachers attended a workshop at which they were introduced to the project and its purpose. All were in agreement with the learning goals of *A Journey Through Space and Time*. Besides examining the educational package, they tested access to the telescope by way of the Internet and examined the interface software. Once back at their schools, the teachers presented the ideas and learning materials to their students. They used the digital video and a *PowerPoint*© advance organiser to suggest the possibilities that the students could explore.

One class was a composite group of 5th and 6th grade children at Bogar Public School. They had already engaged in a science unit on astronomy earlier in the school year when the planets Mars, Jupiter, and Saturn were easily visible in the sky. The work covered two hours per week in a six-week period during which time the students developed projects on aspects of the Solar System and later presented their findings on posters. Because of this previous study, the teacher felt that the learning activities in *A Journey Through Space and Time* would not be as useful as the technical activities concerned with taking control of the telescope and cameras and downloading and processing the images.

The remaining three teachers wished to undertake the project without adjustments, as their students had not studied astronomy. The two 5th grade classes at Gulgar Public School were taught by different teachers, while the remaining class at Colgar Public School, a composite of 5th and 6th grade students, was taught by the remaining teacher. Although 105 students participated in this study, only 74 students supplied a complete set of data (a pretest and a posttest).

LOOKING FOR LEARNING

The program learning activities require four hours a day for each of the weeks in a 10-week period. A pretest is administered at the beginning of the work. One part of the test covers a number of concepts such as the manner in which the Moon reflects light and whether there is an “up” and “down” in Space. Participants can tick one of three boxes for each item (agree/disagree/don’t know), but are also asked for evidence supporting their opinion. This first instrument is based on Osborne’s (1995) *Common Ideas in Astronomy*. The second part invites participants to interpret diagrams or provide self-drawn labelled pictures. This instrument’s source is from Dunlop (2000), who contended that students’ own drawings provide a fairer measure of their actual astronomical knowledge as, in his opinion, questionnaires of the tick-box variety rely too heavily on students’ syntactic knowledge at the expense of eliciting their astronomical knowledge.

After the work is completed, the same test is administered again. The two tests are compared to determine whether the participants have changed their ideas, been able to answer more questions than previously, or can give more detailed answers.

In addition, teachers’ questions and observations were gathered throughout the weeks as an informal indicator of the progress of the learning, and for feedback on the materials and procedures. Records of e-mail interactions contribute to this informal picture as well, especially those conducted between students and the person on duty at the telescope at observation time. Although the instruments were used for research purposes in this case, teachers who want to test students’ suppositions about astronomy also find them useful as the gap between their ideas at the beginning and the end is evidence of learning and increased understanding.

FINDINGS

Coding and Scaling

Students’ responses to the first instrument were coded as follows: 2 (correct answer), 1 (did not know) and 0 (incorrect). Although many did not provide a written answer to support their opinion on each question, the responses they did offer were coded using the Structure of the Observed Learning Outcome (SOLO) Taxonomy (Biggs, 1982). This taxonomy of learning outcomes provides an ordinal method of classifying students’ responses, as expressed thus: Level 0 indicates a prestructural response where the student has either not understood the question or has offered an explanation that is not in any way connected with the original question; Level 1 is a uni-structural response where the student has focussed on only one of the key components of the current accepted scientific belief; Level 2 is a multi-structural response where more than one component is mentioned but their relationship is not specified; Level 3 is a relational response that indicates the student has identified the key components and related them to each other; and Level 4 is awarded when an answer is given that relates the components but in addition, other relationships are hypothesized that could be involved. These levels can be progressive, for example, Level 4 of one learning experience could provide the Level 1 required for more advanced study. Here, however, the level of cognitive development is inferred from the way the student has interacted with the learning situation. This study did not evidence any explanations at, or beyond, Level 3 (relational).

An exploratory factor analysis was computed on the 17 items of Osborne's instrument. One factor of 13 items accounted for 53% of the variance and was adequate to account for the data in the most parsimonious fashion. This factor was interpreted as being the students' general knowledge about astronomy. The internal reliability (Cronbach α) of this factor was 0.5686 on the pretest and 0.7113 on the posttest. The difference in reliabilities from the pre to the posttest occasion is understandable. Students perhaps guessed at answers on the pretest occasion but used the knowledge they had acquired during the 10-week project to attempt more accurate answers on the posttest occasion. The scales formed to measure general knowledge were named *PreGen* and *PostGen.*

The approach used with students' explanations for the ticked items in the general knowledge section involved forming a scale of the total of the individual SOLO responses for each of the items. Thus scales were yielded with internal consistencies of 0.6539 and 0.8270 on the pretest and posttest occasions respectively. These variables were named *PreSgen* and *PostSgen* and measure students' SOLO functional level in relation to general knowledge about astronomy.

The second instrument probed students' understandings of four astronomical phenomena (Dunlop, 2000). They were requested to: (a) draw a labelled picture of the Earth, the Sun, day-time and night-time to show why day-time and night-time happen; (b) draw a labelled picture of the Earth, Sun and Moon showing their orbits; (c) use a labelled picture to show why the Moon assumed certain phases during the course of a week (three pictures of the Moon were provided); and (d) draw a labelled picture of the Earth and the Sun to show why summer and winter happen. In each case, the students were asked to provide a written explanation as well. Students' pictures were coded as correct/incorrect and their explanations were coded using the SOLO taxonomy as before. The scale formed from the four pictures yielded a maximum score of four and internal consistencies of 0.3570 and 0.6348 on the pre and posttest occasions respectively. The internal consistency of the pretest occasion is much lower than on the posttest occasion, indicating that the students had perhaps learned something. These variables were named *PreSpac* and *PostSpac* and measure students' spatial knowledge about the Sun, Moon, and the Earth.

Again, students' explanations for their drawings were coded as to level; the levels were added together to produce a scale score. The internal consistencies of these two scales were 0.5971 and 0.6549 on the pre and posttest occasions respectively. These variables were named *PreSOLO* and *PostSOLO* and measure students' spatial functional level with regard to the SOLO taxonomy.

Both the diagrams and the explanations revealed many of the common alternative (naïve) conceptions held by students of this age. Skamp (1994) suggested that these may be held by their teachers as well. One common example is that the phases of the Moon are caused by light reflected from the Earth. An analysis of misconceptions is beyond the scope of this article but will be reported at a later date.

Results

All analyses were computed with the *Statistical Package for the Social Sciences* (SPSS) v. 10. The summary data of the four dependent variables are presented as graphs while the results of the statistical analyses undertaken are reported in brackets. The data were examined using an analysis of variance (ANOVA) with repeated measures on the occasion of testing. Before computing the ANOVA, the individual and joint distributions of the dependent variables were checked to ensure that they met the assumptions of the statistical procedures employed. In addition, effect sizes (eta squared) and statistical power were calculated at each stage. These are also reported in brackets.

A simple inspection of the four graphs (Figures 1-4) shows that for the majority of the classes the lines slope markedly up to the right indicating that the students performed better on the posttest than they had on the pretest. They indicate that the students learned something. Note that the mean scores for each of the classes on the pretest are tightly clustered at the bottom left of the graphs, indicating that the students all started off at the same level.

In some respects, this latter observation is interesting given that the class from Bogar School had already undertaken a science and technology unit on astronomy prior to embarking on *A Journey Through Space and Time*. Apparently they had learned little that could be related to general knowledge about astronomy using the modified Osborne (1995) instrument, or in terms of Dunlop's (2000) picture exercises. Further, their level of conceptual thinking about the general knowledge questions and in the drawing exercise show no significant differences compared with the other three classes on the pretest occasion.

The statistical tests for the students' general astronomical knowledge reveal that there are no significant between-group main effects. That is, the average score of all classes is not significantly different. There is however, a significant within-group main effect due to the occasion of testing (F=56.566, df=1, 69, $p < 0.0005$, effect size=0.450, power=1). There is also a significant first order interaction between class and the time of testing (F=6.391, df= 3, 69, $p = 0.001$, es=0.218, power=0.96). Figure 1 below shows that the interaction is probably due to the fact that three of the classes increased their general knowledge about astronomy quite markedly while one did not (Gulgar 5M)

The second dependent variable associated with general knowledge about astronomy relates to the students' explanations for their answers to those items. Here the mean score for the total of the Observed Learning Outcomes (i.e., the explanation) is graphed in Figure 2. There is a significant difference between groups' main effect due to class membership (F=7.621, df=1, 68, $p < 0.0005$, es=0.252, power=0.983). Colgar School students offer reasons for their choices of answers to the general astronomical knowledge questions at a significantly higher level than the other three classes. This finding compares with the absence of a significant difference in the pretest scores.

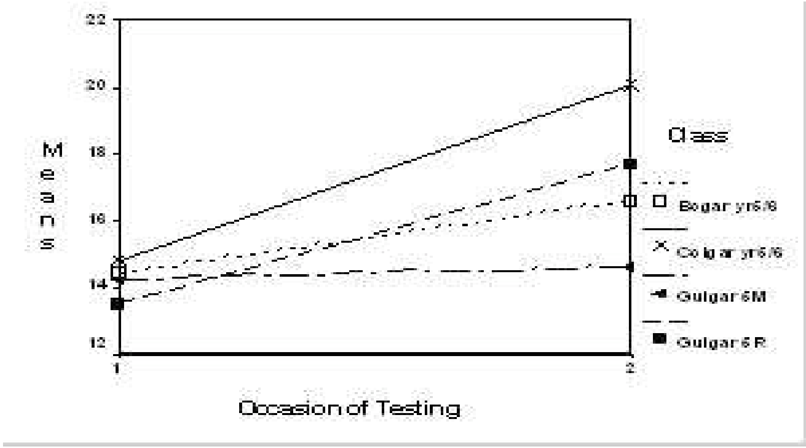

Figure 1. Mean scores by class for students' general knowledge about astronomy

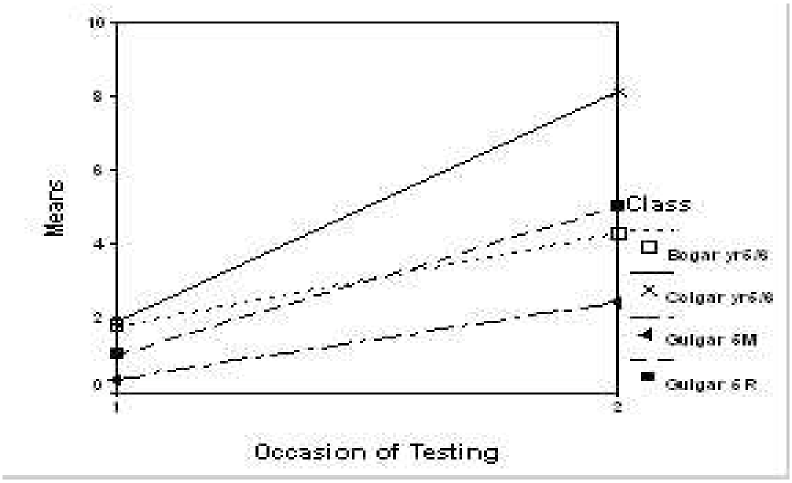

Figure 2. Mean scores by class for students' astronomical general knowledge SOLO functional level

There is a highly significant within-groups main effect for all classes on the occasion of testing (F=95.086, df=1, 68, $p < 0.0005$, es=0.583, power=1). That is, all classes increased their mean scores significantly on the posttest compared with their pretest scores equivalent to almost to 0.6 of a standard deviation. In addition, there is a significant within-groups interaction for class by occasions (F=7.189, df=3, 68, p < 0.0005, es=0.241, power=0.987). This interaction is again probably due to the different gradients of the lines in Figure 2.

The remaining two dependent variables reveal a slightly different pattern of results compared with the previous two. These dependent variables measure students' ability to draw diagrams to explain certain astronomical phenomena (Figure 3) and their ability to explain the diagrams (Figure 4).

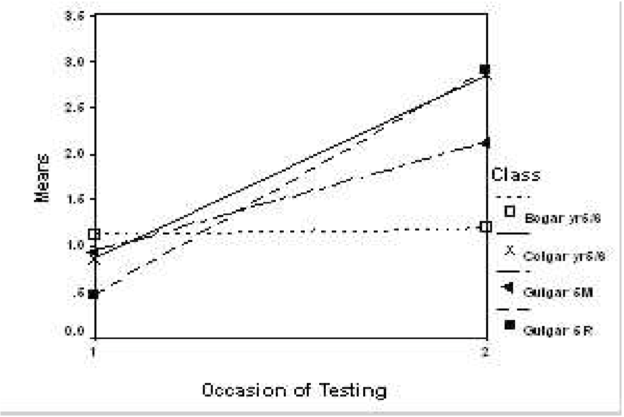

Figure 3. Mean scores by class for students' spatial astronomical knowledge

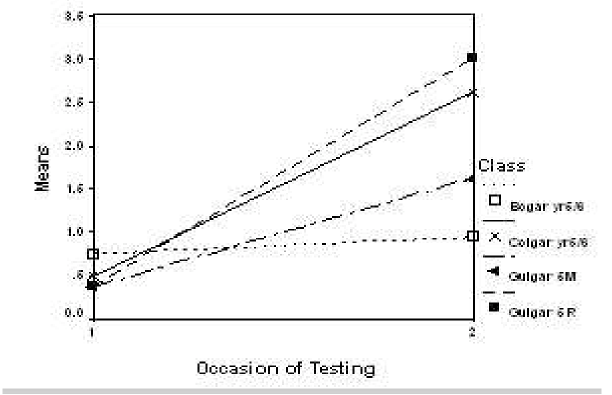

Figure 4. Mean scores by class for students' Spatial SOLO functional level

Figure 3 graphs the mean scores for students' ability to draw what they think causes certain astronomical phenomena such as day and night, the seasons, the phases of the Moon, and how the Earth and Moon move around the Sun.

The between-groups main effect for class (F=2.894, df =3, 73, p=0.042) is marginally significant. Since four dependent variables were measured simultaneously it is wise to err on the side of safety and apply a correction to the accepted probability that the null hypothesis of no difference can more safely be rejected. Therefore, it is unlikely that the between-group main effect is real since the probability level is closer to the 0.05 level than the 0.00125 level that Bonferroni, as cited in Dunn (1961), would apply.

There is a highly significant within-groups main effect (F=171.034, df=1, 73, $p < 0.0005$, es=0.701, power=1) and a significant first order interaction between class and occasion of testing (F=19.461, df=3, 73, $p <$ 0.0005, es=0.444, power=1). Inspection of Figure 3 provides a probable explanation for the class by occasions interaction. Bogar students, who had previously studied astronomy, did not increase their mean score while the other three classes increased theirs significantly. The effect size for the increase in students' spatial astronomical knowledge is large, equivalent to 0.7 of a standard deviation.

Figure 4 graphs the mean scores for the quality of the explanations that students gave for the diagrams they drew. As for the previous variable, there is a main effect for class membership but again caution should be exercised due to the small value of the F ratio (F=3.098, df=3, 73, p = 0.032, es=0.113, power=0.701). The same argument applies here as for the previous dependent variable to discount this main effect due to class membership.

Again, there is a highly significant within groups main effect due to occasion of testing (F=61.280, df=1, 73, $p < 0.0005$, es=0.456. power=1). The first order interaction between class and occasion of testing (F=7.952, df=1, 73, p < 0.0005, es=0.246. power=0.987) is again easily interpreted from Figure 4 as probably being due to the fact that three of the four classes increase their mean score on occasion 2 markedly while again Bogar students barely increase their mean score.

The final research question to be addressed is which of the two instruments: Osborne's (1995) general knowledge about astronomy or Dunlop's (2000) provided a better measure of students' knowledge. In his article, Dunlop only used one piece of evidence to support his contention that the question type influences the rate of correct responses, for example, that drawing a picture of the Earth and Sun to explain why day and night occur produces a higher correct response rate than simply ticking a box in a multiple-choice question.

Dunlop reported in his study that:

> ...29% of grade 4 (8-and 9-year olds) and 50% of grade 8 (13-year-olds) chose the correct answer to a multiple-choice question about the cause of day and night. When the same concept was tested by asking for a drawing and statement in question one, 41% of the grade 4 and 62.5% of the grade 8 received a "good understanding" rating. (Dunlop 2000:198)

In our study we found a similar difference in the responses of the students: 53% of students got the picture-drawing exercise correct while only 30.2% got the multiple choice question correct in the pretest. In the posttest, the responses were 87.2% and 75.6% correct respectively.

In terms of the second question, 28.1% correctly drew the orbits of the Earth, Moon and Sun correctly on the pretest while 71.6% ticked the correct box. In the posttest 68.6% of the students drew the orbits correctly while 86.4% ticked the correct box.

The third question related to phases of the Moon: on the pretest only 3.1% of students correctly drew a diagram while 50% of them ticked the correct box. On the posttest the difference was also marked, with 25% able to draw a diagram correctly and 78.4% could tick the correct box.

The final drawing question related to the cause of the seasons. On the pretest no one got the picture exercise correct while 37.5% ticked the correct box and 48.9% admitted they did not know. On the posttest, 50% got the picture correct while 75% ticked the correct box.

The evidence is sufficient to make an alternative claim to that proposed by Dunlop, so the jury is still out. In this study, the findings agreed with Dunlop that students' drawn explanations of day and night produced a higher correct response rate than the multiple-choice item. The remaining items do not provide compelling evidence for the claim that "multiple choice questions appear to have under-reported the number of correct responses and the result suggests that the extensive use of multiple choice with children of this age may be unwarranted." Rather, as all good teachers already understand, multiple sources of evidence are required to more fully understand how and what students think. Therefore, caution should be exercised.

DISCUSSION

The Remote Telescope Project shows evidence of an increase in students' learning when they use the activities promoted in the educational package of *A Journey Through Space and Time*, in comparison with results obtained when students merely access the telescope. The results derived from the pretest/posttest design showed that students really learned something about astronomy and the statistical results are highly significant. It appears that there is scope for the introduction of other remotely-controlled scientific instruments into the classroom as appropriate for various curricula and levels of understanding. In the case of grades 5 and 6 in Australia, the academic environment requires themes to be taught "across the curriculum," whereas in higher grades, the learning activities relate to specific areas of study. Nevertheless, activities that involve dialogue among peers, the choice of evidence to support group decisions, reflection upon ideas and statements of findings are all valuable at every level because they resemble ways of working in the scientific world while helping students express their ideas more clearly.

Research into students' alternative scientific conceptions is facilitated by the use of meaningful pre and posttest instruments. In the astronomy project, students appeared to perceive the questionnaires as serving a specific and understandable purpose. Teachers who do not utilize the educational package nevertheless can use the evidence of the pretest to construct learning activities that challenge the students and perhaps force them to reconceptualize their explanations.

Dunlop's research into the question type influencing the student's response has been investigated; the data shows that more research needs to be undertaken. Here, like Dunlop (2000), we found that using the diagrammatic approach to explain a relatively simple concept like day and night did produce a higher rate of correct responses than for an equivalent multiple-choice item. We did not find this to be the case for more complex ideas such as the phases of the Moon, the seasons or the orbits of the Earth, Moon, and Sun. Students appeared to experience greater difficulty in expressing their ideas in pictorial form, at least in the pretest. On the posttest, the results of the diagram drawing exercises improved significantly but, as before, they produced fewer correct responses compared to multiple-choice items.

In education, we are now in a time where students and their teachers around the world can use ICTs to access experiences, equipment and resources that previously would have not been possible. The Charles Sturt University Remote Telescope is one of those pieces of equipment that, in the past, only a few children at the elementary school level would ever have had the opportunity to look through, let alone control. Taking control appears to be an intrinsic motivator as judged from the qualitative evidence gathered by e-mail and telephone. The findings of this study open the way for other remote-controlled instruments to "enter" the classroom and make applications of science and technology meaningful to young learners. Because the study has shown the importance of a constructivist learning environment in which focussed activities and technical advice permit the best use of the instrumentation, it appears that any such instrument needs specific materials to enhance its use and facilitate understandings.

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