Introductory astronomy: setting goals and measuring achievements

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Introduction

In 1998 a one semester (6 credit point) introductory astronomy unit, PHYS1500 *Astronomy*, was introduced by the School of Physics to fill a long-perceived student demand for astronomy. Students from all across the University enter *Astronomy,* bringing highly variable physics and mathematics backgrounds. Consequently, a largely non-mathematical and 'concept-based' approach was adopted, in clear contrast to the more mathematical and problem-based approach typical of physics courses. Nonetheless, astronomy and astronomical data *is* intrinsically numerical and the students face this in various places, notably the computer-based laboratories.

This unit of study covers a full range of astronomical topics in one semester, with six contact hours per week as is typical of a 6 credit point Science unit. However the material is presented in a variety of ways that distinguish *Astronomy* from typical physics units:

- a comprehensive, largely non-mathematical textbook;
- fewer lectures than for a typical physics unit;
- 'seminars', featuring invited lecturers and topics building on the core syllabus;
- tutorials based around small group discussions led by teams of students;
- laboratory exercises presenting realistic data based on computer simulation of observations;
- hands-on telescope observations, both daytime and night-time; and
- an essay, but no other formal assignments.

Further details can be found on the Web at http://www.physics.usyd.edu.au/ugrad/astro.html.

The broad goals of the unit are:

- to present astronomy in a way accessible to students from diverse backgrounds;
- to improve the students' conceptual and factual knowledge of astronomy;
- to convey some insight into how science is done, what part it plays in society; and
- to develop some of the communication and computer skills required in a graduate.

Astronomy has been very successful, growing to over 200 students in 2000 and 2001. Their response to the unit has been excellent and at least one quarter of them have suggested that they would consider doing a second astronomy unit if it were offered. Popularity and enrolment numbers are one measure of success but, with its diverse background of the students, is *Astronomy* achieving its goals? To address this question we have studied the student population enrolled in the unit and used a variety of survey tools to probe student attitudes and understanding, including a southern hemisphere version of the Astronomy Diagnostic Test (ADT).

Analysis of student performance

Student academic background

Approximately 120 students completed the unit in 1998 and 1999, rising to 174 in 2000 and 197 in 2001. The profile of the student body remained similar throughout, with 60-70% of students in their first year of university, approximately 15% were in their second year, and approximately 10% in their third year. Approximately 40% of students are female. The proportion of *Astronomy* students who are enrolled in the Science faculty is typically just under 70%, with a further 10-20% from the

Faculty of Arts. The remainder come from a range of other degree programs, with Engineering rising over 10% in 2000 as aerospace engineers entered the class.

Results versus student qualifications

The final mark is one clear measure of the performance of the students in *Astronomy*. Comparing these results with the background of the students provides an indication of our success in meeting the aim of providing a course suitable for students from across the university. Data from the 1999 class are used in this analysis and it is representative of results from all four years.

The results for the class (students who complete the course by sitting the final examination) show a broad distribution in final scaled marks with a mean mark of 61% and a standard deviation of 15%.

The physics background of the students can be gauged from the physics taken at school or in their university career to date. Looking at the first year students only in the 1999 class, only 40% took physics in their final year of high school (i.e. did physics in the NSW Higher School Certificate (HSC) examination, or equivalent). Their *Astronomy* results show a median mark of 64% (Figure 1(a)), compared to 59% (Figure 1(b)) for their contemporaries with no physics background from their final year of high school. The latter group also showed more students with poor marks, however the differences in the distributions are not significant.

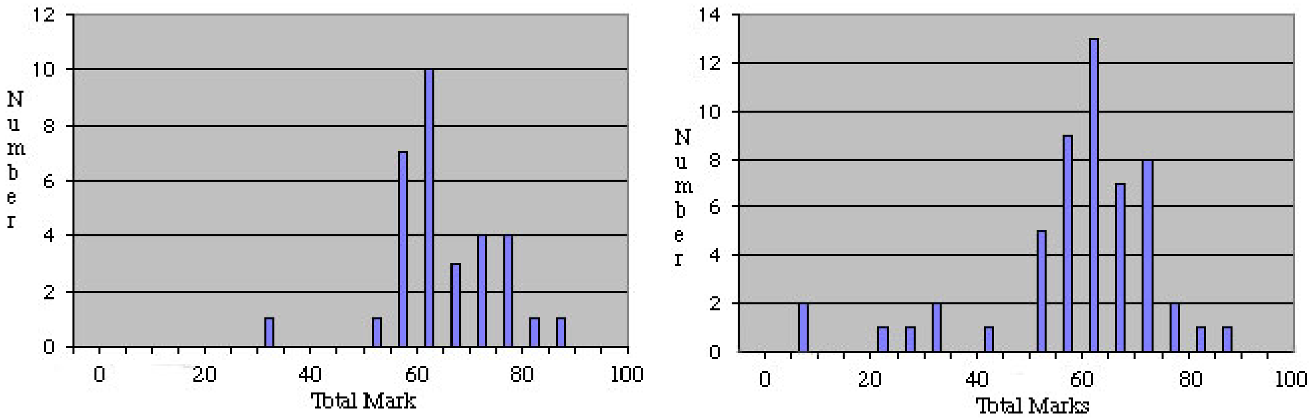


Figure 1. Distribution of total marks for 1999 students (a) with and (b)without physics in their final year of high school

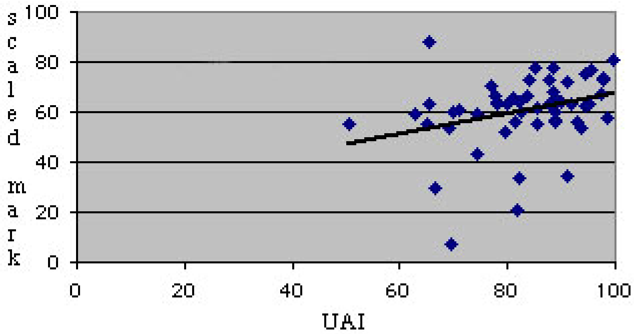
Half of the students had experience in physics at university, 46% in first year physics courses only (including a small number at the advanced level), and another 5% at second year level. There was no significant difference in results of students with and without a university physics background. The distributions were very similar, with median marks of 64% and 63% respectively.

A comparison was also made of results for students in their first year of university and those in their second and higher years, irrespective of their physics background. For these there is again a slight difference between the median of 61 for first year students and 64 for higher year students. One might expect that students with more experience at university do a little better, but the significance is marginal.

Finally, considering only students in their first year of university, the *Astronomy* examination results were compared with measures of student performance across a broad range of subjects. The first of these is the Universities Admission Index (UAI), derived from marks at the HSC examination. The result (Figure 2(a)) is almost no correlation (r^2~0.09) between UAI and *Astronomy* mark.

The second broad measure is the Weighted Average Mark (WAM) of the students' final results from all their university courses. The analysis was restricted to first year Science students to minimise other variables in the comparison. The result (Figure 2(b)) is a stronger correlation

(r^2~0.43) as expected, since overall university performance is likely to be a good predictor of performance in *Astronomy*.



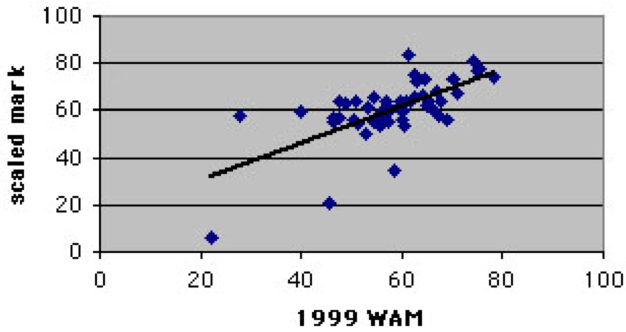


Figure 2. (a) For all 1999 students, correlation of *Astronomy* examination mark versus Universities Admission Index (UAI), (b) For 1999 Science students only, correlation of *Astronomy* examination mark versus university Weighted Average Mark (WAM)

The conclusion to be drawn from these data is that good academic performance in *Astronomy* does not depend significantly on student background. Furthermore, when looking at the students who topped the rankings, they represent a cross-section of the class in every respect. Given the range of student backgrounds, these results are remarkable and indicate that the unit achieves its aim of being accessible to all.

Combatting misconceptions

The final examination is one measure of student knowledge, but educational research judging the usefulness of introductory physics and astronomy courses often emphasizes their effectiveness in combatting basic misconceptions that students bring to the course from their experience of the world. This is often judged by a 'Misconception Quiz' administered at both the start and the end of the course, featuring questions designed to probe students' understanding of basic concepts. There are several reported studies of performance in astronomy misconception quizzes by university students (for example Bisard et al., 1994; Trumper, 2000, 2001; Zeilik, Schau and Mattern, 1998; Zeilik and Bisard, 2000), and even more by secondary and primary (elementary) school students (for example Dunlop, 2000).

The quiz employed in *Astronomy* in 1998 and 1999 (see http://www.physics.usyd.edu.au/ugrad/astro/astro_quiz1.html) was adapted from one supplied by Margaret Mazzolini and used at La Trobe University and Swinburne University of Technology. It asked many typical questions about positional astronomy using True/False statements, and was extended to include the full range of stellar, galactic and extra-galactic astronomy covered in the lectures. It was intended to explore the range of knowledge students brought to the course, and gauge how much the course influenced that body of knowledge. It concentrated on 'factual' questions, rather than more deeply imbedded 'structural' concepts that students have developed from their experience of the world. Factual misconceptions are expected to be easier to change.

The quiz was given twice each year – once at the start of the semester and once near the end. In both years the percentage of correct responses at the first attempt averaged approximately 70%, increasing by 7 to 8% at the end of the semester (see Figure 3). Looking more closely, it is clear that more questions were answered poorly in the second half of the quiz, when the emphasis shifted from basic astronomical concepts and planetary ideas to astronomy beyond the solar system. The earlier questions on basic astronomical concepts were answered with 60-80% correct responses, where overseas quizzes often report scores approximately 40-60% correct on such questions. These success rates may reflect the rather different student backgrounds around the world, but are impossible to compare objectively because of the lack of standard questions. The lower scores reported in

Trumper's Israeli study (2000) for example, may reflect the fact that slightly fewer of his students were enrolled in Science and almost none had any high school background in physics.

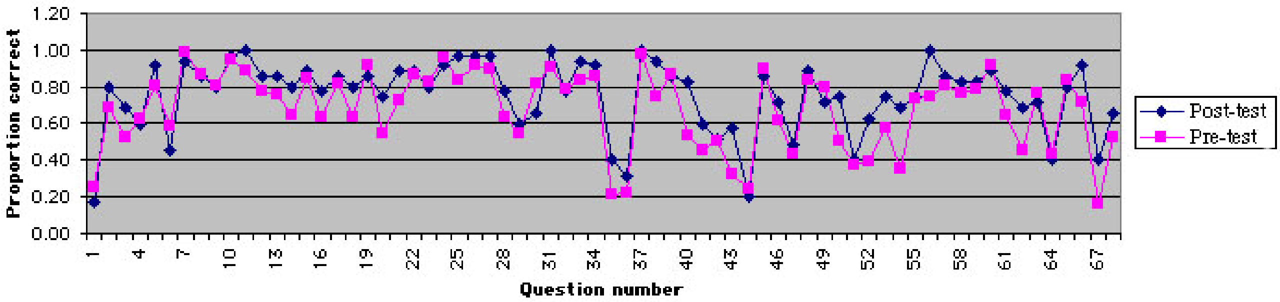


Figure 3. Percentage of correct responses to questions on the 1999 Misconceptions quiz. Pre-test results are typically slightly lower than the post-test results.

The quiz responses deserve closer study using student interviews, but the questions also need to be validated more carefully. The inability to compare these results with others is best addressed by adopting a standard set of questions.

In physics, a standard undergraduate test, the Force Concept Inventory (Redish and Steinberg, 1999), has proven to be a useful tool. In astronomy, the multiple choice Astronomy Diagnostics Test (ADT) has recently been developed and validated as a standard test for undergraduate non-science majors taking an introductory astronomy course (Hufnagel et al., 2000). Version 2.0 of the ADT (see http://solar.physics.montana.edu/aae/adt/) was adapted very slightly for the southern hemisphere and used in *Astronomy* in 2000 and 2001 in place of the earlier Misconception Quiz. ADT questions are intended to test concepts rather than the more factual content tested by the earlier quiz. Questions range from basic astronomy (What is the phase of the Moon when it appears to completely cover the Sun?) through physical concepts (Why do astronauts inside the Space Shuttle float around as it orbits the Earth?) to a little astrophysics (What colour are the hottest stars?). More information on the southern hemisphere ADT can be found at http://www.physics.usyd.edu.au/super/ADT.html.

Analysis of responses by the 2000 class to the southern hemisphere edition of the ADT indicate correct response rates of 45% beforehand, rising to 53% at the end of the semester (see Figure 4). In both cases however the spread is wide with standard deviations of 20%. Looking at individuals, the average improvement from pre-test to post-test is 11%, again with a wide spread.

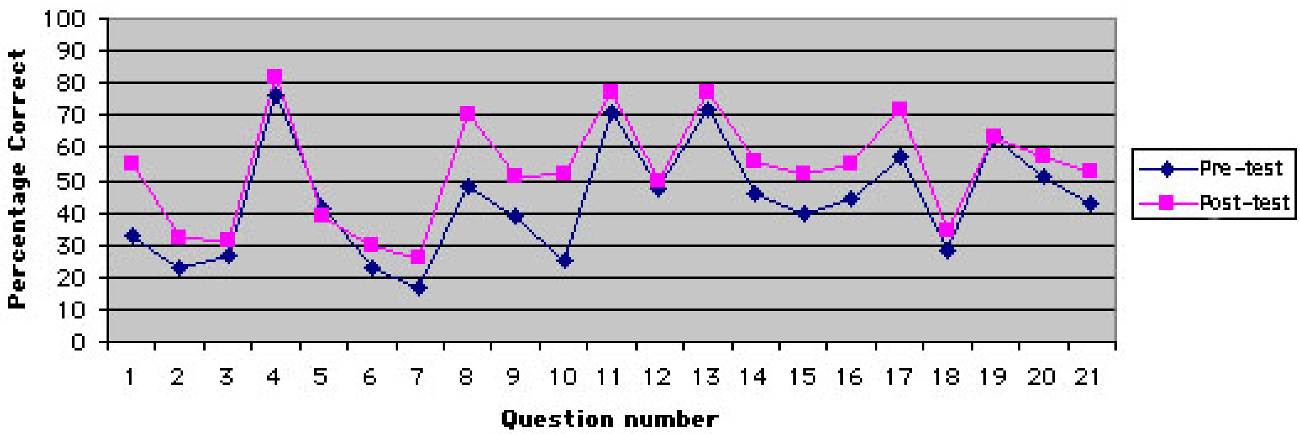


Figure 4. Percentage of correct responses to questions on the 2000 Southern Hemisphere Edition of the ADT. Pre-test results are slightly lower than the post-test results.

These results should not be closely compared with ADT results in the US (Hufnagel et al., 2000) since the southern hemisphere version has not been formally validated with our student group. However the *Astronomy* results do show a somewhat higher rate of correct answers than most of the US universities and colleges surveyed (typical pre-test rates of approximately 35% or less), consistent with the result from the earlier Misconception Quiz. It is likely that this mainly serves to emphasise the different body of students being tested and is therefore a warning against carrying US conclusions about introductory astronomy into the Australian context. Initial results suggest that New South Wales students come to university with a relatively high level of astronomical knowledge, even before changes to the high school syllabus. *Astronomy* further improves the average student response, as revealed by both types of quiz.

Validation of the southern hemisphere edition of the ADT requires participation by a wide group of Australian universities and careful study of the responses in the Australian context. This has begun in 2002 with 4 lecturers at other universities agreeing to administer the southern hemisphere edition of the ADT in semester 1, and potentially more in semester 2.

Student response

We have not interviewed students to probe their opinions on the course, but we have used a variety of questionnaires to probe their subjective attitudes.

Course modules in physics are the subject of routine exit questionnaires to gauge student reaction. The standard format allows direct comparison of student response to different parts of their course and different lecturers. The overall rating for *Astronomy* each year averages around 4.0 on a 5 point scale which is an excellent result, especially for a large and diverse class group such as this. Typical results for junior (first year) Physics units average around 3.3.

The most revealing aspects of any questionnaire are the free-form student responses, although their self-selected nature means that they cannot be treated as strictly representative. Nevertheless they consistently indicate that the unit is well regarded and certain components such as the laboratories, web-based review questions and the night-time viewing sessions are especially popular.

During the 1998 course the Sydney University Physics Education Research (SUPER) group also surveyed various student expectations of the course beforehand, and later repeated the survey to judge how well these expectations had been met. Not surprisingly, 80% of students suggested initially that they expected to gain a general knowledge of astronomy and an understanding of the universe and how it works. This expectation was met for a majority of students.

More specific questions were also asked, such as whether they expected the course would give them a deeper understanding of their own place in the universe. The expectation was high (median value of 4.1 on a 5 point scale) and, as for most questions, these initial expectations were exceeded in the post-course survey. The responses to the entire survey were generally very positive.

All these data indicate a high level of student satisfaction that the style and content are appropriate to their expectations. The question still remains as to whether individual components of the unit presentation are effective. Subjective student opinion is provided in the 1998 survey and some questions on the routine exit questionnaires. The only component to rate poorly is the web-based Discussion Forum which has not yet succeeded in generating genuine discussion among the students, although it has found a place in allowing each tutorial class to report their conclusions to the whole student group.

Conclusion

PHYS1500 *Astronomy* at The University of Sydney is, in many ways, typical of introductory astronomy units in Australia and overseas, although more challenging than many. Are the style and level of presentation of the introductory astronomy units like this appropriate?

An analysis of student examination results clearly indicates that student background is not an impediment to success in *Astronomy*. The highest achieving students represent a genuine cross-section of the student body. Furthermore, surveys indicate that the unit successfully meets student expectations and is popular. Available data do not allow a clear judgement on the educational effectiveness of each component of the unit, but it is apparent that no component is failing in any significant way. On the other hand, the improvement in quiz responses between pre- and post-tests is relatively small, consistent with experience in traditional lecture courses.

These results serve as a baseline for the study of students entering in 2002 and beyond, who are products of a new HSC Physics syllabus in NSW where astronomy features much more prominently. To date however, only around half of the *Astronomy* students have done physics in their last years of school, so this change may increase the difference in student background and pose a greater challenge to the course.

Further work with the southern hemisphere edition of the Astronomy Diagnostic Test (ADT) is clearly justified to measure performance in Australian circumstances and look for changes in student performance as a result of changes to the HSC.

Acknowledgments

The author would like to acknowledge the involvement of other members of the School of Physics in designing and delivering the Junior Astronomy unit, in particular the following staff – Tim Bedding, Anne Green, Richard Hunstead and Mark Wardle – and various postgraduate students. The preparation and analysis of the 1998 class surveys was managed by Ian Sefton for the Sydney University Physics Education Research (SUPER) group.

References

Bisard, W., Aron, R., Francek, M. and Nelson, B. (1994) Assessing selected physical science & earth science misconceptions of middle high through university preservice teachers. *Journal of College Science Teaching*, **24**, 38-42.

Dunlop, J. (2000) How children observe the universe. *Publications of the Astronomical Society of Australia*, **17**(2), 194-206 [Online] Available: http://www.atnf.csiro.au/pasa/17_2/.

Hufnagel, B., Loh, E. and Parker, J. (1998) Learning effectiveness of lecture versus laboratory: Are labs worth it? In L. Gouguenheim, D. McNally and J. R. Percy (Eds) *New Trends in Astronomy Teaching*, Cambridge University Press, 124-127.

Hufnagel, B., Slater, T., Deming, G., Adams, J., Adrian, R. L., Brick, C. and Zeilik, M. (2000) Pre-course results from the Astronomy Diagnostic Test. *Publications of the Astronomical Society of Australia*, **17**(2), 152-155 [Online] Available: http://www.atnf.csiro.au/pasa/17_2/.

Redish, E. G. and Steinberg, R. N. (1999) Teaching physics: Figuring out what works. *Physics Today*, **52**(1), 24-30.

Trumper, R. (2000) University student's conceptions of basic astronomy concepts. *Physics Education*, **35**(1), 9-15.

Trumper, R. (2001) Assessing students' basic astronomy conceptions from junior high school through university. *Australian Science Teachers Journal*, **47**(1), 21-31.

Zeilik, M., Schau, C. and Mattern, N. (1998) Misconceptions and their change in university-level astronomy courses. *The Physics Teacher*, **36**, 104-107.

Zeilik, M. and Bisard, W. (2000) Conceptual change in introductory-level astronomy courses. *Journal of College Science Teaching*, **29**(4), 229-232.