# Implementing a Studio-based Flipped Classroom in a First Year Astronomy Course

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## Abstract

We present a case study of the rapid transformation of a first year astronomy unit from a traditional lecture/laboratory teaching approach to an entirely studio-based flipped teaching approach. Our Physics and Astronomy Collaborative Environment (PACE) studios at the School of Physics and Astronomy at Monash University were designed along the lines of SCALE-UP approach, with the pedagogy adapted to suit our unit. In this paper, we outline the design, early evaluation, and impacts of this transformation. In terms of content knowledge learning gain, we achieved a 0.41 mean gain with a 0.19 standard deviation on a custom hybrid concept inventory, mirroring the high gains seen in other highly interactive physics and astronomy courses. This study shows that a studio-based approach to tertiary introductory astronomy can be viable and successful. We also achieved a significant reduction in overall failure rates from 11-15% between 2012-2014 to 4% in 2015, which we hope is the result of a better student engagement. We will continue to measure effectiveness of our teaching approach and how it reflects on our students' learning gains and success.

## Introduction

Tertiary science education in the 21st century is marked by a shift from a traditional lecture-centred model to more student-centred and interactive teaching approaches. The first strong case for making this shift at a large-scale was argued in physics education by Hake (1998), where interactive courses were roughly twice as effective in terms of student gain on the Force Concept Inventory (Hestenes 1992) than traditional courses.

This success was mirrored in astronomy education, in particular with the early work of Zeilik, Schau, Mattern, Hall, Teague and Bisard (1997) via the use of the Astronomy Diagnostic Test. A recent study uncovered similar comparisons between traditional and active learning in the astronomy domain (Prather, Rudolph, Brissenden and Schlingman 2008). These successes in the closely related fields of physics and astronomy have provided impetus for many physical science departments worldwide to start shifting towards interactive forms of tertiary education.

While this style of teaching already has a relatively long and successful history in mainstream physics (for example, Crouch and Mazur 2001; Beichner and Saul 2004; Dori and Belcher 2004; Pollock 2004; Hoellwarth and Moelter 2011; Deslauriers, Schelew and Wieman 2011), most astronomy undergraduate courses still tend to be delivered in large lecture halls as the core face-to-face component. The main focus of studies in introductory undergraduate astronomy or 'Astro 101' courses has been on improving the instructional quality of time spent in the lecture theatre to deal with the very large cohorts seen in the US institutions (Waller and Slater 2011). In this paper we report a successful transformation to a flipped, lecture-laboratory blended approach achieved over the course of only two semesters in a studio-based teaching environment at Monash University in Australia.

## Our student cohort

ASP1010 - Earth to Cosmos, is a first year elective astronomy undergraduate unit, first presented in 1998 (Hutton and Feteris 2000) in the School of Physics at Monash University. ASP1010 does not form a required part of any major, although it can be used as a component of an astrophysics minor or major. The unit is offered in the first semester only, with a complementary unit, ASP1022 – Life in the Universe, offered in the second semester. With ASP1010, our aim is to support students intending to undertake a major to delve deeper into professional-level astronomy in second year, while also allowing students for whom this is their only astronomy or science unit to continue undertaking or appreciating astronomy at an amateur level.

The majority of the 200+ students enrolled in ASP1010 are first year science and engineering students. A smaller fraction of the students are non-science majors (~20%), while some of the students are from more senior years (~20%).

## Implementation of studio-based teaching

The first 16 years of ASP1010 saw students interact with staff through three one hour-long lectures and one two hour-long laboratory session a week. The labs combined hands-on activities using equipment where possible (e.g., spectroscopy, optics), with paper-based activities or the use of simulated data (e.g., CLEA software). The laboratory spaces only accommodated up to 20 students, working individually, to form a laboratory group led by one teaching assistant. To accommodate the numbers of students enrolling in the unit (200+ students), several laboratory sessions had to be scheduled at multiple times throughout each week of the semester. Thus, the laboratory topics, at best, were related to the material covered in the lectures of the week before.

In 2014, the School of Physics and Astronomy made a major investment to refurbish the existing teaching spaces into two first year teaching studios that closely reflect the optimal Phase-III SCALE-UP design described in Beichner (2008). SCALE-UP stands for Student-Centered Active Learning Environment with Upside-down Pedagogies, where "upside-down" refers to flipped pedagogies. The SCALE-UP design means having round tables that can seat 9 students in a studio room with capacity of roughly 100 students. That year, traditional lectures were still delivered in a lecture theatre, but were transformed to be interactive by the use of the CAPERcard app (http://www.caperteam.com/classroom-resources). This app does not require any wifi connection and simply provides students the choice of coloured blocks to click on, with letters A, B, C and D placed on different colours. Once the student choses the answer for a multiple-choice question, they would turn their mobile devices towards a lecturer, who would be able to assess roughly which colours dominate and how well students have understood the concept being presented. However, only half of the students attended those lectures on average.

Thus, the Physics and Astronomy Collaboration Environment (PACE) studios were built to encourage students to attend in larger numbers, as well as interact with academic staff more, thus making a better learning experience. In 2014, all the ASP1010 labs were delivered in one of the PACE studios, which is equipped with 12 round tables each comfortably seating up to nine students. With over 200 students enrolled that year, there were now only three laboratory sessions, each with approximately 80 students, scheduled after the three lectures in the same week. This led to a better alignment between the lectures and the laboratories, and allowed for increased interaction between the lecturer and the students given that the lead lecturer, who was also the unit coordinator (the first author), could be physically present during all of the laboratory sessions. At this stage, some of the practicals for the laboratories have been updated from paper-based to more hands-on activities that use real astronomical data and software. For example, the first lab that involved the making of a cardboard starwheel to teach the basics of celestial mechanics was replaced with an activity based on an open-source software Stellarium, which simulates a planetarium and provides the opportunity for real-time inquiry-based activities.

## New course design and activities

In 2015 this lecture/laboratory approach was replaced by two, two-hour-long workshops a week, with an emphasis on inquiry-based cooperative learning. The students were organized into four teams of two students per table. Each team had access to one computer, to allow for both members of the team to be significantly involved in hands-on learning.

Our learner-centred pedagogical approach aligns with that of SCALE UP, and is a blend of lecture and laboratory instructions. This approach minimises passive lecturing, instead using a more engaging instructional approach drawing on a variety of education research (e.g. Beichner 2008). The result is an environment where students can work cooperatively and learn from peer discussions and guidance from their instructors.

**Figure 1: Workshops in progress in the PACE Studios**

In 2015 our teaching team consisted of six inexperienced instructors, most of whom were Honours students, and three experienced teaching staff (including the first and second author). The unit coordinator was also the lead instructor (the first author), and was present in each workshop session, along with another experienced instructor to accompany two inexperienced instructors. This led to an approximate staff-to-student ratio of around 20:1.

The unit coordinator created all the pre-class and post-class activities, assignments, and half of the face-to-face workshops, and one of the other instructors (the second author) helped with the other half of the workshops. The most time-consuming aspects of this rapid transformation were preparing and aligning pre-class material with the in-class activities. For activities in the workshops, we relied on many resources in the public domain, such as those available through The Nebraska Astronomy Applet Project, Zooniverse, NASA, ESA, and similar organizations.

**Pre-class activities**

The students were required to prepare before each face-to-face session, initially by reading sections of textbook and watching videos, which were short (up to 20 min) voiced-over slide presentations. Half-way through the semester, the videos were replaced by Moodle "lesson" modules, which allow for a more interactive delivery of material. These lessons consist of a set of pages that contain a short overview of the key concepts to which students should pay attention when undertaking the required textbook pre-readings. The main advantage of these "lesson" modules was that their format allowed us to enrich the preparation material with open source videos from NASA, ESA and similar sources. These provide high-quality visual representations of the concepts being addressed, which is very important for teaching observational science like astronomy. A typical lesson usually consisted of three pages; each page ended with a formative conceptual multiple-choice question that students had to answer correctly to progress to the next page.

After completing the preparatory activities, the students answered a conceptual quiz in *MasteringAstronomy*, which is a product of Pearson Education Publishing, and can be embedded within Moodle. The costs of using *MasteringAstronomy* were covered by the University, and thus the platform was provided free of charge to the students. The quizzes are worth 5% of the total mark for the unit. These quizzes are also used to facilitate just-in-time teaching, as conceptual problems were identified by the lead instructor through the feedback provided by the system, and were then addressed in the face-to-face session.

**Face-to-face activities**

The instructors facilitated face-to-face interactions during the weekly workshops. The workshop schedule covered the full breadth of astronomy: it ranged from the spatial scale of the Earth to the large-scale universe. We did not have to reduce the range of topics taught by the traditional means of previous years, but we did reduce the depth at which some of the less crucial sub-topics were covered.

To facilitate collaborative learning, we adopted a team formation tactic following a suggestion by Slater and Adams (2003), suitable for diverse cohorts of astronomy students. We asked our students to sit randomly and have a quick chat to a potential team member about their personal level of commitment to this unit. If they found that they did not match, they were asked to find a new team member whose motivation matched theirs. It was also explained that teams would be revisited in the mid-semester week, and that they could discuss any issues with the teaching staff at any time. It is known that team development takes time, as the majority of students have not necessarily had the experience of working successfully in teams (Hansen 2006). The teams were also encouraged (and sometimes required) to cooperate with the other teams at their table.

During the workshops, the lead instructor would deliver a 10-15 minute introduction, or mini-lecture, of the topic and go over the ill-performed questions from the pre-class preparation.

The students would then work on activities and discuss interesting questions arising from them. All the activities were based on the principle of guided inquiry and problem-based learning, with an accompanying worksheet for students to fill out as they progressed through the activity. The activities involved simulations, real astronomical data (collected by the instructors themselves or publically available), and/or paper-based problems where no data or simulations were available. Throughout the workshops, all the instructors would help out students in the class, and the lead instructor would occasionally address the whole class to clarify a concept or instructions, if it was found that students were struggling.

Positive interdependence among students was encouraged by requiring the teams to submit a jointly filled worksheet at the end of the workshop. However, if students could not come to an agreement on an answer, they were encouraged to record their differing points of view. Such an approach to in-class assessment was adopted to enhance learning and discussion, rather than to assess students on their knowledge. The worksheets completed in the workshops were collected and marked after each session. They were worth 25% of the total mark for the unit and constituted a "hurdle" requirement. In other words, students had to achieve a passing mark for the practical component to pass the unit.

Formative assessment in the workshops was carried out through the use of class-wide open-ended discussions or multiple-choice questions using the Immediate Feedback Assessment Technique (IF-AT) cards from Epstein Educational Enterprises. Once the cards were delivered to the teams, students would work together to agree upon an answer, then scratch A, B, C or D field on the card for that question. If that reveals a blank field, the students will know that they answer was wrong, and they would continue their discussion until they choose and scratched another field, persisting until the correct answer was revealed by a star in the field. This approach allowed the instructors to listen in on the discussions between the students and gain insight into their learning process. For longer inquiry-based activities, the instructors would also engage in reflective discussions at each table.

**Post-class activities and other assessment**

Non-assessed post-workshop consolidation and revision was facilitated through *MasteringAstronomy* assignments using mostly "tutorial" questions, in which students could access hints to help them to find the answer. Thus, such questions explicitly model the process of how to go about solving the problem. Collaborative learning was further encouraged and supported by Moodle forum discussions throughout the unit. There was roughly 100 forum posts during the semester, with half of them being initiated by the students, and having 2-3 responses per post on average.

The students also had four equally spaced *MasteringAstronomy* assignments, worth together 10% of the total mark for the unit. This enabled timely feedback to be given to the students, as 10 or so multiple-choice questions were automatically marked, and 2-3 essay questions were marked by two of the instructors within a few days. In addition, the unit coordinator thereby had a more realistic measure of students' performance and could create additional resources to bridge any observed gap.

Another component of the unit was a project, which was an individual assessment. This was designed to be a demonstration of what students felt they knew well and had enjoyed the most in the unit. They presented this review as a popular science article, worth 10% of the total mark. The final exam at the end of the semester carried 50% of the total mark.

## Results

### Instructor Observations

This rapid transformation from lecture/lab to flipped workshop-based delivery was possible due to the unit coordinator taking on an education-focused, rather than a standard research-focused position, which entails following the latest educational research findings and implementing them in the teaching practices of the School, as well as leading other innovations in education. Another important factor in the successful implementation of any, especially rapid, innovation in teaching is the willingness of the unit coordinator to refine their delivery straight away where possible. In the words of one of our students from the end-of-the-semester unit evaluation:

> *"Because it is a new unit, I appreciate you <unit coordinator> constantly requesting feedback and improving on the unit. It has definitely improved over the semester and I feel like I am learning more in the workshops - meaning less study to do at home!"*

An example of this timely change is the switch from the preparatory videos to the Moodle lessons. While some students found videos helpful, others found them less engaging than the textbook, so the unit coordinator came up with the lesson mode explained earler. Our students found this approach to class preparation very engaging:

> *"I prefer this format. It's easier to get through, and for taking notes. The animations are also great for helping me visualise how things form/change, as well as showing the progression of astronomical research."*

The PACE environment naturally fostered collaborative learning between the students. We frequently observed half or the whole table deeply engaged in task-oriented discussions. This led to more heterogeneous groups of students participating in constructing knowledge on the topic explored. The chosen approach to team work was appreciated by the students and is evident in their end-of-semester evaluation comments (see below). This reflects similar findings by other educators employing cooperative learning strategies (for example, Christensen 2005).

### Quantitative Evaluation of Student Learning

In order to understand the level of conceptual understanding achieved by students, we used a custom-designed multiple measures pre/post content knowledge questionnaire, which is an extended version of that outlined in Fitzgerald, McKinnon, Danaia and Deehan (2015). Unfortunately, we did not construct this questionnaire before 2015, so we have the data just for 2015.

Use of an existing conceptual inventory was not an ideal option, because any one instrument does not cover the content of our unit adequately. Our Astronomy Knowledge Questionnaire (AKQ) is a hybrid concept inventory containing 36 items, of which 23 are sourced from a variety of existing astronomy concept inventories and altered, where appropriate, for our southern hemisphere location. The remainder are the items created by the second author and an example is given below:

> *Q25. What is the primary function of a telescope?*
> *A: To allow us to magnify small things in the night sky.*
> *B: To allow us to observe dim things in the night sky.*
> *C: To allow us to make things in the night sky less blurry.*
> *D: To remove the effects of the Earth's atmosphere.*
> *E: To see the night sky in colour.*

The AKQ is not intended to be a focussed concept inventory for external comparisons, like the Astronomy Diagnostic Test (Zeilik 2002), but rather as a more general probe of content knowledge of most topics covered by our unit. The AKQ was taken at three points during the semester: in the first class (P1), in the middle of the semester (P2) and at the end (P3). The topics covered by the P2 stage included question no. 1, 2, 3, 4, 7, 9, 16, 18, 19, 20, 25, 29 and 31.

**Table 1: Performance on the custom-tailored content knowledge questionnaire. Results are shown by question, over three occasions, P1, P2 and P3. Question sources shown in the far right column are: Dunlop= Dunlop (2000); TOAST = Slater (2014); ClassAction = UNL; SPCI = Bailey et al. (2012); LSCI = Bardar (2006); Trouille = Trouille et al. (2013); Coble = Coble et al. (2013).**

| No | Topic | | P1 | P2 | P3 | p | Sig? | Gain | Source |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Causes of Day and Night | **Q1** | 86% | 94% | 97% | **0.000** | **Yes** | **0.81** | Dunlop 5a |
| 2 | Why does the moon go through phases? | **Q2** | 81% | 86% | 87% | **0.105** | **No** | **0.34** | TOAST 5 |
| 3 | Causes of the Seasons | **Q3** | 57% | 91% | 96% | **0.000** | **Yes** | **0.90** | Dunlop 4a |
| 4 | Blackbody, Temperature and Luminosity | **Q4** | 54% | 70% | 80% | **0.000** | **Yes** | **0.56** | SPCI 16 |
| 5 | Big Bang Description | **Q5** | 77% | 75% | 85% | **0.013** | **No** | **0.33** | TOAST 9 |
| 6 | Expansion between Galaxies over time | **Q6** | 86% | 94% | 97% | **0.000** | **Yes** | **0.81** | Trouille et al. 2013 |
| 7 | Motion of the sun through the sky over a day | **Q7** | 12% | 18% | 23% | **0.000** | **Yes** | **0.13** | TOAST 2 |
| 8 | Galaxy Colour of spiral galaxy and star population | **Q8** | 50% | 61% | 45% | **0.000** | **Yes** | **-0.10** | UNL |
| 9 | Size and Shape of Asteroid Belt | **Q9** | 13% | 23% | 25% | **0.001** | **Yes** | **0.14** | UNL |
| 10 | Dark Energy Description | **Q10** | 39% | 52% | 86% | **0.000** | **Yes** | **0.76** | Coble et al. 2013 |
| 11 | Ranking Distances of objects | **Q11** | 78% | 83% | 93% | **0.000** | **Yes** | **0.68** | TOAST 10 |
| 12 | Relationship between stellar lifetime and mass | **Q12** | 24% | 23% | 70% | **0.000** | **Yes** | **0.61** | SPCI 5 |
| 13 | Ranking Sizes of Objects | **Q13** | 78% | 85% | 93% | **0.000** | **Yes** | **0.67** | TOAST 11 |
| 14 | Expansion of the universe description | **Q14** | 61% | 68% | 66% | **0.274** | **No** | **0.11** | TOAST 15 |
| 15 | Stars beginning life as gas/dust | **Q15** | 85% | 92% | 97% | **0.000** | **Yes** | **0.78** | SPCI 14 |
| 16 | Interpreting emission spectra | **Q16** | 30% | 38% | 47% | **0.001** | **Yes** | **0.24** | LSCI 17 |
| 17 | End of sun-like stars life | **Q17** | 31% | 36% | 71% | **0.000** | **Yes** | **0.58** | TOAST 17 |
| 18 | How did the planets form? | **Q18** | 31% | 55% | 58% | **0.000** | **Yes** | **0.39** | TOAST 19 |
| 19 | Peak wavelength and temperature | **Q19** | 40% | 59% | 68% | **0.000** | **Yes** | **0.46** | LSCI 12 |
| 20 | orbital transitions producing photons | **Q20** | 79% | 85% | 86% | **0.014** | **No** | **0.34** | LSCI 13 |
| 21 | Source of Carbon Atoms | **Q21** | 37% | 40% | 57% | **0.000** | **Yes** | **0.32** | TOAST 24 |
| 22 | Definition of a star | **Q22** | 59% | 65% | 82% | **0.000** | **Yes** | **0.56** | SPCI 15 |
| 23 | Large-scale structure description | **Q23** | 36% | 39% | 46% | **0.057** | **No** | **0.15** | Original |
| 24 | Galaxy distance in proportion to size | **Q24** | 25% | 20% | 73% | **0.000** | **Yes** | **0.64** | Original |
| 25 | What is the primary function of a telescope? | **Q25** | 14% | 49% | 45% | **0.000** | **Yes** | **0.35** | Original |
| 26 | Inverse Square Law | **Q26** | 55% | 82% | 93% | **0.000** | **Yes** | **0.84** | Original |
| 27 | How many stars experience parallax? | **Q27** | 26% | 32% | 35% | **0.061** | **No** | **0.13** | Original |
| 28 | Distance and apparent motion | **Q28** | 53% | 60% | 62% | **0.141** | **No** | **0.19** | Original |
| 29 | Visible light, energy and speed | **Q29** | 45% | 62% | 70% | **0.000** | **Yes** | **0.45** | TOAST 23 |
| 30 | Globular Cluster ID | **Q30** | 39% | 46% | 67% | **0.000** | **Yes** | **0.47** | Original |
| 31 | Planetary Nebula ID | **Q31** | 36% | 38% | 55% | **0.000** | **Yes** | **0.29** | Original |
| 32 | Elliptical Galaxy ID | **Q32** | 33% | 43% | 77% | **0.000** | **Yes** | **0.66** | Original |
| 33 | Spiral Galaxy ID | **Q33** | 82% | 90% | 94% | **0.000** | **Yes** | **0.70** | Original |
| 34 | Open Cluster ID | **Q34** | 53% | 62% | 75% | **0.000** | **Yes** | **0.46** | Original |
| 35 | Supernova Remnant ID | **Q35** | 32% | 35% | 52% | **0.000** | **Yes** | **0.29** | Original |
| 36 | Diffuse Nebula ID | **Q36** | 36% | 41% | 62% | **0.000** | **Yes** | **0.41** | Original |

The students were given 40 minutes to complete paper-based bubble sheets in the workshops. Out of 226 students, 181 undertook all three of the tests. Each item was recoded to a dichotomous correct/incorrect variable. The percentage of the class getting the question correct on each occasion, P1, P2 and P3, is shown in Table 1. Cochran's Q was used to estimate the statistical significance of the change in these variables per question over the three occasions. The value for *p* was set at the Bonferonni-corrected level for 36 items with a mean inter-item correlation of 0.095 and $p < 0.002$. With these comparisons, 29 out of the 36 items were statistically significant.

The distributions of student scores on each testing occasion did not have normal distributions. Hence a Friedman test was undertaken to test for statistically significant differences between the three (P1, P2 and P3) distributions. The calculated probability was 8.4 x10$^{-84}$, meaning that the differences are highly statistically significant. The maximum gain per question per student was 0.93 and the minimum -0.16. The mean class scores on the pre-, mid- and post-tests rose steadily over the semester from an average of 49% to an average of 69%, with a common standard deviation of 14%, as shown in Table 2.

**Table 2. Broad summary of class-wide performance on our content knowledge inventory.**

| | Pre (P1) | Middle (P2) | Post (P3) |
|---|---|---|---|
| Mean score on the test | 49% | 59% | 69% |
| Standard deviation | 14% | 14% | 14% |
| Max score on the test | 81% | 87% | 97% |
| Min score on the test | 14% | 20% | 30% |

The median gain, in the form defined by Hake (1998), <g> = ( %<posttest> – %<pretest>) / (100 – %<pretest>), between the first test score (P1) and the final test score (P3) was 0.41, with a standard deviation of 0.19. This is similar to findings from Hake (1998) for more interactive teaching approaches (0.48 +/- 0.14), but not quite as high (0.49 to 0.74) as those claimed for Peer Instruction approaches (Crouch and Mazur 2001).

To visualise overall performance, we plot each student’s pre-test (P1) and post-test (P3) AKQ scores in Figure 2. The red line represents equal performance in the two tests. We can see that the vast majority of students scored better on their final attempt compared with their initial one.

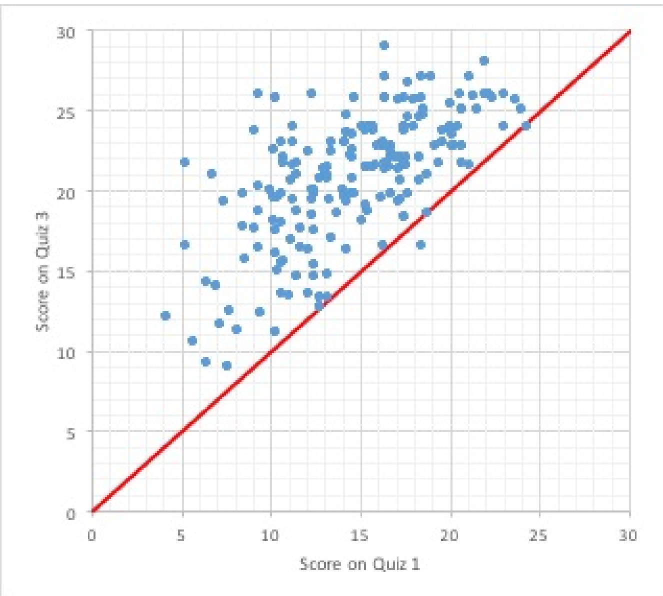


**Figure 2. Comparison of the post-test (P3) results to the pre-test (P1) results.**

The graph shown in Figure 3 compares students' initial raw scores on the pre-test to their fractional improvement in terms of their possible gain. It can be seen that there was little dependence on students' prior knowledge on their capacity to learn in terms of gains in their content knowledge. This is a similar result to that reported in Zeilik, Schau and Mattern (1999), and Hufnagel, Slater, Deming, Adams, Adrian, Brick and Zeilik (2000). Nevertheless, this is an important result for a cohort with a significant range of background knowledge.

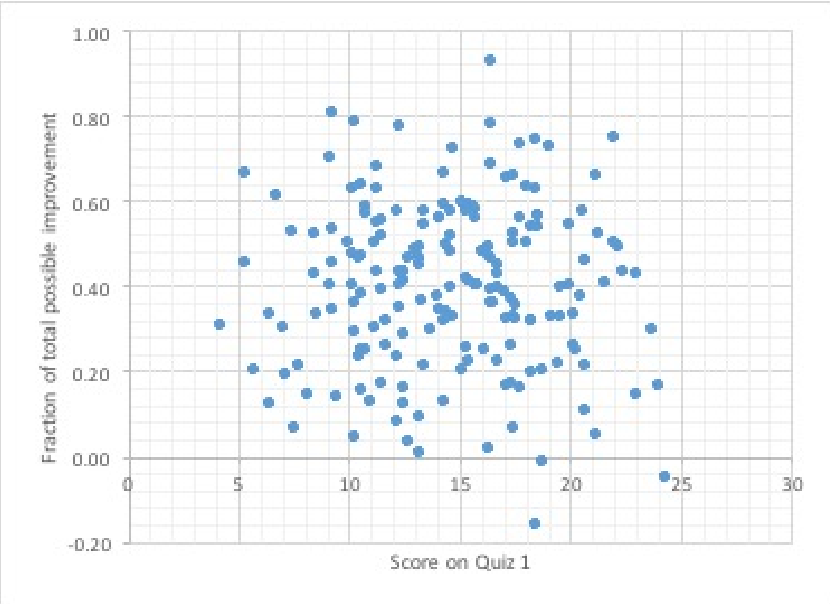


**Figure 3. Comparison of total possible improvement achieved to the pre-test (P1) results.**

**Exam comparison**

Measures were also taken to compare the students' performance in the new approach to the more traditional teaching format undertaken the year before. We took 13 exam questions from 2014 and repeated them in a slightly changed form in the 2015 exam. For seven of these questions we expected the 2015 students to perform better, as these topics were expanded through inquiry activities in 2015 workshops. For the other six questions we expected a similar or worse performance, as these topics are covered just in reading or video material. Indeed, the average improvement for those seven questions of new focus was (12+/-18)%, and for the other six questions was (-1+/-13)%.

These outcomes are better than expected, and it validates the ability of the newly implemented pedagogical approach to enable better learning outcomes for our students.

We also compared overall failure rates with the previous three years that this unit coordinator was in charge. We find a significant reduction in failure rates in 2015 to 4%, compared with 14% in 2012, 15% in 2013 and 11% in 2014. Over those years 4, the exams were of similar difficulty. Thus, the low failure rate in 2015 could be a result of a better engagement through compulsory four hours/week face-to-face workshop sessions, in comparison to only two hour/week compulsory lab session in the past. Another reason could be that we had a self-selected group of dedicated students, as we explicitly made a point that this unit requires dedicated work and that responsibility is on a learner (the student) to actively seek to acquire knowledge. A future comparisons will help us understand this better.

**Student evaluation of Learning Experience**

Monash University's quality control student survey is called "Student Evaluation of Teaching Units" (SETU) and contains 10 items, which are shown in Table 3. End-of-semester student evaluations have been shown to have little correlation to actual desired unit outcomes and have limited use as feedback to unit coordinators between cohorts (see e.g., Fraser, Timan, Miller, Dowd, Tucker and Mazur 2014). However, as a within-group same-unit comparison, such evaluations can still be of some use. The surveys allow us to compare broadly the student evaluations of the traditional lecture/laboratory unit from 2012 to the entirely altered unit in 2015 (run by the same unit coordinator). The mean scores, drawn from a five-point Strongly Agree - Strongly Disagree Likert scale, for each item and year is provided in Table 3 along with the averages for the previous three years (2012-2014). This post-unit survey is optional, and less than 40% of the cohort responded, leaving the results open to potential selection effects.

**Table 3. Student evaluation (SETU) results for ASP1010 from 2012 to 2015.**

| Question | 2012 | 2013 | 2014 | 2015 | Average (2012-2014) | Diff |
|---|---|---|---|---|---|---|
| Response Rate % | 32.54 | 27.17 | 23.81 | 25.22 | | |
| No. of Responses | 68 | 75 | 50 | 57 | | |
| The unit enabled me to achieve its learning objectives | 3.99 | 4.19 | 4.03 | 3.88 | 4.02 | -0.14 |
| I found the unit to be intellectually stimulating | 4.15 | 4.54 | 4.52 | 4.04 | 4.31 | -0.27 |
| The learning resources in this unit supported my studies | 3.82 | 4.16 | 4.12 | 3.81 | 3.98 | -0.17 |
| The feedback I received in this unit was useful | 3.59 | 3.88 | 4.06 | 3.58 | 3.78 | -0.20 |
| Overall I was satisfied with the quality of this unit | 3.94 | 4.2 | 4.11 | 3.83 | 4.02 | -0.19 |
| The organisation and progression of the topics covered is sensible and coherent | 4.14 | 4.3 | 4.2 | 3.98 | 4.16 | -0.18 |
| The lectures helped me achieve the unit learning objectives | 4 | 4.2 | 4.09 | 3.45 | 3.94 | -0.48 |
| The tutorial/practical classes/field work helped me achieve the unit learning objectives | 3.86 | 3.92 | 4.35 | 3.83 | 3.99 | -0.16 |
| The assessment tasks helped me achieve the unit learning objectives | 3.96 | 3.93 | 4.11 | 3.65 | 3.91 | -0.26 |
| Individual assisstance (either face-to-face or online) was available when needed | 4.06 | 4.16 | 4.24 | 4.34 | 4.20 | 0.14 |

There is a general trend of improvement between 2012 to 2014. The main changes implemented over the first two years involved mainly introducing new lab activities which are based on contemporary topics and techniques in astronomy. The major changes were implemented in 2014 by introducing pre-reading quizzes and in-class polling via the CAPERcard app in lectures. That year the labs were conducted in the PACE studio, and the unit coordinator was able to be present in each of the three session.

It can be seen that responses to all of the 2015 SETU questions bar one moved in the negative direction. The items #10 has been moving in the positive direction in the last two years since moving to the PACE studio, indicating that students appreciate the level of interaction with lecturers that this form of teaching provides. The largest difference, in whether the lectures helped (#7), led to the largest decrease of 0.65 which is easily explained by the fact that there were no lectures in 2015. The other items saw roughly a 0.25 Likert point decrease in student satisfaction. It is a common occurrence that the first feedback occasion after changing instruction approach in a course will produce a decrease as students' expectation of what constitutes a 'good learning experience' is heavily based on their prior learning experiences (Entwistle & Peterson 2004). The lower 2015 SETU scores could also be a product of the mismatch between the style of the questions, which are directed heavily towards lectures only, rather than including the practical or interactive components of the unit. This indicates a possibly widespread problem in the use of institutional surveys that assume traditional teaching formats. In any case, we will monitor further SETU scores and compare them with other forms of evaluation to identify any additional trend in SETU evaluations.

In terms of open-ended feedback provided in the 2015 SETU survey, the responses were coded according to the topics mentioned in response to two questions: ‘What were the best aspects of the unit?’ and ‘What aspects of this unit are most in need of improvement?’ Out of 71 topics mentioned for the question about the best aspects, the most-frequently mentioned items were “Workshops” (12), “Content” (10), “Working in teams” (9) and “Instructors” (6). Out of the 62 topics mentioned for the question about suggested improvements, the only item that gained a significant number of responses was “The lack of lectures” (20). Thus, while students appeared to be positive about the workshops, the instructors, team work and the content, they felt that a traditional lecture should be a part of the unit:

> *“I feel as though the recent change in the course material this semester of removing lectures entirely was not the best idea. Whilst this does makes the course arguably far more enjoyable and exciting, I and others I've spoken to concerning the course agree that the lack of lectures makes it harder to learn course content and will likely make the exam considerably more difficult.”*
>
> *“Given I am paying a great deal of funds for my undergraduate degree, it begs the question, what am I paying for in <this unit>- it seems to me I am paying for the testing of my astronomical knowledge that I gained myself. I do not expect to be spoon fed all the material required to succeed in my university units, but as a minimum I do expect an expert in the field to introduce me to the material.”*

In response to the criticism, note that we did provide comprehensive pre-workshop lessons, guides and videos, as well as explicit introductions (mini-lectures) in the face-to-face sessions. It appears that these provisions were not considered as an introduction to the material for some students. Indeed, statements such as these are found to originate from the fact that students find self-directed learning unnerving due to the complexity and volume of information needed to learn (Raidal and Volet 2009).

The teaching philosophy was explained in great detail and supported by showing the latest education research findings on the inefficiency of passive learning through lectures. For some students the new teaching approach worked as intended:

> *“Its dynamic new way of providing two 2hr workshops per week instead of separate lectures and labs meant that not only did I learn everything more thoroughly but they eliminated the problem that other units sometimes have where the lectures and the labs are teaching different material, making the labs very difficult to have the appropriate knowledge for. This new structure was very helpful and allowed me to learn the content more thoroughly than any course before.“*

## Conclusions

In this paper, we have presented a case study of a first year astronomy unit being fully transformed from a traditional lecture/laboratory format into an active, learner-centred studio-based unit similar to the SCALE-UP approach.

We have evidence of significant learning by students in this unit format. We have utilised a customised content knowledge survey that covers the content in our unit and measure a mean content knowledge gain of 0.41 with a standard deviation of 0.19. This result is consistent with other studies that find interactive teaching approaches increase learning gains in comparison with a more traditional teaching approach. Our 2015 students performed better on a small sample of the same exam questions from 2014, and overall failure rate dropped from over 10% to 4%.

Whether it is a simple by-product of an increase in human interaction or arising from a much more sophisticated mechanism will be the course of our future research. Our main focus for the future unit development is development of more pre-class resources and modification of the assessment to encourage further self-regulated learning in our students.

Studio-based teaching provides huge flexibility in what kind of instruction, activities or formative assessment can be implemented, which is one of its main attractions. As massification of tertiary education continues, University courses will require the ability to adapt to the fast-changing needs of upcoming cohorts with varied knowledge and skill backgrounds. The initial significant investment of time for the lead instructor(s) is desirable, but not compulsory – a transformation could be implemented at a slower pace over a few semesters. Sharing the load between at least two academics would ensure a sustainable workload long term.

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