Enhancing Student Engagement in Physics Using Inquiry Oriented Learning Activities

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Abstract

The adoption of Inquiry Orientated Learning (IOL) activities has proven to be a successful way of engaging students in learning first year physics. IOL activities were incorporated into a variety of undergraduate learning environments, including laboratories, lectures and tutorials. They were trialled with students from a diverse range of majors and they were also developed to operate with, on-campus and external modes of study. Two academic staff members and several tutors involved in the IOL activities monitored their level of success as indicated by the amount of student engagement and on-campus attendance. The aim of this paper is to provide a narrative of the process of implementation in a real teaching and learning environment. We do not provide systematic data but capture the essence of integrating IOL across various elements of a range of subjects. This "soft touch" process ensured staff and departmental buy-in. The implementation of the IOL activities was found to improve student engagement within the first year physics offerings.

Introduction

In 2011 Professor Les Kirkup's invitation to develop, trial and evaluate, Inquiry Orientated Learning (IOL) activities as part of his OLT Senior National Teaching Fellowship (Kirkup 2013) was accepted because IOL looked like a way to engage, motivate and enrich the learning experience of students taking first year physics or bridging units, both in the on-campus and external modes. IOL, as Kirkup described it, sounded interesting

> IOL is a student-centred, activity-intense, approach to learning. While there are many alternative labels to IOL they are all variations on the theme aimed at placing students at the core of their own learning; engaging and stimulating both learning outcomes and student self-belief (Kirkup, 2011)

The learning landscape at Murdoch University is changing: student numbers in face-to-face lectures and tutorials are decreasing even though enrolments in units are stable or increasing, and the teaching of physics needs to change to meet this challenge. It follows that if an immersive face-to-face learning and teaching relationship with students is to be maintained, there has to be something of value to the student, in the face-to-face learning environment. To give them a stronger reason for attending on-campus activities this valuable experience should not easily translate to the on-line environment. The IOL activities hold promise in that they require students to interact in real time with other students, something that is difficult to do in an on-line environment.

Using IOL activities with students was appealing because it dove-tailed with the university and schools focus on the students as learners. Staff at Murdoch University have had strong leadership in understanding a wider view of the learning and teaching process, as highlighted in the LEPO Framework

> learning environments facilitate learning processes, and these lead to learning outcomes, which, in turn, determine the learning environment… teachers design learning environments, facilitate learning processes and assess learning outcomes, while students work within learning environments, engage with learning processes and demonstrate learning outcomes, as well as interacting with their teachers (Phillips, McNaught & Kennedy, 2010).

More focussed thought has also been given by the academic staff to the learning and teaching environment in physics and engineering and a student-centred approach to learning and teaching is well understood for students in the second part of their degree (Armarego, Agelidis, & Cole, 2005). Many of the first year students in physics units go on to do engineering, so adoption of IOL activities enables us to extend the focus on student-centred learning into the first year units for all students. This allows students to engage with learning in a hands-on way, with interactive lectures, tutorials and laboratories and thus equip themselves with the skills and abilities they need to think and act for themselves in their future studies.

Murdoch University enrols students as either on-campus or external students. On-campus students are expected to attend lectures, tutorials and laboratory sessions. In reality, many only turn up to activities if they are being marked for it. Laboratory sessions are therefore well attended, tutorials are attended if there is a test, but the attendance tends to drop off as the semester progresses. Physics units have been studied in the external mode for nearly forty years at Murdoch (Creagh & Parlevliet, 2011). External mode students do not have to attend any on-campus classes but are expected to have computer and internet access. External students include people, working on mine sites, on remote farms, in the armed forces, overseas, or doing shift work, as well as students who have timetable clashes with other units and are therefore unable to attend tutorials and laboratory sessions. There can be as many as fifty Murdoch students studying in this mode across the bridging and first year physics units at any time. Whichever way the university classifies students, as far as they themselves are concerned, they choose the activities to engage in on the basis of what is valuable and available to them. In general, a student's final grade has a positive correlation with the level of that student's participation (Massingham & Herrington, 2006), therefore it is important to have learning activities that students can value and want to participate in.

Bridging and first year physics units at Murdoch University are also offered via Open Universities Australia (OUA). The number of students completing Murdoch's OUA physics units has increased dramatically in recent years and is currently near seven hundred per annum (see Table 1).

Sending out experimental kits to provide hands-on activities for students does not scale up to these large numbers. This challenging problem was already under consideration when the invitation to participate in the IOL project was issued and it was recognised that this was as a unique opportunity to trial new activities with the off-campus students.

Table 1: Student completion numbers in first year physics units taught in the internal and external modes

Unit	Mode	2011	2012	2013
PEC120 General Physics	Internal	144	128	145
	External	49	64	47
	Total	*193*	*192*	*192*
PEC152 Principles of Physics	Internal	106	119	108
	External	22	30	34
	Total	*128*	*149*	*142*
SCI16 General Physics	External	323	876	634
SCI19 Principles of Physics	External	30	45	72

The initial intention of this IOL project was to develop activities and gather formal feedback in the way that an ASELL project would (Yeung, Sharma, Pyke, Barrie, Buntine, Burke Da Silva, & Kable, 2011; ASELL, 2006; www.asell.org), however, the short timeframe, organic development of the activities and timing of interactions with the students precluded such a structured methodology. Instead, information about the level of success of the campus-based activities came from routine student surveys conducted by the university, attendance data in the tutorials and the work of the students themselves whilst engaged in the activities. A journal of events was also kept by the calculus-based physics academic. Entries in the journal were made as soon as possible after the event, documenting the tutorial/activity, plus any comments from students or tutorial staff (from directed questions and *ad hoc* comments), and the engagement of the students as evidenced by their level of participation in activities.

> *Everyone seemed to enjoy the tutorial yesterday both staff and students. There was a continuous working buzz in the air… Wrap-up was quick and easy but I had to shoo some students out of the room as they were still talking physics! The tutors were keen to comment on the activities saying teaching large groups was very different to small groups but that they think the activities were very successful. They had enjoyed themselves.* (Excerpt from the unpublished journal of events kept by the calculus-based physics academic 23/08/2012)

Comments about IOL activities included in the algebra-based physics units, from the academic coordinating those units, were based on at least four years of experience teaching in both semesters as well as OUA equivalent units.

OUA students and external Murdoch students were surveyed via e-mail after their results were released. Ethics approval (#2012/160) was obtained for this "Inquiry Orientated Learning in Physics" project.

IOL Activities for a Range of Student Groups

Initially IOL activities were incorporated into the OUA equivalent first year calculus-based physics unit at the beginning of 2012. More development of the IOL concept took place in the calculus-based physics units over the second semester of 2012 and the results migrated back into the OUA units as the year progressed.

Previously, students in the tutorials in the first-year calculus-based physics unit had been separated into groups of 15-18 with a tutor each, so, at the beginning of 2012, all of the smaller tutorials were combined into one large group with one academic staff member and enough tutors to provide a staff-to-student ratio of 1:20. This reduced tutor training time and associated costs, and had the added benefit of critical student mass. If the total complement of students did not turn up to the tutorial there were still enough students there to do the group activities.

IOL activities were incorporated into the first year algebra-based unit during 2012. These activities were introduced to a fairly traditional lecture environment of up to 145 students and also implemented in small group tutorials of 15-18 students. They were also used for a workshop session for high-school students participating in the summer school hosted at the same university.

The above synopsis of the work in IOL over the 2012 / 2013 period is expanded upon in the sections below.

External Laboratory Work

The Open Universities Australia (OUA) equivalent of the external offering of the first year calculus-based physic unit is offered three times a year and has around 25 students in each offering. Previously it required experimental kits to be sent out to the students so that they could do practical, hands-on laboratory work. This was problematic, as kits did not always arrive in time for the students to do their experiments. Also, this approach was not scalable to large numbers of students as the university does not have the necessary infrastructure. It was therefore decided to develop laboratory activities that the students could do with whatever equipment they could find around them, in order to retain their hands-on experimental experience, without the difficulties of ordering and waiting for the arrival of experimental kits.

This strategy proved very compatible with an IOL approach and, because of the short development timeframe, the students themselves ended up being the beta-testers for the experiments. Even though there were a few teething problems, which arose from the way the experiments were worded, the end results were rewarding, as evidenced from the replies to an e-mail sent to the students after they had received their final grade, asking them what they thought about the laboratory activities.

> *"I do like the hands on and strangely enough I even like when I fail and have to look harder as to why"* (study period 1, 2012, email feedback)

> *"I was very happy with the experiments as they allowed for a real life understanding of the underlying physics involved and thus a better understanding overall"* (study period 1, 2012, email feedback)

> *"I have also enjoyed doing the experiments. Even though repetitive at times, which is understandable, they do give better insight to the basic physics at hand. So much so that they have inspired a few ideas for other little home experiments"* (study period 1, 2012, email feedback)

In the first iteration of the experiments, the IOL element was mainly about finding suitable materials and a small amount of experimental design as in the following example.

Example Activity: Equipment List for the Experiment *Determining the Acceleration Due to Gravity Using an Object Rolling Down an Incline*

- Incline (about 2m long) e.g. table, piece of pipe, guttering, hollow log, cardboard tube;
- Ball to roll down the incline e.g. marble, ball bearing, rubber ball, stone;
- A timing device e.g. stop watch, second hand on a clock, metronome, your pulse (you might need a very long incline if you are going to do it this way), anything that has a regular rhythmical beat (I clap at 70 claps/minute +/- 1 clap)

In subsequent iterations of the experiments, the IOL component has been increased by including an extension section to the laboratory exercises. For example, the extension to the buoyancy experiment is:

Example Activity: Extension to the Buoyancy Experiment

- Qualitatively determine the relative density of a variety of liquids using the principle of buoyancy. You could then try to fill a tall thin glass with different layers of liquid and take a photograph of the experiment for your tutor.

In answer to this challenge, students sent in photographs of their successful density stacks as follows, layered from the bottom up:

- Water, oil and methylated spirits;
- BBQ sauce, water and vegetable oil;
- Decreasing concentrations of coloured salt solutions.

These pictures demonstrated, in a very practical way, that the students had gained a level of understanding of relative densities and buoyancy above that which can be gained from reading a textbook. Murdoch external students profited from the revamp of the laboratory activities initially developed for the OUA students, and they proved to be just as successful, as one student indicated when asked,

> "*The external labs provided an opportunity to really take charge of my own learning and create my own experiment to fit the topics. I liked that they used objects that we could find in our own homes because it showed how physics could be applied to everyday objects in non-laboratory environments.*" (S2 2012 Unit Survey)

On-campus Tutorials for Calculus-Based First-Year Physics

PEC152 Principles of Physics is a calculus-based first-year physics unit offered in both semesters for on-campus and external students. The cohort consists mainly of students studying towards engineering majors with a small number of students doing chemistry, physics and secondary education. Total enrolment of students in this unit is approximately 25 external and 70 on-campus students per semester.

The tutorials contain hands-on activities, demonstrations, discussions, diagrams, tests, traditional problem-solving activities and reviewing marked assignments and tests. The main problem with the tutorials was that unless there was an in-house test, student attendance decreased over the semester, sometimes falling below critical mass for useful discussion and activities. Something needed to be brought into the tutorials that the students found valuable, and it was thought the IOL activities might fill this role.

While the majority of the tutorial activities remained the same, they were presented in an IOL way and 4 new IOL activities were added. With these changes, there appeared to be a marked improvement in attendance for this unit. Unfortunately an exact comparison in attendance cannot be made between pre and post introduction of the IOL activities because student attendance in tutorials was not officially recorded before the introduction of IOL activities.

For the first two trials of the IOL activities attendance at the last tutorial, compared with the maximum attendance (which coincided with the first test) was:
Trial 1: 55% (Semester 2, 2012)
Trial 2: 72% (Semester 1, 2013)
All staff involved in the tutorials agreed that there had been more students in tutorials and an increase in student engagement with the tutorial activities since the IOL format had been introduced however more data needs to be collected as there may be influences other than the introduction of IOL activities.

The improvement in the participation rate could be partially attributed to the total-cohort tutorial size, as it was easier for students to form friendship groups with a larger number of students to choose from.

> Many students persisted despite contrary predictions because their successful social integration and feelings of fit with the institution compensated for academic performance inconsistent with expectations (Kennedy, Sheckley, & Kehrhahn, 2000).

A description of the four IOL activities that were included in the tutorials can be found in Appendix A. These IOL activities worked on many levels. Students formed into groups, which they were encouraged to think of as "research teams", and naturally discussed the IOL activity challenge and potential solutions in their team. This interaction was useful because students were able to ask questions of others who had just learned the underlying concepts and they had the time and inclination to explain what was going on. Vygotsky (1978) defined this form of peer learning as significant because many students were working in their "zone of proximal development", i.e. they had the right preparation and motivation to learn and the person teaching them had recently been through the experience and so understood the pitfalls in thinking better than someone for whom this learning task was ancient history. For example in Activity B) *Strength of a Magnetic Field*, Appendix A, the students are asked to design a way to "map the strength of the magnetic field with increased distance from the sample of magnetic sheeting", only one group out of seven was still drawing lots of small positive and negative signs in their diagrams of magnets whereas in previous years this misconception was much more prevalent.

Working in teams also gave all students, and in particular, the English as a second language (ESL) students, the opportunity to work with the specific language of physics which adds a depth and complexity to ordinary words. In the final part of each IOL activity, the teams presented their "project", or solution to the challenge, to the class. At this stage, using this feedback method, students realised that there was more than one way to solve a problem and that it is important to define your terms, as well as to make sure you are testing what you think you are testing.

All of the student designs for the testing equipment in the *Magnetic Fields* IOL activity (see Appendix) used diagrams. Some even had graphs giving an idea of what the expected results of the test would be, so the students were using multi-modal forms of communication, which is something previous students had not shown an interest in doing. In the experimental designs, some groups attached the magnet to the ruler with the washer-bag hanging vertically between the two, others attached the magnet under the ruler and attached the washer-bag to the magnet. Some put paper between the magnet and the ruler and others did not. One group attached the washer-holding bag to the end of a vertical ruler and then the magnet was attached to the other end. Each group, even with the same equipment, would therefore have achieved different results if the test had actually been performed, as opposed to being a thought experiment, and this could be teased out in the plenary session at the end.

The students did give presentations about their designs to the whole tutorial group but the audience were not very skilled in critiquing the presentations. In future it might be worthwhile priming the audience to use such questions such as, "*Is this what the group was asked to test?", "Does the test do what it was intended to do?", "Is there a direct cause and effect relationship or are there several variables involved?", Are there wider implications for this information / knowledge?"* (Excerpt from the unpublished journal of events which was kept by the calculus-based physics academic 23/08/2012).

With the introduction of IOL activities, the tutorials have moved away from the traditional tutorial structure which had given rise to the major negative feedback in the student surveys *"Completely restructure the tutorials to a focus on answering physics problems", "The tutorials need improvement. More practice problems and feedback is needed"* (S2 2012 Unit Survey). These comments indicate the need for the tutorial staff to manage students' expectations early in the semester. Other students, however, had no problems with the structure of the tutorials: "*I enjoyed the tutorials the way they were structured was far more beneficial than other tutorial I have had.*" (S2 2012 Unit Survey).

There are practice problems in the unit which can be found on the unit website, at the end of each textbook chapter, as well as illustrative problems being worked through in the lectures; previous students did not engage with practice problems in the tutorials as well as the 2012 students engaged with the IOL activities. From S1 2014 tutorials will be called workshops to reduce any confusion in the minds of the students and there will be no return to the tutorials of yesteryear.

Students learn in diverse ways, by seeing, hearing, doing, discussing, sitting quietly and thinking through a problem, as well as by designing experiments. The varied activities, including IOL activities, in the Principles of Physics tutorials set out to encourage students to learn by whatever means is best for them, as individuals.

On-campus Tutorials for Algebra-based Bridging Physics

General Physics is an algebra-based bridging physics unit taken by students who have little or no background in physics. The students may not have studied physics before or are returning to study after many years and need a refresher. The number of students in this unit can be as high as 100 on-campus and 40 in external mode each semester. The majority of the students intend to do engineering majors with the remainder of the students studying in disciplines from across the whole spectrum of majors at the university.

The on-campus tutorials are run in a traditional format with high attendance by students, due to a small summative assessment (a multiple-choice quiz) occurring in most tutorials. The activities usually undertaken in these tutorials are focussed on developing problem-solving skills, communication skills and conceptual understanding of the course materials.

To improve student engagement in the tutorials, IOL activities have been introduced into the tutorials.

The IOL activities were presented as a challenge to the students. For example, an activity was developed based on projectile motion which provides a small Nerf Gun (spring-powered with foam projectiles) and a 1 metre ruler and asked guided questions as shown below.

Example Activity: Exploring projectile motion with a Nerf Gun

- If you were to fire a Nerf gun straight up in the air, how high would the projectile go?
- What is the muzzle velocity of the projectile?

The students are organised into groups of 3 or 4 then asked to design an experiment to find the answers to these questions. This is followed by a general class discussion about the problems they might encounter in designing the experiment and what they may need to consider when collecting their data.

When a group has worked out a method for finding the height and muzzle velocity of the projectile, they go outside, for about 10 minutes, and take some measurements. When all groups have returned to the tutorial room, they present their results for the maximum height and muzzle velocity of the projectile as well as their experimental design and approach. The class is then led in a general discussion on experimental design and approach.

Informal feedback from senior tutors and students involved in this activity was very positive. Certainly students were more engaged and active within the tutorial and were discussing the physics concepts they had learned thus far in the unit so that they could apply them to the problem at hand. One student even mentioned this IOL activity in the unit survey conducted at the end of semester as a highlight during the semester:

> *"My favorite (sic) part of the entire unit was when we did the experiment in our tutorial on the nerf gun to see that the projectile motion of it would be".* (S1 2013 Unit Survey).

This is a sample quote which demonstrates the effectiveness of the IOL activities to foster student engagement within the unit.

On-campus Lectures for Algebra-Based Bridging Physics

Simple and quick IOL activities have been introduced within the lecture format for General Physics. These activities expand on the active learning and 'clicker' style questions already being used.

The initial IOL activities used in the lectures were based on the projectile motion activity conducted in the tutorials, but interwoven into the projectile motion lecture in short three-minute timeslots. In one activity the students were encouraged to form groups of 2-3 people and asked, *"if you were to grab a projectile (scrunched up paper, ball, etc.) and throw it, how could you find out how high it goes?"* The groups were then called upon to share their approach with the class. Later, during the same lecture, the students were asked to throw a projectile and actually try to find out how high it went, using the approach they outlined in the first activity.

Initially this style of activity in the lecture was met with surprise from students as they did not expect they would be asked to get into groups to actually discuss concepts and arrive at their own conclusions. Most of the students engaged with the activity and discussed the questions and concepts at hand. The outcomes of the discussions were not always in the direction anticipated when developing the activity, but were creative and on topic.

Overall this approach was effective and students were more engaged with the material being presented within the lectures. For some it was a new and pleasant experience. *"approach to teaching is refreshing... use of interactivity in the lecture theatre was a novel experience for me…"* (S2 2012 Teaching Survey). It is clear from survey responses over several semesters that these small IOL activities and active learning methodologies have resulted in students finding the lectures engaging and interesting

> *"I liked the interactive lectures, they kept it interesting".* (S2 2012 Unit Survey)
>
> *"Easy to interact with during lectures, while lectures are also fun."* (S2 2013 Teaching Survey)
>
> *"This unit had interactive lectures which was a welcome change"* (S2 2013 Unit Survey)

However, some students found the necessity of working in groups to participate in the IOL activities did not match their style of learning. For example, a student commented, with regard to the lectures and activities, that: *"I'm not a people person, so the working in groups questions were a bit off-putting for me"* (S2 2012 Teaching Survey). Rather than discouraging the use of IOL activities in the lecture environment, this style of comment highlights the need for varied teaching practices to facilitate multiple styles of learning.

External Offerings of Algebra-Based Bridging Physics

The OUA equivalent of the external offering of General Physics is offered four times a year and routinely has enrolments in excess of 200 students. This unit is used by several Australian universities as the bridging unit for their physics and engineering degrees. It is also taken by students from a very broad range of backgrounds, many of whom are studying at university for the first time or returning to studies after a substantial amount of time in the work-force.

The primary area where IOL activities have been introduced is in the online delivery of the lecture material. So that external students have an equivalent learning experience to their on-campus counterparts, they are asked to undertake the activity described in the previous section individually and to use the online discussion board as a proxy for class discussions. This is not an ideal situation, as it is asynchronous with external students attempting the activities at very different times, in some cases several days apart. However, in a number of study periods, students have actively posted contributions about the results they found or their thoughts on the methodology of these activities.

There is strong evidence that the external students appreciated these activities and requests for external student contribution, during the recorded lecture, and that it increased their engagement and their feeling of belonging within the student body. *"…rapport with me as an external student was built further by [the lecturer's] continual referral to external students in lectures; ensuring that we were as much part of the class as was possible"* (S2 2012 Teaching Survey).

Summer School Workshop Activity for High School Students

Each summer at Murdoch University, a group of students of high-school age attend a live-in, on-campus summer school, which involves a range of activities and events from across Science and Engineering. After learning how to think about and develop IOL activities, the physics contribution for this event was re-energised by developing a new IOL activity. In this activity, the students were asked to design a solar-powered mobile phone recharging station for deployment at festivals, concerts and other off-grid social gatherings. They were given enough background information to get them started and enough equipment to find the operating characteristics of a solar cell and to create a reflector for concentrating sunlight onto the solar cell. As designing, building and testing a complete recharging station was asking too much in a 90 minute activity, the students were guided, using the focus questions below, towards investigating the optimum tilt for a solar panel; and how the output of the panel could be increased, using concentrating mirrors.

Example Activity: Designing a solar-powered charging station

- What angle to the horizontal should these panels be at when attached to the recharging station?
- Would the design need to be changed if there was an event in Broome compared to an event in Perth? Or can we use the same design?
- Do the recharging stations need to be facing in a certain direction or be placed in a certain place? – i.e. do we need to hire or reserve certain bits of the festival ground?
- What happens if it gets cloudy?
- With the equipment that you have what is the maximum output you can get from your solar panel?

The students were grouped into teams of 4 or 5 people and provided with solar panels, multimeters, mirrors and various building materials. On the walls of the room were placed information posters about how solar cells, solar concentrators and other renewable energy technologies work. At several points during the activity whole-of-class discussions were held to find out how the students were approaching the problem, the design process they were going through and the test results they were getting. At each stage, each group was given time to present their findings to the whole class. The staff involved in running this workshop considered that the level and quality of discussion was significantly higher than in previous years where more traditional physics activities were used, as also was the level of enthusiasm and engagement with the activity.

Prior to running the activity for the first time with students, a group of four experienced tutors and academic staff members were invited to trial the activity and complete a short survey. The responses from the survey were positive, with the activity being credited with allowing the students autonomy and control over the experiment, and the involvement of critical thinking skills.

Overall Conclusion

The aim of this paper was to provide a narrative of the process of implementing IOL in our physics subjects at Murdoch University. We capture the essence of integrating IOL across various elements of a range of subjects. This “soft touch” process ensured staff and departmental buy-in. The inclusion of IOL activities as part of the physics teaching and learning environment at Murdoch University has been successful and they will remain embedded in the units in which they were trialled. The IOL activities are being used in tutorials, lectures, and external laboratory activities as part of the overarching pedagogy to present physics concepts and understandings in a practical, student-focused way. A key advantage of the IOL activities, as discussed in this work, is that they use low-cost, readily available equipment and apparatus. Where specific equipment is required (for example: the NERF gun) this can be purchased by the educator or student at very low cost. By using readily available materials the IOL activities are anchored within the student's own context, allowing for deeper engagement. The feedback from both students and staff has been positive and the IOL activities have demonstrably improved the level of attendance, activity and engagement for students participating on-campus, as well as those studying in the external mode.

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Appendix A

A) Coefficient of Friction – Safety First

This activity was developed by the authors for the physics tutorials.

Your friend was acting as the roadie for a local band and had to push some pyrotechnics equipment across the stage during the performance. Unfortunately, his feet slipped out from under him while he was pushing the equipment and the pyrotechnics did not go off as expected. The band members were rather angry but your friend said that he had done a test run earlier and everything had worked fine. The only difference was the night had been a bit cool and there could have been some condensation on the stage. Your friend notes that the surface of the stage is exactly the same material as the table you are sitting at and wonders if there is any test that you, as a physics student, could do to find out what went wrong.

For your friend's peace of mind, try to find out how significant the effect of the condensation on the stage was to the coefficient of friction between his joggers and the stage, by testing a jogger on the table. The only equipment you have is what you have with you and any materials you can find in the room.

Put together a report which includes

- What you know before you start;
- A free body force diagram of the experiment you would like to do;
- A "proof of concept" test;
- Tables of data;
- A conclusion that says how significant the condensation was;
- The reasons for your conclusion.

B) Strength of a Magnetic Field

This thought experiment activity was developed by the authors for the physics tutorials.

A fridge magnet is only as good as the number of bills it can hold!

You just happen to be in China on a holiday when your boss calls and asks that you take a detour to Zhejiang to check out some magnetic rubber sheeting, with a view to purchasing it to make whiteboard and fridge magnets. You are asked to give some sort of quantitative analysis of the magnetic field strength and its "sticking" ability but you have none of your usual magnetic field measuring equipment with you. When you get to the factory the manufacturer gives you some samples of the material and leaves you alone in an empty office to conduct your tests. You scrounge around for things that might be useful and find a steel ruler, bulldog clip, small zip-loc bag, photocopy paper and a pile of washers.

Design an experiment using only the equipment you have found that will enable you to map the strength of the magnetic field with increased distance from the sample of magnetic sheeting.

You might like to start by

- Writing down what you know about magnetism and magnetic fields;
- Drawing a free body force diagram of the experiment you would like to do;
- Sketching a graph of the results you expect to get.

C) Which Sticky Tape is the Best?

This activity is a modified version of a workshop activity run by Les Kirkup at the beginning of 2012 and is therefore different enough from the published version (Kirkup, 2013) to warrant inclusion here.

In this activity we are going to pretend that you are part of the research and development team employed by *Tape X - The sticky tape that marks the spot*. The Executive Officer of your company asks you to do some research on a new type of sticky tape that has entered the market *Tape Y would you use any other sticky tape?,* which claims that it is "the best tape for the job". Your Executive Officer wants to know the truth of the matter. Which is better, your "Tape X" or their "Tape Y"?

The Challenge

- First of all you might like to work out what "job" the tape is to be used for.
- Then decide what "best" means in light of the job it has to do.
- Next, design an experiment that will test the property in question for the two tapes, as indicated by your definition of best.
- Explain how your experiment will test these properties.
- Work out what data you are going to record and how you are going to record it.
- Think about what other factors in the experiment could affect the results and modify your experiment if necessary to make sure you are testing what you think you are testing.
- Test a sample of each tape, collect and analyse your data.

You will be asked to report your findings to other research groups and your Executive Officer. It is important that you are able to describe and defend your methods, your data, analysis and conclusion.

The fundamental question is: **Can you tell the difference between the two tapes and if so, is the difference significant?**

D) Putting Paper Under the Microscope

This activity is a modified version of an activity developed by Kirkup et.al. in 2012 which may not yet be in publication.

You work for a company that produces a paper towel (Towel X). The Executive Officer of your company gives you a roll of a competitor's towel (Towel Y) that he has just purchased. The competitor claims to produce the most absorbent paper towel (which is something your company also claims). Your Executive Officer wants to know the truth of the matter. Which is more absorbent? Towel X or Towel Y?

The Challenge

You are given the task of determining which towel is the better of the two by devising and carrying out a test to decide which is the most absorbent towel. You must report back your findings to the Executive Officer. It is important that you are able to describe and defend your methods, your data and any subsequent analysis and conclusion.

The key question is: **How well (if at all) are you able to discriminate between the absorbent capability of each towel?**

You might like to start by answering the following

- Why do paper towels absorb water as opposed to just getting wet? i.e. why does the water prefer to be in the spaces inside the paper not just lying on the bench with the paper on top of it?
- Define your terms before you begin so that you can design an experiment that tests what you set out to test.
- What are the variables you need to consider?
- Are there any environmental effects that you should take note of?
- Are there any non-scientific considerations?
- Devise your test.
- How are you going to ensure repeatability?

What results are you expecting to get and how are you going to display them?