Implementing A Focus On "Diagrams For Understanding" In A First Year Physics Unit

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Abstract

In 2005 the student cohort of a first year physics unit, Principles of Physics, changed from students doing physics majors to students who were mostly doing non-physics majors. The majority of the new cohort did not have an extensive physics background and this prompted the author to consider the importance of well-constructed diagrams as an effective tool for facilitating student understanding. Construction of diagrams was modelled in lectures, discussed in tutorials and 20% of the assignment marks were allocated to diagrams. Various technologies were trialled in lectures to allow real-time modelling of diagram construction, the best to date being a Tablet PC with Microsoft OneNote software. This paper provides the reason for choosing diagrams to facilitate learning and describes how the diagrams were incorporated into learning activities. It is a preliminary paper which sets the scene for further research and therefore does not offer any detailed evaluation of the results of these actions.

Keywords: Education, Physics, Diagrams, Understanding, Learning,

Introduction

Currently the first year undergraduate unit, Principles of Physics, is taken by students from several programmes. The majority of these 80 or 90 students per semester are engineering students, others are metallurgy students, and there is a smattering of environmental science and chemistry students. Students doing physics majors make up around 10% of this diverse population. Four years ago, because of a different university structure, there were only around 15 internal students per semester in this unit and they were all physics students.

The majority of physics students come to the unit with the skills they need to study the content of the unit. In the past, teaching and learning amounted to building on their prior knowledge and skill set. Little thought was needed about the exact mechanism whereby students come to grips with the content, context and culture of the discipline, as they were already "native speakers". At the beginning of my academic career I was told that students learn to be a physicist by osmosis, by being around other physicists. This could be true when there is a critical mass of physicists and physics students. Unfortunately for the students in the more recent classes the only physicist in their tutorial could be the tutor, who is more than likely a final year or honours student themselves. So it was time to start thinking about how physicists come to grips with physics.

Every physicist probably has a different view of what physics is about, but typically, the first thing most physicists do when faced with a problem is reach for a pencil and start drawing a diagram. This seems like a good entry port into the world of physics for non-physics students. As noted by Yap and Wong (2007) "one main characteristic that distinguished experts from novices was the use of qualitative analysis before 'selecting' the appropriate equations or formulae. One concrete piece of evidence or extension of such qualitative analysis is the use of appropriate diagrams/sketches" and from Van Heuvelen (1991) "A physicist depends on qualitative analysis and representations to understand and help construct a mathematical representation of a physical process."

Materials and Methods

Why Diagrams?

It was noted in the 2005 final examination that the students who did the "best" diagrams ended up with better grades than students with less effective diagrams. Whether students who understood the physics concepts were then capable of constructing useful diagrams, or whether students who constructed good diagrams could then use them to solve physics problems, was not readily evident. A similar observation was made by Roberts et al. (2008) who indicated that, on average, higher marks were given for examination questions that included diagrams because they helped the students better communicate their understanding to the marker. Whichever reason proved to be the case, it seemed possible that requiring students to work with physics diagrams would facilitate their learning and communication in the discipline. Since 2006 the students' assignments have been marked so that 20% of their marks are awarded for the diagram. Examining the assignments in the tutorials provided another opportunity to discuss the construction of diagrams, and of course diagrams have always been part of the lectures. Further qualitative observation of students and their work over time, indicated some students still had difficulty, or were reluctant to include, good diagrams in their assignments and final examination. To help engage and motivate these students, student answers from past examinations were used to start discussion. This technique proved valuable in highlighting the misconceptions of current students. It was reported by some students that the exercise was useful, as they remembered the diagrams when undertaking their examinations.

Diagrams in Lectures from a Practical Point of View

The physics programme at Murdoch University has been offered to external students as well as internal students since the university's inception over 30 years ago. This means that every effort is made to provide external students with the same standard of study material as that for the internal students. Lectures are audio recorded and these recordings, along with the PowerPoint lecture slides, are included in the unit website. The university is also keen to allow students study in a "flexible learning mode", giving internal students the opportunity to catch up missed lectures via the on-line materials. These decisions have locked the lecturer into this technology. The disadvantage is that while PowerPoint presentations are useful to keep a lecturer on track, they do not give as flexible delivery as overhead transparencies. The diagrams and illustrations in the presentations tend to be the ones that come with the textbook and are presented to the students as a finished product. This means they are used as illustration and spring into existence whole and complete. Importantly, there is no modelling of how they are constructed or accompanying discussion of their usefulness.

Since 2006 several ways to incorporate more diagram construction into lectures have been trialled. Initially overhead projectors were used but the scanning and uploading that was required to get the diagrams onto the web was time-consuming. Next, whiteboards were tried, but the thin lines of the whiteboard markers were difficult for students to see from the back of the lecture theatre. In addition, it was necessary to change the illumination in the lecture theatre when alternating between the presentation and the whiteboard. Another disadvantage was that these diagrams could not be made available to students beyond the lecture. The next technology to be investigated was an electronic "ebeam" portable interactive whiteboard. Sketches on a standard whiteboard were recorded by an attached device and sent via USB cable to a laptop. From the laptop the image was directed to the projector and onto the lecture theatre screen. This reduced the need to change the lighting when toggling between diagrams and PowerPoint presentation. While it worked to a limited degree, and there was the potential to electronically capture the images, the system was still time-consuming to set up and saving the images at the end of the lecture was not always undertaken.

Second semester 2008 saw the trial of a Tablet PC and the Microsoft OneNote application. Text and diagrams scribed onto the PC's touch screen were projected directly onto the lecture theatre screen. OneNote automatically saves what it contains when it is closed so the diagrams were easily edited later for uploading onto the unit webpage. The lighting in the lecture theatre does not have to be changed when toggling between applications and the set-up is no more difficult than a standard presentation using a laptop. This combination of Tablet PC, OneNote and PowerPoint applications has proved the most efficient to date.

The Teaching and Learning Point of View of Diagrams in Lectures

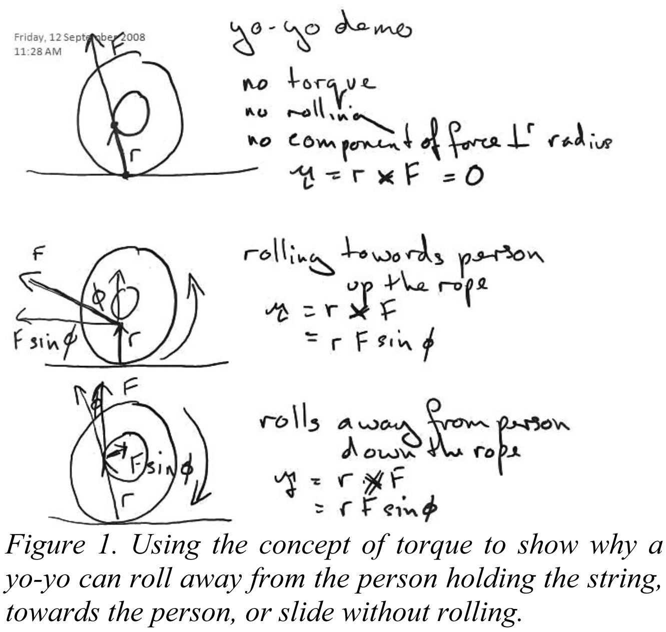

Figure 1. Using the concept of torque to show why a yo-yo can roll away from the person holding the string, towards the person, or slide without rolling.

For the students in the lecture the present technology combination works in a similar way as overhead projectors. The type of diagram produced in this way can be seen in Figure 1. The important aspect is that students can see the diagram being constructed with accompanying comments in real-time. They can, and do, ask questions about the diagrams, and the associated problem solving. This, along with the value placed on diagrams in the assignment, appears to be working well for the students. The quality of the diagrams in the first two assignments for second semester 2008 were much better than in previous semesters.

The use of Diagrams in Tutorials

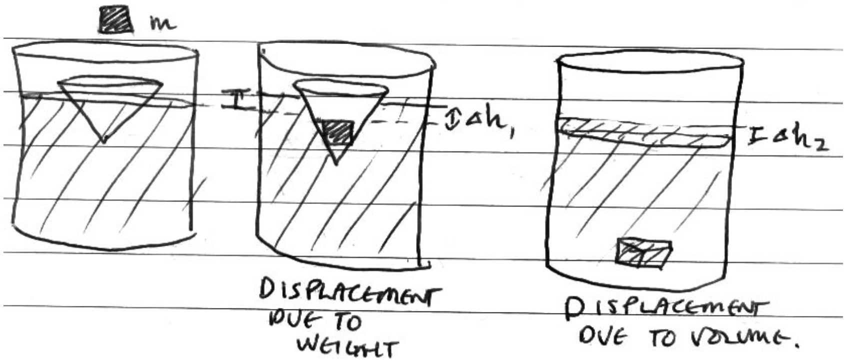

Figure 2. How to use buoyancy to find the density of an irregularly shaped object

Figure 2 is an example of a diagram obtained from a past examination paper, with permission from the student. Examples like this, and others that demonstrate misunderstandings are used in small group tutorials of around 16 students to stimulate discussion. Using diagrams in tutorials allows students to discuss their understandings with their peers and challenges them to put their thoughts in order so they can communicate clearly. This process of peer-to-peer communication enhances learning as indicated by Vygotsky (1987) in describing the "zone of proximal development". The fact that the diagrams were produced by students in past examinations adds relevance to the exercise and makes it easier for students to relate to them.

Results and Discussion

This paper proposes the use of diagrams as a means of enhancing the understanding and communication skills of physics by first year students who are non-physics majors. It is still early days in this endeavour and more data needs to be gathered. The indication from the first two assignments in first semester 2008, is that the diagrams the students are producing are of a better quality than in previous semesters and on average the students have higher marks for the assignments.

The quality of the assignments can be compared between semesters as the same questions have been set for the last three semesters. This can be done because marking focuses on how the students answer the questions, as much as on getting the right answer. Students are informed that more is expected than the "text-book" solution.

Quality of diagrams is difficult to define. At its most basic, in this context, it could be defined as usefulness in assisting students to answer their assignment questions, as 20% of their marks are for the diagram. They are required to draw, clear and correct diagrams that contain all relevant information. In their first tutorial they explore the difference between pictures, photographic like representations of given situations, and diagrams, which indicate a conceptual understanding. Diagrams in the students assignments therefore need to capture the underlying concepts of the situation being investigated. In later tutorials during feedback on the assignment the tutors go over the questions paying particular attention to how diagrams could be used to assist in solving them. For example a velocity time graph of a truck in motion can give information about acceleration and displacement directly, by investigating the slope of, or the area under, the curve. Constructing one of these "diagrams" can therefore be a short-cut to solving the problem. It was most gratifying to find, later in the unit, students using this approach when solving problems involving angular acceleration.

Conclusions

Construction of useful diagrams is proposed as an aid to assist students in their understanding and communication of physics. In order to engage the students in this activity, diagram construction is modelled extensively in lectures, discussed in tutorials and assessed in assignments. Several technologies have been trialled to enable diagram construction to take place in real time in lectures. The combination of a tablet PC and Microsoft OneNote software has proven to be the most effective. Early indications are that this multidirectional approach has improved the quality of the answers in the students' assignments.

Acknowledgements

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