Work-It-Out: A Strategy for Teaching First Year University Students "Things They Should Already Know"

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Abstract

There is an expectation in first year university courses that students with the required pre-requisite knowledge, skills and attitudes, will succeed and transition into second year. Unfortunately this is not always the case. Even though students may have the necessary pre-requisites, as listed in the university handbook, they may not be metacognitive about their university studies. This inadequate understanding, on the part of the students, about the learning and teaching process, means that students do not fully appreciate what they should already know, what they need to learn, and why. The aim of this paper is to describe the rationale and pedagogical features of the Work-It-Out (WIO) teaching strategy which has been developed to fill the gaps in student understanding and to engage them in the basic skills, activities and thought processes that experts employ as a matter of course. Also discussed in this paper are the operational elements developed to support the WIO teaching strategy, such as videos portraying experts in physics discussing the underlying "why" and "how" of learning in diagrams and formulas.

Introduction

The Work-It-Out (WIO) teaching strategy was developed as part of an Australian Office of Learning and Teaching National Teaching Fellowship, to help first year university students get "up to speed" with the basic study and communication skills needed in first year Physics and for the future. As the work developed, it became apparent that the teaching strategy was not subject-specific and could be generalised, at least to other areas of science and engineering. The pedagogy behind the WIO teaching strategy is outlined in the paper below. Examples of learning activities are taken from the discipline of Physics to demonstrate the skills that might be taught using the WIO teaching strategy. All of the learning materials developed during the Fellowship have been released as open education resources and can be found on the Work-It-Out website at www.WorkItOutTS.com and on the YouTube Channel *Physics Vids* https://www.youtube.com/channel/UC_zW442B84-s9m7NvypAcoQ/playlists.

Many engineering and physical science majors have a fundamental Physics unit/course (hereafter called a "course"), and if students do not pass this course early in their degree it can have a detrimental impact on their progression, or even on their chances of completion. Many Australian students struggle with first year university Physics because they lack basic skills and background knowledge (Mills & Sharma, 2005; McCarthy, Carew, Gardner, Goldfinch, Henderson & Thomas, 2010). This problem has also been noted in the United States of America: "Completion rates for all undergraduate students, including whites and Asians, are significantly lower in science, technology, engineering, and mathematics than in other disciplines" (National Research Council, 2012, pp 8), and in Australia the problem may become more severe as recent economic, policy-driven initiatives require Australian universities to take more students from non-English-speaking backgrounds and alternative entry pathways. Mills and Sharma (2005, pp i) found that a "broader cross-section of the tertiary-student cohort is now studying Physics in an increasingly wide range of subjects" and that "their weaker background in Mathematics and Physics… ranks high on the list of challenges reported by departments". Further complexity comes from an "… increasing diversity of prior learning in incoming engineering students. In efforts to meet demand for new graduates in industry, and increased interest in engineering studies, universities are accepting new students through more flexible pathways" (McCarthy et. al., 2010, pp 2).

University handbooks specify the prerequisite level of knowledge in Mathematics and Physics a student should have before starting a first year course. Students who come to university straight from their final year of high school, having scored well in Physics and Calculus, have no problems meeting the prerequisite requirements but this does not mean they have a deep understanding of physics. It appears, however, that the majority of students who have difficulties often face challenges because they have come from a different educational system; have English as a second language; have just scraped through the final year Calculus and Physics examinations; have focused on passing examinations rather than learning underlying principles, or are mature students returning to study after a significant break. On paper, each of these students may have the right prerequisites but there is sometimes a mismatch between claims and demonstrable abilities.

Students who do not have the necessary academic background to start first year Physics can complete bridging courses and, in theory, this gives them the prerequisite knowledge, skills and abilities they need, but it is difficult to gain an appreciable depth of understanding in one bridging course. Even with bridging courses there are still under-prepared students in the first year Physics courses. At this early stage in their learning career, students do not realise what they do not know, nor what skills they must acquire in order to succeed. National Research Council (2012) identified the issues, as follows:

> *To gain expertise in science and engineering, students must learn the knowledge, techniques, and standards of each field. However… students have incorrect understandings about fundamental concepts… as novices in a domain, students are challenged by important aspects of the domain that can seem easy or obvious to experts, such as problem-solving and understanding domain-specific representations like graphs, models, and simulations. These challenges pose serious impediments to learning* (National Research Council, 2012, pp 2-3).

In the current learning and teaching climate, where first-year class sizes are large and resources are limited, remediating these problems on a one-to-one basis is prohibitive. It is apparent that a strategy is needed that enables students to be metacognitive about acquiring knowledge and the expert skills they require for learning. One such strategy is the Work-It-Out (WIO) teaching strategy.

The WIO teaching strategy has been tested in workshops and will take approximately 1.5 hours to complete, depending on the number of students in the workshop. The tutors guide students through each of the following stages:

1. Students, in groups of four, make an initial response to a challenge which is an edge-of-ability/zone of proximal development (ZPD) activity.
2. Students watch a video containing a discussion between experts, then individually complete a video-watching worksheet.
3. There follows an analysis of the video as a whole-of-class effort.
4. Students work in pairs on a focus activity to practice what they have learned.
5. Students in their original groups finish the initial ZPD activity.
6. Students give their group presentation to the rest of the class.

The students are not allowed to fully complete stage 1, the preparation for the final presentation, before moving on to the next stage because it is important that they incorporate what they learn from the following activities into their final presentation.

Redish & Steinberg (1999) found that "expert problem solvers indicate that there is much more to being a good problem solver than agility with mathematical manipulations and a good knowledge of concepts… physics is more than a set of facts and equations to be memorised (Redish & Steinberg 1999, pp 6). This is why the videos, developed for the WIO teaching strategy allow students to see experts working with the tools and discourse of the discipline. The focus activities then provide the opportunity for the students themselves to work with those tools and the language.

The WIO teaching strategy is suited to novice learners because it is well structured and provides guidance without being teacher-centric. It has at its core, a master-apprentice approach to learning, also called a Cognitive Apprenticeship, originally described by Collins Brown, & Holum in 1991 who state

> *Apprenticeship involves learning a physical, tangible activity. But in schooling, the "practice" of problem solving, reading comprehension, and writing is not at all obvious-it is not necessarily observable to the student. In apprenticeship, the processes of the activity are visible. In schooling, the processes of thinking are often invisible to both the students and the teacher. Cognitive apprenticeship is a model of instruction that works to make thinking visible* (Collins et. al., 1991).

The WIO method is based on this model of instruction where the key aspects of expertise are made visible to the students, and, as described by Collins et. al., (1991), the learning and teaching environment includes "the content taught, the pedagogical methods employed, the sequencing of learning activities, and the sociology of learning". According to Collins et. al., (1991) in a traditional apprenticeship the master involves the apprentice in authentic tasks, at times modelling the task for them and thereby making the process visible and at other times encouraging the apprentice to undertake the task with the amount of support gradually being reduced as the student improves. Running through the whole apprenticeship process is a level of coaching where the master structures the environment, and activities, to facilitate and consolidate the student's learning (Collins et. al., 1991). The main differences between a traditional apprenticeship and a Cognitive Apprenticeship is firstly, both the teacher's and student's thinking must be made visible, secondly the abstract tasks required by the curriculum have to be incorporated into a realistic situation and finally the students have to discover for themselves the wide contexts in which the skills they are learning can be used (Collins et. al., 1991). With this in mind the following section looks at the WIO teaching strategy in more detail.

A deeper look at the WIO teaching strategy

Stage 1. Edge of ability/zone of proximal development activity: Small group work
In the first step of the WIO teaching strategy, the students are given a challenge whichwill be just at the edge of their combined ability as a group, in Vygotzky's zone of proximal development (ZPD) (Vygotsky, 1978). Therefore this activity is a peer teaching activity where students in the group who have some ability to tackle the activity share their understanding and techniques with their peers.

The challenge is selected by the teacher and should be directly related to the skill that the teacher wishes the students to develop as well as to the knowledge content of the course. In selecting the challenge the teacher would have had to have previously tested the students' skills in some way, either formally or informally, to know their capabilities. In the case of the first year physics course, the challenge related to the WIO workshop materials might be one of the following skills:

- read a textbook for information and understanding;
- construct diagrams to aid in explanation and understanding;
- interrogate formulae to "tease out" relationships and enhance basic subject knowledge understanding;
- design an experiment to solve a problem which also helps to enhance basic subject knowledge understanding;

By working in groups of four, students are enabled to teach each other, and reinforce their individual learning by the act of teaching. Groups of four are small enough to facilitate discussion between all of the students in the group but large enough to have a varied degree of expertise. The teacher should make it known that some groups of students will be asked to give a presentation on their challenge at the end of the workshop. It is not necessary to give every group a different challenge nor is it necessary for every group to give a presentation. By having four challenges with four groups working on each independently, it is possible to engage 16 groups of 4 students totalling 64 students. As the students do not know which group will be asked to make a presentation, all will be motivated to take the challenge seriously.

With the presentation due at the end of the workshop, students are keen to complete the task so they have something to share. The task allows the students to explore what they know; however, it may not raise any questions regarding what they do not know, but should. Before this activity is completely finished, the tutors move them on to the video-watching activity so that they can explore what they do not know. Students are now primed and looking for ideas to help them improve their class presentation. The next steps of the WIO strategy will help them in this respect.

Initial Challenge
Example 1:
In a workshop it was noted that students had difficulty constructing a free-body force diagram of a jogger on an incline. The task in that workshop was to develop an experiment and use it to determine the coefficient of friction of all the shoes in the room but the stumbling block for the students was constructing a free-body force diagram.

A WIO Diagrams workshop which uses the video *A Toolbox of Diagrams* was therefore constructed to
a) improve the students' ability to construct free-body force diagrams;
b) help students see the connection between these diagrams and the underlying physics;
c) help students explain their understanding of the underlying physics to others;

The initial challenges used with the first group of students were standard equilibrium situations but it was too easy to look them up in a textbook, so, the following challenges will be used in future workshops.

a) Construct a series of 3 free-body force diagrams for an object on a slope as the angle of the slope increases from 20 to 90 degrees.
b) Construct a series of 3 free-body force diagrams for an object in equilibrium suspended by two wires as the angle of the wires to the horizontal decreases from 70 degrees to 20 degrees.
c) Two objects of the same mass are connected together by a piece of string. One object is placed on a table and the other object is suspended over the end of the table by the string running through a pulley. Construct a series of 3 free-body force diagrams to show what happens as the coefficient of static friction between the table and the object on the table increases from 0 to 1.1. Assume the coefficient of kinetic friction is 90% of the coefficient of static friction.
d) Construct a series of 3 free-body force diagrams for an object in water as the density of the object changes from 70% of the density of water to 100% and finally 130% of the density of water.

Example 2:
In the video *Interrogating Formulas* F=ma sums up a large section of first year mechanics if the many possibilities are considered for the type of force causing the acceleration and the angle of the force to the direction of motion. So the following challenges could be used in the Formulas workshop.

We know an unbalanced force will cause a mass to accelerate (F = ma). Describe the acceleration of an object where the accelerating force is
a) $F=-kx$
b) $F=Gmm/r^2$
c) $F = mv^2/r$

Stage 2. Expert video and video-watching worksheet: individual student activity
The videos consist of experts discussing the underlying concepts, and motivations that relate to the activity the students have been asked to do. They use appropriate language which is academically correct but not exclusive or heavily jargonised. In the video, during the discussion between experts, the answer is supplied to the important but unasked student question, "Why are we doing this?" The videos are short (less than ten minutes), firstly, to

enable the delivery of the message, without taking up too much of the workshop time; and secondly, to hold the students' attention.

Video Watching Activity Sheet: Formulas Workshop

Content

a) How and why do scientists and engineers use formulas?
b) How can understanding the relationship within a physics formula be helped by knowing which area the formula comes from?
c) Formulas look at the ideal situation. What does this mean?
d) What should you be looking at when you wish to discuss the boundaries and limitations of a formula?
e) Give an example of how you would use a formula to more easily explain a situation to someone who has a very basic understanding of physics.

Communication

a) What strategies do the experts in the video use to interrogate the formula F=ma? Where do they start and how do they move from one aspect to another?
b) Are there any gestures the experts' use that help clarify what they are saying, or indicate that what is being said is important?

Linking to other knowledge

a) What background knowledge is assumed that the audience has?
b) How do the "experts" link the information they are trying to communicate with the everyday knowledge of their audience?

Before the students watch the video, they read the accompanying worksheet so that they know what to look for. The worksheet is structured in such a way that it will highlight the skills and knowledge the teacher hopes the students will unpack from the video. The worksheet also needs to alert the students to things that they may not yet know. Each video has a different, specific worksheet. For example, the worksheet which relates to the Physics video *Interrogating Formulas* has a question "How can understanding the relationship within a physics formula be helped by knowing which area the formula comes from?". The *A Toolbox of Diagrams* worksheet includes the question, "What are the characteristics of a good diagram? Think about the diagrams that you find easy to understand."

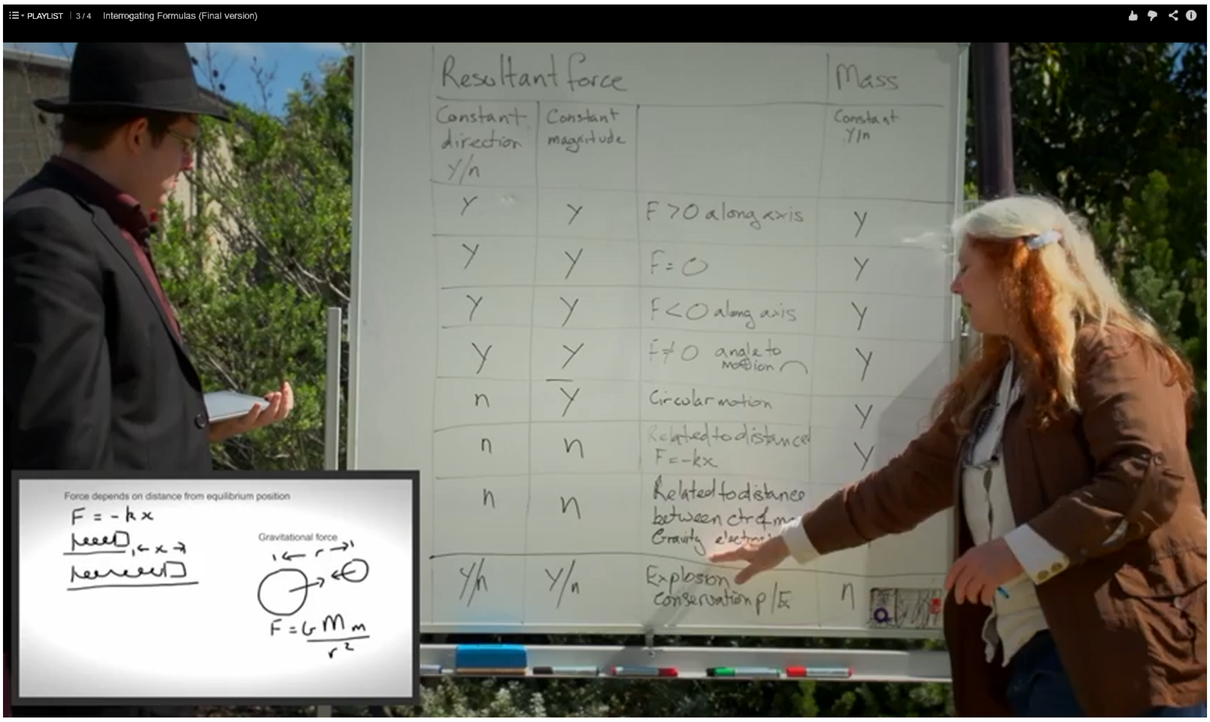

Figure 1 Screen shot from the video *Interrogating Formulas*

The underlying structure of the knowledge information contained within the expert video can also be discussed as the video is unpacked by the class. In the video *Interrogating Formulas* (Figure 1) the general case formula $F = ma$ is used as the starting point of the video and then a structure is built linking it with particular force expressions, such as $F = -kx$, the force which causes a mass to undergo simple harmonic motion; or $F = \frac{Gmm}{r^2}$, which causes the Moon to stay in orbit around the Earth; or the forces that cause bodies to accelerate or change their momentum. This is not the traditional way of structuring mechanics information for students, but it could be very productive once the students understand how to build these overarching concepts and also how to ask questions of the general case formula in situations that have specific force expressions. In this particular example, using the video to demonstrate that formula can be linked by an overarching concept helps the students to complete their challenge in a more advanced way, leading them to discuss the underlying concept behind the formulas rather than the mathematical expressions alone.

Stage 3. Analysis of the video/video-watching worksheet: Undertaken as a class effort.

This exercise involves a whole-class discussion. By drawing on the students' varying perspectives, levels of understanding, observational skills and, possibly, some students' ability to be metacognitive about the learning process, the tutor can highlight the knowledge and skills that students will need to succeed. Students and their tutor work together using the answers to the video-watching worksheet to unpack the video as an example of an expert presentation.

During this process the tutor can highlight the multiple modes of communication employed by the expert to deliver the message. National Research Council (2012) found that

> *Visual/spatial, mathematical, logical and verbal representations are central to human thinking, as well as to learning and instruction in virtually all disciplines…*

> *Representations like diagrams, graphs and mathematical equations are important in science and engineering because they facilitate communication, aid in discovery of scientific facts, assist in problem solving, serve as memory aids, and generally function as tools for thinking* (National Research Council, 2012, pp 97-98).

This aspect of communication is assisted in all of the videos produced for the aforementioned Fellowship by the "Wandering Whiteboard" which gives the experts a place to draw/write as well as verbalise what they are thinking.

Before moving to the next stage the tutor should give the students a few minutes to work out how they can use what they have just learnt to improve their final presentation. More practice and useful information can be found in the focus activity with which the students next engage. This structured way of providing learning specifically when it is needed works well when students are primed to make the most of the opportunities that are presented.

Stage 4. Focus activity to help the students practice what they have learned: Students work in pairs.

The initial assumption in creating expert videos was that a "good" video would be able to convey all that was required for the students to learn the required knowledge and skills. While writing the video scripts it became apparent that this assumption was not accurate. It might be possible to put everything into a script but it was not then possible to turn that into a short engaging to-the-point video. Realistically the video could never convey the whole message because when using a Cognitive Apprenticeship (Collins et. al., 1991) approach to learning and teaching the message is about *doing* as well as listening. This revelation led to the creation of associated focus activities for each workshop which provide an opportunity for students to learn by doing as well as listening. The focus activity associated with each workshop package can be found on the Work-It-Out website and is summarised in Table 1.

Table 1. Focus activity for each workshop

Workshop on	Focus activity
Reading a textbook	Quiz night-type of activity where the answers can be obtained by examining different parts of the textbook - with some answers needing a more analysis than others.
Constructing diagrams	Matching photographs to appropriate free-body force diagrams, energy and momentum diagrams.
Interrogating formula	Matching formula to diagrams and graphs.
Designing an experiment	Students design an experiment for new students based on specific subject content to highlight the set of skills the new students will need during their first year at university. The skill-set is determined by the university students themselves based on their own experience.

During this activity the tutors are interacting with the students on a group by group level providing just-in-time support to help the students with their task. This could be anything from giving hints and tips or, asking pointed questions to demonstrating how appendices work at the back of a textbook. Tutors may have to explain that the length of a vector is related to its magnitude or point out that the same force on an object can result in different motion depending on the prior motion of the object. With this ongoing input, each intervention assists the students to discover what they need to know to be able to move on to the next part of the activity.

Stage 5. Finishing the initial ZPD activity: Students working in their initial groups.
The students now refine their original work in light of what they have learned during the associated activities in the workshop. Again this takes the form of group-work, so that students can pool their newly-learned resources and help each other improve their initial work. Group-work makes this strategy an effective and efficient way of teaching new knowledge and skills to a large group of students with limited per-student teacher time and resources.

Stage 6. Group presentations.
The final presentations give students the opportunity to showcase what they have learned while the students watching the presentations have the opportunity not only to learn about the material other students are presenting, but also about presentation techniques. By electing one group to present from each of the challenges, only four presentations are needed for all of the students to be able to compare their presentations with those of the rest of the class.

Questions about the WIO teaching strategy

1. Why use the WIO teaching strategy as opposed to other current teaching strategies?
It is not intended that the WIO teaching strategy be used to replace other teaching strategies but that it should be used as another tool in the teaching toolbox. The focus of this strategy is to quickly "bootstrap" student learning in basic study skills and discipline specific communication. WIO is likely to work best in workshop groups of 20 to 60 students with one staff member for each 20 students. The workshops take 1.5 hours leaving time for other activities in a 2 hour workshop.

2. Why does the WIO teaching strategy keep changing the number of people a student interacts with?
The reason for changing the number of students involved in sequential activities of the WIO teaching strategy is to make students interact with as many people as possible over the course of the semester. It has been demonstrated that getting students to interact with other students in the workshops helps to build a class community, gives individual students a better chance of success, and improves retention rates and completion rates (Lotkowski, Robbins & Noeth 2004). In a study where refugee students were asked to suggest ways in which the Australian university could prepare them and support them in their university life, two of the recommendations were,

> *Students need to be encouraged to participate in university life, especially socially as well as in tutorials. Participants noted that, although they may be familiar with a tutorial topic, their English and shyness inhibits them from participating*. (Silburn, Earnest, DeMori & Butcher 2010, pp 59)

> *Staff members should ensure all students have an opportunity to participate in tutorial discussions and are suitably grouped for group assessments and encourage students to introduce themselves to fellow students to foster friendship building* (Silburn et. al., 2010, pp 59)

Another outcome of changing students' interactions is knowledge-building through student-talk, which means that increased validity is attributed to the activity because peers who recognise the need for the required skills are explaining this need to others.

3. Why open educational resources?

The Australian Office of Learning and Teaching (OLT) owns the Fellowship Material and the Intellectual Property (IP) Rights on it as soon as it is created; however; they then grant the Fellow a permanent, irrevocable, royalty-free, world-wide, non-exclusive licence to use, reproduce, adapt and exploit the IP Rights in the Fellowship material for any purpose. In the same sprit the WIO materials are available to all under the Creative Commons (CC) Attribution (BY) Licence, http://creativecommons.org/licences/by/3.0/au from the WIO Fellowship website http://www.workitoutts.com/ and the YouTube Channel *Physics Vids* https://www.youtube.com/channel/UC_zW442B84-s9m7NvypAcoQ/playlists.

The intent of the OLT is to "advance learning and teaching in higher education by supporting a group of leading educators to undertake strategic, high-profile activities in areas of importance to the sector." (Australian Office for Learning & Teaching, 2013) and through that support, enable the Fellow to "contribute to the growing community of scholars in higher education learning and teaching" (Australian Office for Learning & Teaching, 2013).

Apart from this practical reason for making freely available all of the Fellowship resources, which include, workshop guides, challenge activities, videos, worksheets and focus activities, via the Fellowship website, there is also a pedagogical reason. The WIO teaching strategy is not a "polished" final product, it is a starting point. The teaching strategy is based on solid pedagogy and there are reasonably well-developed resources for first year university Physics teachers. However users should not be limited by the use of the materials as given in this paper. They should modify it and make it fit for their purpose with their students. In the widest possible sense the resources can be used to start a deeper discussion on how we construct learning and teaching environments for our students.

Results and discussion

Two of the proposed workshops were developed and tested with a group of first year students in a calculus-based physics course. The results from the feedback forms for the Diagrams workshop can be found in Appendix A; the results from the Forces workshop have still to be analysed. The answer to the first seven questions in the feedback survey was a choice between yes, some and no. The last two questions allowed extended answers. Only 53% of the feedback forms could be used because students were working in groups of four so if one student in the group did not give permission for their work to be used then no material from that group could be used as it was not possible to identify individual students.

Overall, the students found the workshop to be useful in helping them understand why diagrams are used in physics and in helping them to understand how to create them. They also had a better understanding of how diagrams can help them to communicate their understanding of physics to others. Unfortunately these students still associated diagrams only with mathematics and statistics, engineering (electrical and chemical), physics, chemistry, and finance. They did not fully appreciate the capability of diagrams as a tool for communication in a wider sense.

The last question on the form asked for any other constructive comments related to the workshop. There was a range of answers but when these were grouped according to the answer given to the first question "Did this activity help you understand why diagrams are used in physics?" It was interesting to note that those students who answered "no" did so because they felt they already understood why diagrams are used in physics.

Students who answered "some" to this question were more concerned with the mis-match between their expectations of university learning activities and the actual activity. Those who said that the activity did help them would have liked to have had it earlier in their academic careers. There is evidence in the answers of this group that they think that there is a defined list of diagrams that they should use - "We should get a sheet from the tutor", and that the tutor needs to continuously demonstrate how to use them and "work through an example of the diagram with all forces provided by the tutor".

The following is an excerpt from my teaching journal about the activities in the Diagrams workshop in second semester 2013 indicating that there was a high level of engagement of the students with the WIO activities,

> *The students were fully engaged in the video, video watching worksheet and in finding matches between the diagrams and pictures. There was silence during the first two and good working noise with the latter. The treasure hunt* (picture diagrams matching) *was done in pairs and tutors report that students were on-task and discussing the diagrams in the activity.*

During the workshop two tutors were working the room as well as myself.

In conclusion

WIO videos, materials and activities were developed to engage students in the basic skills, activities and thought processes that experts employ as a matter of course in their daily work. The WIO teaching strategy draws on existing well-verified cognitive apprenticeship teaching pedagogy compiled into a multi-modal package that encourages peer learning. This takes some of the pressure off the teacher as the "source of all knowledge" and helps to make students more self-reliant and resilient.

WIO promotes a learning community within the classroom and a trial of the Diagrams workshop with first year students in a physics course proved reasonably successful. The majority of the students in the sample group could understand the usefulness of the activity and the level of engagement was high. This workshop is now embedded within the physics course.

The WIO teaching strategy is not necessarily discipline specific. To be able to make use of the teaching strategy, each discipline would have to determine their areas of focus; a possible place to start could be the threshold capabilities and concepts for the discipline as described by Male (2012) for engineering or Taylor, Ross, Hughes, Luze-Mann and Tzioumis (2011) for biology.

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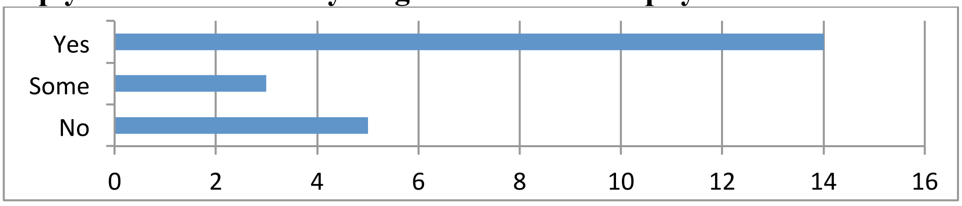
Appendix 1: Feedback Sheet Analysis

A Toolbox of Diagrams Video & Diagrams - Picture Matching Workshop

This data comes from 23 students out of a possible 43 students in the workshop and the 56 enrolled in the on-campus mode of studying. It is therefore potentially biased to the thoughts of on-campus students, who turn up to workshops and are prepared to fill in permission slips.

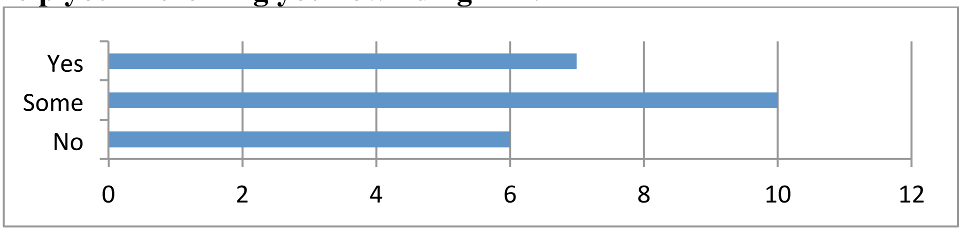
Did this activity help you understand why diagrams are used in physics?

Yes 14
Some 3
No 5
(4 already knew)



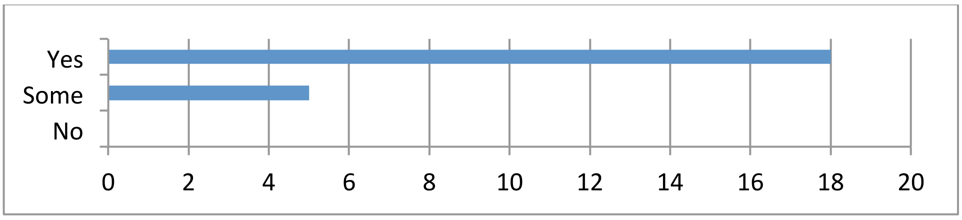
Did this activity help you in creating your own diagram?

Yes 7
Some 10
No 6



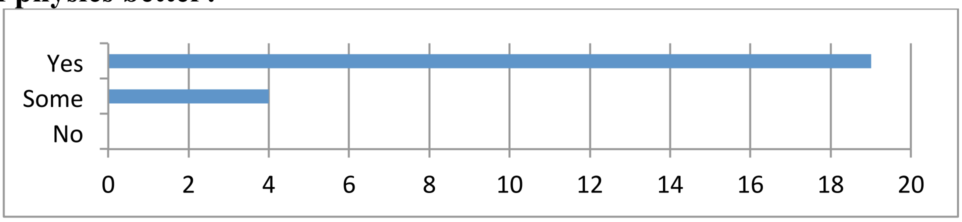
Do you think improving your ability to draw diagrams will help you understand physics better?

Yes 18
Some 5
No 0



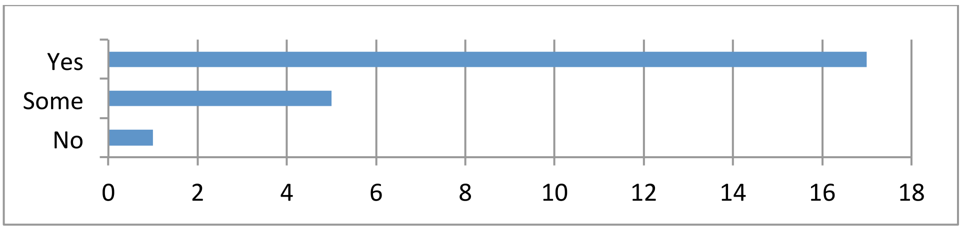
Do you think being able to draw good diagrams will help you communicate your understanding of physics better?

Yes 19
Some 4
No 0



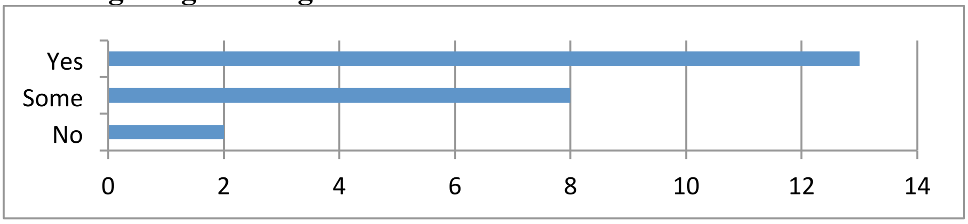
Do you think improving your ability to draw diagrams will help you with your assignments?

Yes 17
Some 5
No 1



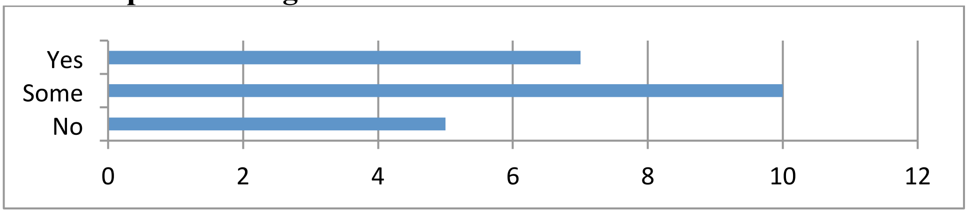
Will you continue looking for good diagrams?

Yes 13
Some 8
No 2



Did you find this workshop interesting?

Yes 7
Some 10
No 5



In what other units/subjects do you think you would be able to use diagrams?
Answer: Maths, engineering, electrical, chemistry, finance, statistics, applied maths, PEC120
Author's Note: This is obviously where students have seen diagrams used in the past but they have not generalised the concept of diagrams being a valuable tool for communication to other areas yet. This is acceptable as they are first year students and have a few more years of learning ahead of them.

Answer: Whenever possible
Author's Note: This interesting student response from one student would indicate a high level of understanding about why we use diagrams except that the student also indicated in other answers that we use diagrams just because it is conventional to do so. Therefore the studentis a good way along the path to fully understanding how important diagrams can be for communication but not quite there yet.

Any other constructive comments relating to this workshop
The students who said this activity did **not** help them understand why diagrams are used in physics

- Useful but I feel that we have already covered this before.
- The content was important but the lesson seems more suited for high-school children, not university.

The students who said this activity helped **some** in understanding why diagrams are used in physics also made the following comment.

- Not too interesting, very primary school level activities and teaching approaches.

The students who said this activity **did** help them understand why diagrams are used in physics also gave the following comments.

- We should get a sheet from the tutor/lecturer that has many types of diagrams that we may be required to draw for a test/assignment/exam.
- I feel this is a workshop that would better suited to the first (workshop) of PEC152 or even used in PEC120.
- It was a good and interactive exercise and workshop.
- Would be better to have a list of diagrams to work on for each group. Then work through an example of the diagram with all forces provided by the tutor. Would allow

more practice of difficult types of diagrams rather than just one
- Best we have had so far.
- It was lovely! I had a blast.

Author's Note: It appears the students who needed the most help with understanding diagrams got the most out of this workshop while other students who needed less help were not disengaged.