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A sweeter way of teaching health and safety

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Abstract

The underpinning educational theory for practical work is that of experimental learning or "**learning by and through doing**". Hands-on practical work promotes learning as it provides students with an opportunity to put theory into practice. There are many hazards with practical work, each with an associated risk that students will encounter while they are working in the laboratory and, therefore, adequate instruction should be given before students carry out any practical work. Getting students to engage with this in the past has been difficult due to the dryness of the material. Here we show how every students sweet tooth can be used to teach them risk assessment, experimental design and embedding health and safety as part of their scientific culture.

Introduction

30 years ago Richard Feynman reported on the Challenger shuttle disaster and identified a culture at Nasa where risk was not properly understood [1]. Today understanding and dealing with different levels of risk is an integral part of science, however teaching such concepts are difficult and generally dry and dull.

> WIDER DISCUSSION...
> The need for considering health and safety training carefully however is put into stark relief by the accident statistics for the UK from 2014/15 where 1.2M working people suffered from a work-related illness and 133 people were killed at work.

Accidents reported at work can be minor, but may also involve the loss of a limb, eyesight, hearing or even worse. Most accidents are entirely preventable and are not accidents at all, but are caused by carelessness, lack of consideration for others and poor training. Accidents in an education environment can be prevented through careful assessment of the risks associated with practical work and ensuring that students are trained appropriately to the correct level.

Previously, we inducted students in health and safety using a 2-hour lecture that discussed risk assessments, control of hazardous substances along with their legal requirement. Many of the students, as well as staff, disengaged from the importance and significance of performing a risk assessment and the key message was lost.

In collaboration with our departmental health and safety manager and the laboratory team, we have developed an induction that couples both aspects of risk assessment, experimental design and material properties into an engaging engineering practical by incorporating a degree of danger. The student engagement and feedback for this experiment has been excellent making it an instant success in the department. Due to this, it is now delivered to every engineering student (>2000 students) as part of the induction for the Diamond, the new £81M building for the faculty of engineering. This has not only improved safety within undergraduate experiments, but embedded risk assessment into common experimental practice.

The experiment

In our Risk Practical we get students to risk assess an experiment that measures the toughness of chocolate using a mini-Charpy impact tester. More information of this type of test can be found in previous teaching articles [2,3] and we quickly describe the main points here. A notched rectangular beam of material is placed between two anvils, facing inwards and the material is broken using a swinging pendulum. By measuring the angle to which the pendulum swings after impact compared to the horizontal position from which it was dropped, one can calculate the total energy absorbed by the sample during fracture. This is known as the **impact fracture toughness** of the material.

This can then be used to characterize different materials and aid in material selection. For example, a brittle material has low toughness. This requiring a little amount of energy to break generally 'snapping' it into two piece with a clean fracture surface. In contrast, a ductile material has high toughness requiring a larger amount of energy to break. This generally results in a rougher surface as the crack travels objects such defects or inclusions.

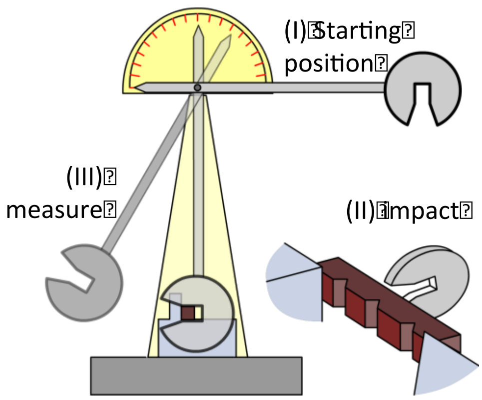

Figure 1. A Charpy tester in operation (I) The starting position of the swing. The pendulum has gravitational potential energy. As it is released (II) the pendulum swings down and impacts the sample. A certain amount of energy is required to break the material. The remaining energy (III) allows the pendulum to continue swinging which can be measured to calculate the impact fracture toughness.

Previously, we have used this testing device successfully in a practical class to measure the impact fracture toughness of chocolate at room temperature. However, to use this on its own for health and safety training we felt that it was too straightforward and thought that students may get a little complacent with this experiment. To put the students on the back foot, the experiment more challenging and incorporate an aspect of real risk to the experiment, we introduced liquid nitrogen to measure the impact fracture toughness of cryogenically frozen chocolate. As students generally have little or no experience of handling liquid nitrogen they are unsure of what could happen, and are then engaged with the idea of thinking through the risks and hazards before undertaking the experiment.

Risk assessment

Firstly, we describe the process of a risk assessment by explaining that a **hazard** is anything that can cause harm, such as poisonous chemicals, electricity, an open drawer and sharp or pointy objects. Additionally, we point out that an untrained person is also a hazard, as they do not have experience working with equipment in that particular environment and we make reference to the students themselves within the experiment. We also ask if there are any ways in which they can minimise this risk, and generally we get resounding shouts of “train us”.
We continue explaining that a **risk** is a chance, whether high or low, that someone can be harmed by these hazards. This can be quantified using the risk matrix in figure 2. In this matrix, the Severity of Injury, *S*, and Likelihood of Injury, *L*, are assigned an integer from 1 – 5. The overall Risk is quantified as the product *S* x *L* and gives an indication of if it is a *high*, *medium* or *low* risk.

Hazard (Severity) / Risk (likelihood)	Minor (S=1)	Few days off (S=2)	Many days off (S=3)	Major injury (S=4)	Death (S=5)
Highly improbable (L=1)	1	2	3	4	5
Remote but possible (L=2)	2	4	6	8	10
Quite possible (L=3)	3	6	9	12	15
Likely (L=4)	4	8	12	16	20
Almost certain (L=5)	5	10	15	20	25

Figure 2 – The risk matrix showing how the combination of likelihood and severity can be combined for a risk assessment.

STUDENT COMMENTS
“We did not need to sit inside the lab for hours to listen to the safety protocols. The whole activity is well structured.“

To complete the risk assessment, we get students to go through four steps: identify the hazards, examine who may be harmed, evaluate the risks and record their findings. Identify the hazards requires the students to look around the laboratory or work area and see what could reasonable be expected to cause harm in that environment. We explain that the hazards should relate to the activity that they are about to carry out and that the risk assessment should not include hazards such as an outbreak of a deadly virus or a meteorite hitting the building, as these events are so remote. We also get the students to think about the instructions of the experiment and consider long terms hazards, such as how to

leave the work area after they are finished and who might come across it. This is to emphasise the importance of cleaning up and making a safe environment after they have finished their work.
The next process is to examine who may be harmed by the hazards, which they answer with typically themselves, but with further thought many will consider a colleague or even just a passer by. Following this, the students evaluate each of the hazards and the risk of harm using the risk matrix shown in figure 2,and then record their findings on the risk assessment form. We also ask that they think of possible control methods to reduce the risk of harm, including considering personal protection equipment (PPE), as well as how they may be applied.

Experimental design

Once completed, we task the students in modifying a basic experimental protocol for measuring the impact fracture toughness of room temperature chocolate, shown in table 1, to an experimental protocol for measuring the impact fracture toughness of chocolate at cryogenic temperatures. This allows students to appreciate the reasoning for performing a risk assessment, as they can now refer to the hazards, risks and control methods they have considered and apply them to task they will undertake. We find it is at this point that students begin to see the risk assessment as no longer a paper exercise, but a starting process for performing an experiment. Here we look to make sure that they have included the main safety aspects of the protocol, such as wearing thermal protective gloves, a face shield and using tongs when cooling the chocolate with liquid nitrogen. Further points to consider are making safe the working areas, such as where frozen tongs and chocolate shards should be placed after use. After providing feedback to the students on how well they have completed the risk assessment and experimental protocol, the students perform the experiment following their own experimental protocol.

STUDENT COMMENTS
"It was fun to do. Learning about risks and hazards whilst conducting an experiment at the same time make these skills easier to remember"

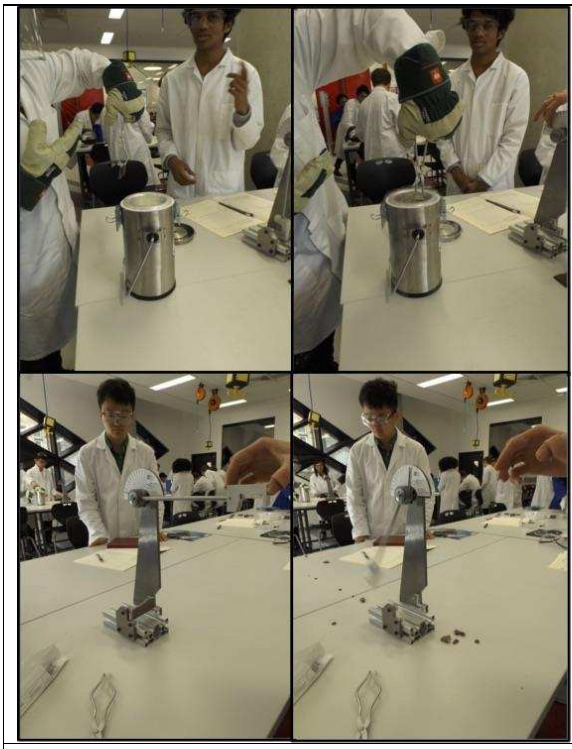
Figure 3 showing the cooling of the chocolate (3a and 3b) and the breaking using the mini-Charpy machines (fig 3c and 3d)

Performing the Experiment

Firstly, PPE is worn and the chocolate is prepared (fig 3a). The chocolate is then placed into the liquid nitrogen for approximately 10-15 s as shown in figure 3b. This is typically the time it takes the nitrogen boiling to subside and the chocolate is cool enough to show a difference on impact. The chocolate is then placed into the Charpy impact tester and the hammer released (fig 3c). The chocolate then shatters into many shards (figure 3c), as compared to the two typical pieces if performed at room temperature

The calibrated Charpy impact tester also shows a significant difference in the energy required to break the chocolate. In contrast to cold chocolate that requires 5-10 mJ of energy, room temperature chocolate requires 25-30 mJ of energy to break, however using just the angle then pendulum swings to is sufficient as previously used other tests [3]. The students observe directly the impact of temperature on the mechanical properties of materials by seeing how the temperature can change a material that was originally ductile into a brittle material that explodes when broken. Following on, a discussion related to operating temperatures and materials selection can be made. Depending on student level it can also be related to atomic bonds and crack propagation.

WIDER DISCUSSION...

The amount of energy can be related to the number of bonds broken. For the brittle material, if the dimensions are taken, an estimate of the bond strength can be made.

Material properties changing with temperature can also linked to the Challenger shuttle disaster where the mechanical properties of one small part - an O-ring seal - failed during a launch in cold weather.

The student feedback has been excellent with the majority understanding undertake risk assessment and appreciate the relationship into planning of the experiment. After the students finish this practical, we have found that students have an increased awareness of hazards in a laboratory, a better understanding as to how to evaluate the risks associated with practical work and the process of putting control measures in place.

By learning how to manage risks, students gain the necessary skill that any scientist or employment require as it becomes embedded in common practice.

WIDER DISCUSSION...

Putting students on the 'back foot' ensured maximum engagement in the hazard perception and risk assessment. This could be done with anything from electrical current, temperatures as well as chemicals. The latter could also be expanded to COSSH (control of substances hazardous to health)

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[1] http://www.bbc.co.uk/news/magazine-35432071
[2] L. B. Parsons and R. Goodall, 'Testing the fracture behaviour of chocolate', Physics Education, Vol. 46 No. 1, 50
[3] Julian Dean et al. 'High-performance composite chocolate', Physics Education, Vol 48, No. 4. 465