Innovative Learning in Civil Engineering at The University of Edinburgh

Alison Furber, Martin Crapper, Martin Gillie, Tim Stratford, Luke Bisby, Jane Blackford and Douglas White

School of Engineering, The University of Edinburgh, The King's Buildings, EH9 3JL, UK

Martin.Crapper@ed.ac.uk

0131 650 5727

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Abstract

Activities available to civil engineering students during The University of Edinburgh's *Innovative Learning Week* in 2012 were examined. Academic staff proposed a wide range of possible activities and student participation was optional. Popular activities were those with a "hands-on" element, making or doing something, and included designing and building trebuchet, relaying railway permanent way on a nearby heritage railway, practical workshops in engineering in international development and learning to juggle. The practical activities exposed in some cases that safety culture messages still had some way to go, and also suggested that heuristic learning by trial and error was likely to enhance the visualization skills that contribute to good engineering design. Further the linking of achievement to purposeful practice rather than innate talent could inform teaching methods in the future.

Keywords

Education & training

Innovative Learning Week – an Opportunity for Engineering Education

In 2012, The University of Edinburgh introduced Innovative Learning Week (ILW), providing a week free from normal timetabled classes, during which students can engage in a variety of innovative learning activities. The university provided minimal guidance about what should be offered during ILW, beyond stating it should offer an opportunity for experimentation and innovation in forms of learning without the constraints of the normal curriculum, and that it should not be assessed for academic credit. The implementation of ILW was left to be carried out at department level by individual staff enthusiastic enough to devise and lead activities. This paper discusses the experience of ILW within the School of Engineering at Edinburgh in 2012. The School of Engineering at Edinburgh is large and diverse, covering the disciplines of chemical, civil, electrical and mechanical engineering as well as various electronics fields and employing approximately 80 full-time academic staff and teaching over 1000 undergraduates as well as taught MSc students. The activities that form the focus of this paper were mostly based in the civil engineering discipline, but were open to students from other disciplines.

The introduction of ILW within the context of engineering was opportune because it is widely recognised that there is a need for change in engineering education "because of demands for technologies and products that exceed existing knowledge bases and because of the changing professional environment in which engineers need to operate" (NAE, 2005 p13). Moreover, the mismatch between student learning processes and academic teaching methods identified by

Felder and Silverman (1988) persists today (Clark, 2009) because teaching methods in engineering education have changed little over the past 20 years (RAE, 2007). Underlying these problems is the need to find ways to engage staff and students in new and innovative methods for teaching and learning that spark students' (and staff) passion for engineering and education, whilst helping students (and staff) develop core engineering skills (NAE, op cit p39). ILW has provided an opportunity to experiment with such teaching methods, assess their effectiveness from both staff and student perspectives.

By examining the experience of ILW within civil engineering at Edinburgh, this paper contributes to the ongoing debate about how engineering education can be made, "exciting, creative, adventurous, rigorous, demanding, and empowering" (Vest, 2006), and about how to engage and prepare students for the exhilarating challenges they will face during their careers as professional civil engineers.

The aims of this research are to:

- Identify what academics do when requested to develop innovative learning activities, looking particularly at different opinions that pertain to what exactly constitutes innovative learning;
- Explore how students react to various differing ideas of innovative learning; and to
- Identify some of the positive and negative outcomes of ILW for both students and staff.

Methods

A number of methods have been used to collect the data necessary to inform this discussion.

Analysis of quantitative data from ILW

Records kept by the Engineering Teaching Organization at the university of the number of activities put forward by academics and the number of students who signed up to the activities offered were analysed.

Student questionnaires

Students who participated in the activities run by the authors were asked to complete a two-part questionnaire which is included in the Appendix. The first part was completed prior to undertaking an activity and was designed to ascertain students' motivations and what they hoped to gain. The second part was completed after the activity and asked students to identify both expected and unexpected benefits, and any issues encountered.

Questionnaires were anonymous to allow students to give honest opinions and a linking question (What is the name of the first street on which you lived?) was used to link corresponding before and after questionnaires without giving away the identity of the student.

A content analysis was then undertaken on student responses. A coding scheme was applied to the data to select responses in which either a motivation or benefit was identified. These extracts were then grouped into categories in which two or more students had identified the same motivation or benefit. This resulted in quantification of the number of times a particular motivation or benefit had been identified. It was then possible to rank the factors identified in order of popularity.

Informal conversation with staff from within the School of Engineering

Many of the staff who contributed activities for ILW are authors on this paper and have therefore been able to input their views directly. Much informal conversation with the wider university staff regarding ILW has also taken place and this has been referred to below to give an impression of the general tone and attitude that exists towards ILW.

Results

Activities Offered

Details of proposed activities available to civil engineering students are provided in the first two columns of Table 1 below. Some of these were available across all disciplines within the School of Engineering and some only to civil engineering students. Most were available to students of all years of the degree programmes. The five activities proposed by civil engineering academics are indicated in bold face in Table 1. The Engineers Without Borders/Royal Academy of Engineering (EWB/RAEng) workshops were proposed and developed directly by students. A further 18 ILW activities were proposed by School of Engineering staff from the non-civil disciplines, including ten available to civil engineering students shown in Table 1, and a further eight available only to students of other disciplines and hence not discussed in this paper nor shown in the table.

Student Response

The student response to the proposed activities is indicated in the third column of Table 1. Some activities attracted very few bookings, resulting in the activity not going ahead, as indicated in the fourth column of the table. Other activities were full. It should be noted that the activities proposed involved varying time commitments, for example the Trebuchet building and target practice was a five-day activity, whereas the Railway Engineering could be undertaken for one, two or three days and thus combined with other, shorter activities. Availability of places also varied widely, due to constraints such as room capacities and transport issues.

Activity Name	Description	Bookings/ Capacity	Did the Activity Run?
Sustainability Poster Competition	A poster competition, to produce poster(s) aimed at the general public explaining the why and how and wider benefit of the tri-generation centre in George Square. Aimed at all 1st year and 2nd year Chemical Engineering students, but others welcome.	0/72	No
Civil Engineering Smartphone Guided Tour	**Interesting infrastructure identified around Edinburgh. Tour with questions devised and made available via smartphones.**	**96/ Unlimited**	**Yes**
Engineers Without Borders (EWB)and Royal Academy of Engineering (RAEng)Workshops	Workshops designed to introduce students to engineering in international development run by EWB and coordinated by local student and professional EWB members.	75/75	Yes
Trebuchet Target Practice	**To build trebuchets/catapults to hurl a fixed mass a given distance using selected supplies/budget per team (teams of 3-6).**	**43/50**	**Yes**
Railway Engineering on the Bo'ness and Kinneil Railway	**Carrying out a variety of civil engineering related tasks on the Bo'ness and Kinneil Railway (a heritage railway 20 miles from Edinburgh). Strictly practical and hands-on.**	**36/48**	**Yes**
Change the world in a week: key skills development activities	**A course to help engineers develop key skills by developing an engineering idea that will change the world. Includes idea generation, decision making, concept design and presentation as well as engineering ethics.**	**0/30**	**No**
Value of Water Scientific Communication	**Workshop and public engagement activity. How do people value water? Different aspects of this question will be explored in the workshop along with training in different**	**0/30**	**No**

	means of scientific communication. The students will then work in groups to develop an exhibition, activity, website, film, game etc, to communicate one idea related to the value of water.		
Energy, Climate Change and Fossil Fuel Depletion Conference	Theme; Energy, Climate Change and Fossil Fuel Depletion. Day 1: Informative/inspirational talks to kick off. Day 2: Students work individually to research topics. Day 3: Facilitated debates and groups formed. Day 4: Groups produce a presentation to reflect the group view. Day 5: Conference where each group presents and the house decides a policy.	0/65	No
Student Debates	A series of debates on contemporary topics. Day 2: Meet for group and topic allocation. Day 3: Continue research and preparation. Day 4: Debates held with voting on outcome.	0/60	No
Research Institute (RI) open half-days	Open half days to be organised by RIs. To be coordinated and delivered by postgraduate students and research staff. Intention is to provide an overview of the broad area covered by the RI - i.e. should not just include local work.	60/95	Yes
Mobile Phone Mapping Exercise	Talks on mobile phone networks. Students will then disperse across Edinburgh to collect signal strength data using smart phones. Group reassembles at end to view/discuss signal strength map of Edinburgh.	13/30	Yes
Visit to UKAstronomy Technology Centre (UKATC)	Students to visit and tour UKATC at Blackford Hill adjacent to campus, to see workshops and current and past projects.	10/10	Yes
Excel Expo	Introduction to Excel.	17/45	Yes
G-Clamp workshop practice	Hands on work shop practice, to make a simple hand tool.	11/24	Yes
“Bounce: The myth of talent and the power of practice”	Students will learn to juggle, considering their success against the concepts of innate talent and practice of skills. Based on Syed (2011)	20/72	Yes
Sustainable Energy Systems Seminars	A series of seminars from Private Sector, International Researchers and Policymakers on Sustainable Energy Systems.	258/596	Yes

Table 1: Details of activities proposed by academic staff

The five activities proposed by civil engineering academics are indicated in bold face

Survey results from participating students

Students who participated in the four activities proposed by the authors which went ahead were asked to complete a two-part questionnaire as described above. Table 2 lists the activities for which surveys were conducted and gives details of the number of students who took part along with response rates for the activity.

Activity name	Number of Participants	Beginning of Activity Survey Responses	End of Activity Survey Responses
Trebuchet Building and Target Practice	43	38	29
Railway Engineering on the Bo’ness	36	7	6

and Kinneil Railway			
EWB &RAEng Workshops	75	26	12
Bounce: The Myth of Talent and the Power of Practice	20	13	4

Table 2: Authors activities and questionnaire response rates

Motivations for participating

Motivations for engaging in ILW activities varied greatly according to the activity for which students had signed up. The top ranking factors for motivation to participate are shown in Figure 1.

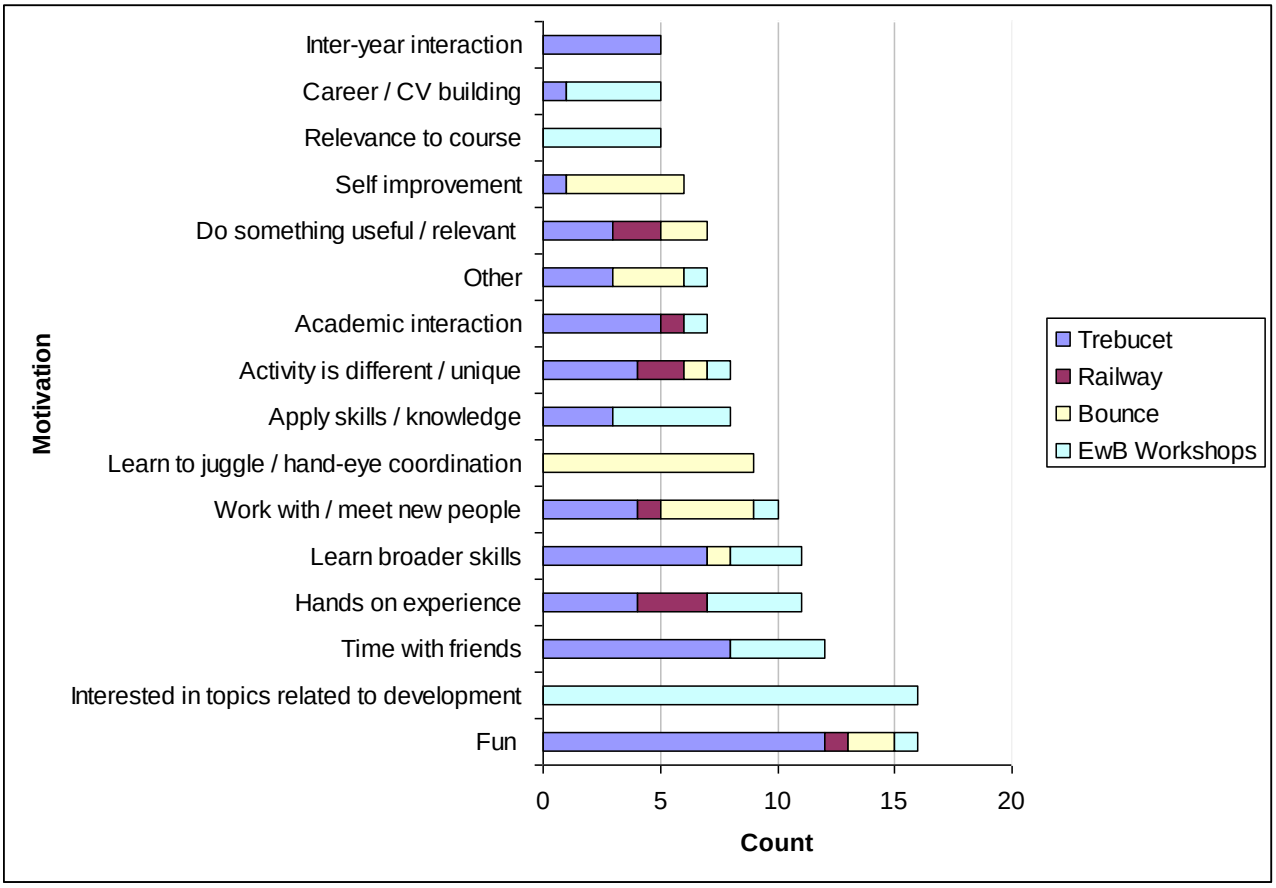

Figure 1: Reasons for engaging with ILW activities as given prior to ILW

Student perceptions of the benefits of ILW

According to the student survey, the top ranking benefits brought from participation overall were as shown in Figure 2 . These varied by activity, with each of the activities also producing unforeseen benefits, as detailed in Table 3.

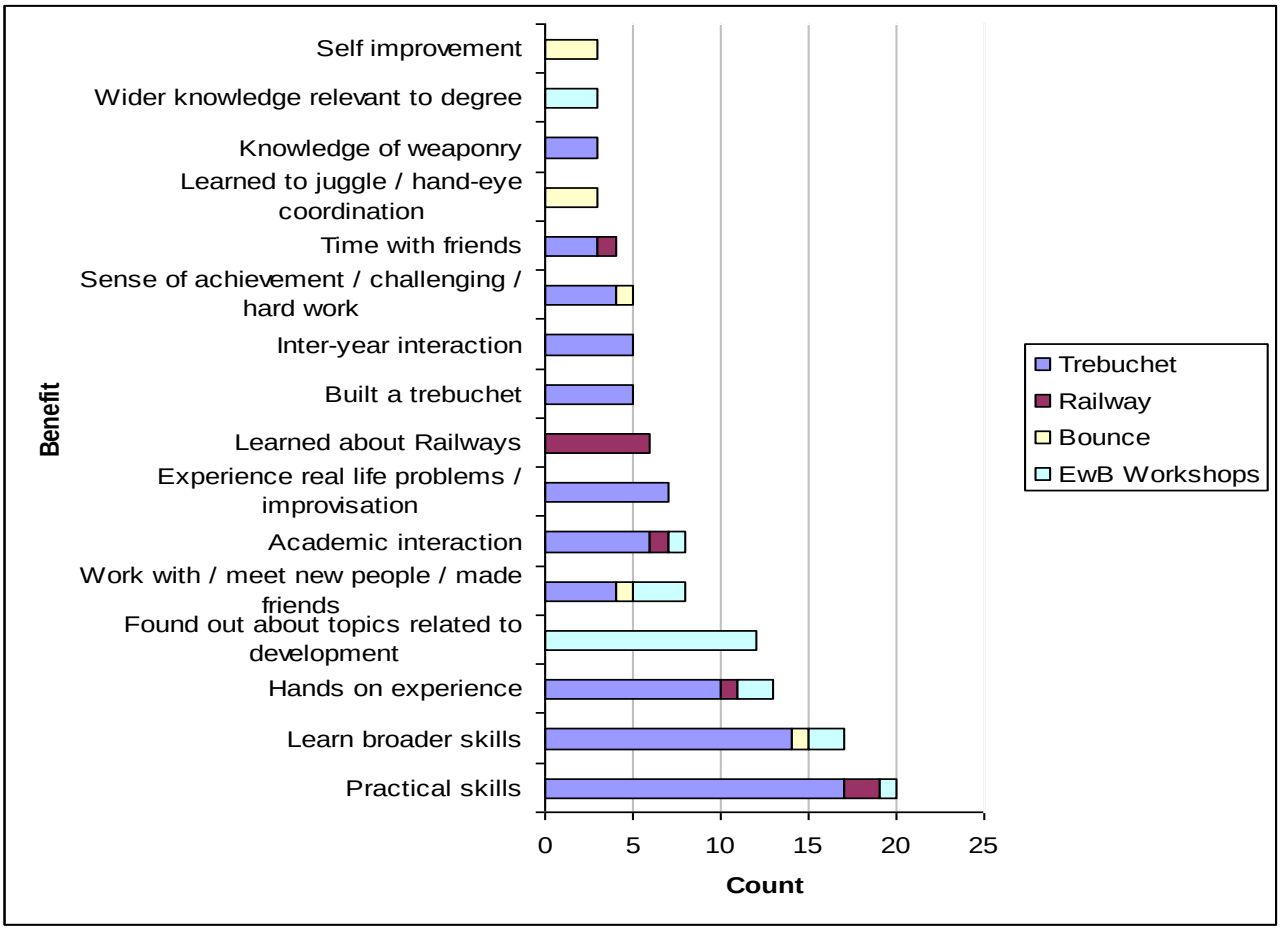

Figure 2: Benefits of participation in ILW from student survey

Activity	Unexpected Benefits Itemized by the Students
Trebuchet	• Engineering judgement • The ability to cope with failure • Making use of limited resources • Learning much about how wood connects together • Understanding the difference between design and implementation • Experience of real life problems and the need for improvisation • Thinking about things differently • Sense of achievement
Railway	• Meeting older generation of people working on the railway line • Got to learn more than expected from professionals as they were open to any questions • I was surprised how much dedication and pride the volunteers had for the railway
Bounce	• Sense of achievement
EWB/RAEng Workshops	• Different view points • It made me realise charity organisation is not as simple as it seemed to me • Think about things differently

Table 3: Unexpected benefits by activity

Discussion

Breadth of ideas about what constitutes innovative teaching

ILW provided an opportunity to explore the response of academics when asked to contribute activities they consider innovative. Despite an element of self-selection which arose due to

academics choosing to opt-in or –out of organising ILW activities, the activities that were offered to civil engineering students suggest highly divergent ideas across the School of Engineering about what constitutes innovative teaching.

Some academics led ILW activities aimed to help students develop specific skills such as use of software (Excel Expo), or workshop skills (G-clamp workshop practice). Others targeted scientific knowledge more or less related to curricula within the School of Engineering (Energy, Climate Change and Fossil Fuel Depletion Conference, Visit to UKATC, Sustainable Energy Systems Seminars). Other activities were more unusual, but still classroom based (Change the World in a Week, Value of Water Scientific Communication). Others, including the four activities analysed in this paper (see Table 2) were specifically aimed at being hands-on, practical activities carried on outwith the normal classroom environment, and to develop skills, knowledge or thought processes that have not hitherto fitted into standard curricula.

Academics not contributing

At the time of ILW there were 16 full-time academic staff employed in the civil engineering discipline within the School of Engineering. Only six of these were involved with one or more proposed ILW activity. Across the school, around 30 academic staff proposed ILW activities, leaving 50 who elected not participate.

In part this may be because many are currently involved in delivering a number of initiatives which aim to enhance the student experience. ILW is just one of these initiatives. Contribution to ILW, unlike contribution to some other initiatives is not compulsory for either students or academics.

There is also the issue of the relative importance of research, rather than teaching in driving academic activity at The University of Edinburgh. The authors' perception following informal conversation with other academics is that with a limited number of hours in the day and stronger pressure to achieve research rather than teaching goals, many did not feel they had the time available to contribute ILW activities.

Rewards for participating staff

Academics who did contribute ILW activities did so with a clear understanding that doing so would not lead to any tangible reward such as enhanced promotion prospects, salary increase or other payment or compensatory time to spend on other activities.

However the authors' experience in leading their own activities (see Table 2) was universally positive. They enjoyed interacting with students in a more informal manner, seeing students develop new skills and knowledge and developing new skills and knowledge themselves. As one author commented at the time: "What a brilliant week, I'm proud of us!"

Pedagogic Issues for Engineering Learning

Safety Culture

One important factor in some of the authors' ILW activities was safety. This was particularly significant in the Trebuchet activity, which involved practical work using hand and power tools and relatively large pieces of wood and other components, and then shooting projectiles in a sometimes unpredictable direction; and in the Railway activity which involved relaying railway track, working with heavy components and tools and in proximity to road-rail equipment (RRE) and with occasional works train movements.

Both these activities were subject to detailed risk assessment and safe systems of work, which included compulsory safety briefings. In the case of the railway activity the provisions of this were generally followed by the students, with only a few minor infringements such as standing between a rail vehicle and a bridge parapet and passing uncomfortably close to the RRE while it was slewing.

In the case of the Trebuchet the safety message from the briefing seemed to have been less well absorbed, with entering the workshop sessions without safety footwear or removing safety glasses,

sometimes repeatedly and after individual warnings – though it was noted that some of the University's technical staff present were not a good example on this matter. Some students also failed to follow advertised protocols when shooting projectiles and in one case two students were asked to leave the shooting area after being observed jumping on a piece of wood containing sharp screws whilst wearing only trainers – having changed out of safety boots slightly earlier.

Clearly the issue arises as to what can be done to further instil safety culture in students (and staff, but our mission here is *primarily* to form the young civil engineers who will need to pass on this message in the future). It is postulated that a key difference between the two activities was that whilst both were unfamiliar to the students, the Railway activity was very obviously in a new environment with very obvious hazards (trains and RRE) whereas the Trebuchet building was taking place on University sports fields with which the students were accustomed as regarding as " "safe" in other contexts. This may give a steer to possible ways of teaching safety culture in the future by taking students away from the familiar.

A dilemma faced by staff with all the safety incidents was to immediately exclude the student from the rest of the activity, or simply to carry on emphasizing the message with individual, announcements to individuals or groups. The latter approach was the one taken, it being deemed unnecessary to and not conducive to learning to exclude students given the nature of the incidents which actually occurred.

Design Skills

With specific regard to the Trebuchet activity, it was notable that only two of the eleven designs actually worked. This was surprising to the authors given the information available on trebuchet design and the known ability of the students. Bearings and connections were almost universally weak points in the designs, and despite their extensive theoretical training in the preceding years of curriculum, no students working on the trebuchets appeared to have done *any* design calculations, whilst drawings submitted were artistic impressions rather than engineering communications. It is postulated that this was in part a result of students' expectations that ILW was primarily intended to be *fun* and they would not be required to think.

Whilst the authors who teach design classes have noted that standards of drawing and sketching – despite explicit teaching – remain poor, it is also postulated that we are not actually giving civil engineering students sufficient practical experience of designing and making things. Most curriculum laboratories are highly prescribed, and there is no opportunity to learn heuristically, by trying something and failing (or succeeding). Yet without a practical understanding of "how things work" it is difficult for students to visualize a design concept (and hence to draw or sketch it usefully).

Failure was also significant in *Bounce*. This activity, based on Syed (2011) juxtaposed the idea of innate ability with that of purposeful practice to achieve a skill, and central to this is the acceptance of repeated failure prior to success. Syed gives the example of a skater who fell 20,000 times before successfully performing a quadruple loop and notes that the idea of embracing failure seems to be generic among elite performers – they fail more than non-elite performers. This would tend to further support the view that students would benefit from more opportunities for heuristic learning.

The essence of EWB-style engineering is applying relatively simple engineering concepts to complex and often contradictory social circumstances. Through introduction to 'appropriate technologies', the students had to think hard about the end-user of their designs; which is an integral skill to becoming a successful engineer in the UK industry – but difficult to teach in a formal university classroom environment.

Teaching resources – not just staff and money, but curriculum time and physical space – are an issue here but the authors believe more can be done to teach open-ended design, making mistakes and going round the design cycle of conceive, visualize, refine, communicate, implement.

In passing it was noted that at least one student building a trebuchet did not know how to use a screwdriver.

How did the students respond to the innovative teaching methods implemented?

Signing up to ILW activities was optional for civil engineering students. As shown in Table 1, whilst some activities were fully booked, others did not run due to in some cases complete lack of interest. In this way the students made clear their preference for particular types of activities. The survey conducted with those students who did sign up suggested that students opted for activities which they perceived as fun, hands-on and which offered an opportunity to mix with other students and academics, as shown in Figure 1.

In addition some students opted for activities in a subject area in which they had a specific interest. For example, the Railway activity attracted students with an interest in railways and EWB workshops attracted students with an interest in international development (Figure 1).

Those activities which were classroom based and of a more general nature tended to be less popular. For example, activities such as *Change the World in a Week* and *The Value of Water* did not run. Both activities offered students the opportunity to learn useful skills, but clearly did not match student requirements for ILW. A further issue may have been the differing levels of time commitment between activities, with some students wishing to take part in something, but avoiding activities that required the full week.

Outcomes of ILW for students

The outcomes of ILW determined from the student survey are indicated in Figure 2 and Table 3. The unexpected outcomes, which were all suggested without prompting by individual students, are particularly interesting. Many of the comments under the trebuchet activity echo the authors' perceptions regarding design teaching discussed above, but it is also salient that no student mentioned anything to do with safety, perhaps re-emphasizing the continuing cultural gap in this area.

Although not a top-ranked benefit for any activity, one pervasive piece of feedback was that students overwhelmingly found the week fun; in fact, nobody who filled out a survey said they had *not* had fun. A selection of quotes in response to the survey question asking students if the had fun is included below:

- "Yes, it was incredibly fun, innovative and hard work" (Trebuchet)
- "Yes, very enjoyable. Won't get a chance to do it anywhere else" (Railway)
- "Yes – Learned a new skill and learned that through deliberate practice it doesn't take long to learn a new skill or improve on one" (Bounce)
- "Definitely. Amazing. Really enjoyed it" (EWB)

As noted by Willmot and Perkin (2012), "A key challenge for Universities is to provide motivators beyond those gained by the award of marks". The students who took part in ILW did so despite there being no academic credit available for participating, meaning the activities successfully motivated students to participate in engineering activities where no academic credit was available.

Student led activities

ILW provided an opportunity for students to lead activities in which they have a particular interest. The EWB/RAEng workshops were co-ordinated by students themselves, with support from the EWB head office in Cambridge. This enabled students to take ownership of the learning opportunity, encouraging them to focus on design applications that were genuinely interesting to them, but still, of course, underlain by traditional engineering theory. By teaching on topics about which students were passionate, the workshop sessions were made more inspiring for participants than is sometimes the case with traditional teaching.

Broader Skills

In *Bounce*, it was clear that improved skills (in juggling) correlated with the amount of practice participants had put in. In some cases, too much practice without resting made performance

worse, showing that for many there was an optimum practice/rest schedule. While all participants did some practice, only one person managed to practice for the target of one hour per day for the week; this is an important finding and leads to the question of what motivates someone to practice, or engage deeply with a topic. The concept of a *growth mindset*, where great performance stems from careful practice, rather than talent, is highly applicable to any complex activity including engineering. In his book Syed quotes a figure of 10,000 hours of purposeful practice (typically over at least ten years) to achieve mastery, a figure which appears to be generic, leading to the question *How long does it take to become a good engineer?*

Conclusions and further work

Activities available to civil engineering students during The University of Edinburgh's *Innovative Learning Week* in 2012 were examined. It was concluded that academic staff took a wide view of what constituted innovative learning, but that the activities most attractive to students were those with a "hands-on" component involving making or doing. These practical activities exposed in some cases that safety culture messages still had some way to go to be embedded in the student mindset. They also suggested that heuristic learning incorporating the experience of failure prior to success was likely to enhance the visualization skills needed for good engineering design, whilst the linking of achievement to purposeful practice rather than innate talent could inform teaching methods in the future.

Innovative learning week will be repeated in 2013 and 2014 and further hands-on activities will be proposed and their effectiveness analysed to develop these themes.

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