Hands on Workshop on Teaching Forensic Engineering Teaching Students Critical Thinking by Investigative mindset

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Hands on Workshop on Teaching Forensic Engineering
Teaching Students Critical Thinking by Investigative mindset

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INTRODUCTION

When teaching Engineering to students it is important that we not only teach about how to engineer new things but also look at the failures and performance problems from an engineering point-of-view. The field that studies this part of engineering is known as Forensic Engineering. The American Society of Civil Engineers defines this field as: "The application of engineering principles to the investigation of failures or other performance problems. Forensic engineering also involves testimony on the findings of these investigations before a court of law or other judicial forum, when required." [1]

1 TEACHING FORENSIC ENGINEERING

For the past 7 years a course in Forensic Engineering has been running in the Master of Science Programme at The Faculty of Aerospace Engineering at Delft University of Technology in the Netherlands. In the beginning the course was taught by academics only, but three years ago it was taken over by a Senior Air Safety

Investigator from the Dutch Safety Board who was appointed as assistant professor to increase the links with standard working practice. As such the course was revamped and many principles of active learning and CDIO [2] were applied in the course design. In particular, attention is given to additional required skills such as working in teams, and Critical Thinking skills, Interviewing skills, and Investigative/observation skills. These were specifically added to the Forensic Engineering learning objectives. The students are taken through the whole process of an air accident investigation. During the lectures these skills are practiced and at the end the course this cumulates in an exam which consists of carrying out a (simulated with role-play) aviation accident investigation (see figure 1). A full description of the course, its learning objectives and outcomes have been previously published in a paper at the American Institute for Aeronautics and Astronautics [3].

Fig. 1. Set up of Aviation Incident For Exam

To a certain extent the forensic engineering course teaches students the reverse way of thinking to the students' engineering education. At this point in time, students are taught how to create, design and analyse engineering objects with (sometimes) a clear end user and sets of requirements in mind. In this course the students are confronted with an incident or accident of an engineering object with an end user interacting with it. Students are asked to reconstruct what may have happened and if that there are lessons to be learned with respect to design and engineering and user interaction with the engineering object. This is where the need for the additional skills next to "normal" engineering skills comes in. Students have to observe, gather evidence, interview witnesses, distinguish between useful and not useful information, deductive and inductive reasoning, think critically and communicate well with each other to ensure no information is lost. The two skills which the authors will highlight in the workshop at this conference are critical thinking and investigation skills. In this paper a brief literature background will be given of these skills and why engineers need them and why traditionally they do not form part of an engineering curriculum. The principles of the workshop are then briefly described without giving too much away that would spoil the workshop experience. Finally, in the last section a set of conclusions and recommendations is given with the aim to aid fellow lecturers who are interested in teaching similar skills to students in their courses.

2 THE IMPORTANCE OF CRITICAL THINKING AND INVESTIGATION SKILLS

The recent SEFI position paper on Developing Graduate Engineering Skills [4] called upon engineering educators to implement more ‘soft skills’, such as critical thinking and investigation skills in the curricula to better prepare students for the rapidly changing and evolving work environments. This call is supported both morally and in evidence by many stakeholders in engineering curriculum development such as Sheppard et al. [5], Trevelyan [6], Goldberg and Somerville [7] and Kamp [8]. All argue that these skills should be taught in a coherent way, combined and contained within an engineering context that is engaging, challenging and motivating for students ideally within a context of real engineering challenges ideally taught by inspired academics with support or experience from the professional field. So if everyone agrees it is important, how come it still not actively and visibly implemented in many engineering curricula? We hope this paper will encourage fellow engineering educators to make these outcomes more explicit as it will empower students and prepare them better for the future.

2.1 Critical Thinking Skills

So what are Critical Thinking Skills and how to teach them? Halpern in 1999 [9] states:

“Critical thinking refers to the use of cognitive skills or strategies that increase the probability of a desirable outcome. Critical thinking is purposeful, reasoned, and goal-directed.”

Halpern [9]

She also states that these skills transfer across the whole academic domain meaning that students are not limited to just their engineering knowledge and skills. It requires an ability to acquire and synthesise knowledge from all relevant fields to come to reach the desired goal. This type of thinking requires students to go outside of their comfort zone and to evaluate their outcomes of their own thought processes. This is not easy for engineers, contrary to popular belief, as indicated by Trevelyan who claims that “critical thinking and presenting logical arguments can be more challenging for engineers than for those with a background in humanities [6].” This claim is based on research by Ahern et al. [10] who provided evidence that staff in engineering academia have the least developed ideas on critical thinking compared to other disciplines in academia. Trevelyan [6] blames this in part on engineers having been encouraged to build on their natural strengths in maths and science at school, fields in which logical thinking is facilitated by formulas.

2.2 Investigation Skills

Investigation skills in the context of this course is about how to find out what may have actually happened and what factors contributed to it. This is not unlike a crime scene investigation only with a slightly different objective: not to assign blame but to see what lessons can be learned from the incident or accident to improve safety.
From a very hands-on point-of-view, this includes the ability to collect, document & preserve all evidence while minimising additional damage, interviewing witnesses and experts and much more practical skills belonging to this.

On a higher abstraction level, the investigation skills also include: Observation skills, the ability of forming hypotheses, examination skills (of the evidence) with regards to the hypotheses, Analysis skills, the ability to synthesise the ability to draw conclusions with regards to the hypotheses and the ability to formulate the findings with regards to the research questions posed. These skills often also claimed to be taught as scientific research skills but in that context they are aimed at how to do scientific research, not how to deal with investigative questions in the working life of an engineering professional. As Kamp argues in his vision on engineering education [8] students should be encouraged to ask the right questions, to approach a problem systematically and do research because they need the knowledge to solve their problem. This is also iterated in the CDIO curriculum [2] where inquiry skills are part of the required personal skills students should develop. Universities should train students to become investigators rather than just scientific researchers in the academic realm. It is important that as academic researchers and teachers we do not mould students into ourselves but rather ensure they are able to excel in the world of the working professional engineer.

So how do we apply this in an engineering education context? The CDIO principle [2] advocates an approach of an 'integrated learning experience'. It argues that by learning and practicing skills with learning disciplinary and technical knowledge enables deeper learning and is more resembling the working practice of a professional engineer. They rightly point out that these integrated learning experiences are a key factor in achieving the higher level within Bloom's taxonomy which is what we strive for in MSc level engineering courses. The integrated learning approach is likely to be more engaging for students and thus more motivating than traditional theoretical courses on research methodologies or critical thinking by a theoretical philosophy or psychology course. And although not specifically mentioned these skills are of course practiced in teams allowing students to practice and develop their team working and verbal communication skills as well creating a win-win situation all around.

Therefore, an integrated learning approach was chosen for the Forensic Engineering Course and the results seem to indicate that this has worked well as can be seen from the student evaluation results reported in an earlier publication [3] and later on in this paper.

3 WORKSHOP SET UP

3.1 Workshop Objective

The workshop's objective is to have participants experience through "Learning-by-Doing" how to teach students critical thinking skills by investigative mind-set to which participants are inspired to think up ways in implementing these skills within their own courses and curriculum. This means that in this paper the authors will not give away the exact set up of the workshop nor the solutions to the challenges posed in the workshop. This would defy the workshop's purpose.

3.2 Workshop Set up (2h)

After a short introduction on the Forensic Engineering course and its Learning Objectives participants are divided into a number of groups and are asked to look at sets of evidence of a simple event. In this workshop participants will be asked to solve 'the mysterious case of the cracked eggs' (see also figure 2). The goal of the group exercise is to try work out what may have happened and under what circumstances given the evidence file presented. After 30 minutes, teams report back on their findings and share them with the rest of the group. At the close out the authors will share what students typically pick up from this exercise. This is then followed by a 30-minute brainstorm session in which participants are challenged to come up with a similar activity fitting within the constraints of their own curriculum. The outcomes of the brainstorm are then presented to the group.

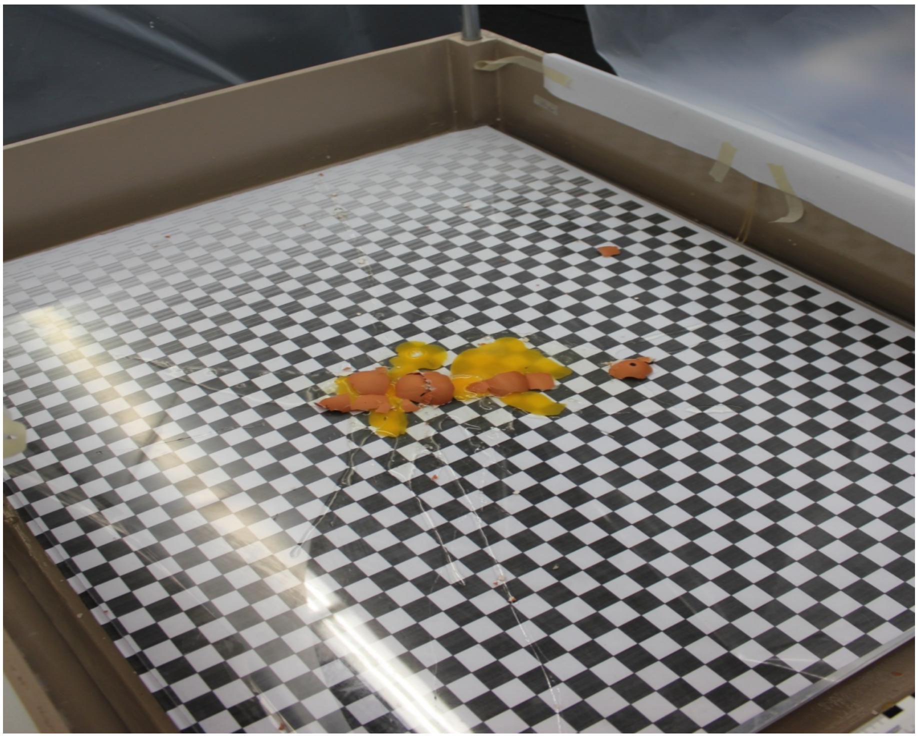

Fig. 2. “Egg” investigation`” (Eggstigation)

3.3 Workshop outcomes

Participants like students before them will walk away from this workshop with an understanding of the importance of critical thinking and investigative mind set in Engineering Curricula and a better understanding of Forensic Engineering. So what are these outcomes?

The authors have run the workshop several times, both in-class as part of the course and with educators as part of educational training workshops.

When running with students the authors found that at times students were very confused when non-aviation exercises were presented during the Forensic Engineering lectures. From a student point-of-view the exercises seemed to be irrelevant and distracted them from learning what they thought was essential. However, experience from the authors has shown that having aviation related events will at times overpower students or draw their attention away from the learning objectives of a particular lecture like critical thinking. Therefore, students are challenged during the lectures with an exercise that seems so easy that they feel it is not worth even thinking about. The simplicity and student underestimation has a high likelihood of mistakes being made creating a solid breeding ground for learning. In the students’ self-reflection and evaluation forms many students clearly realised that mistakes were made and reflect on them:

> *“What are we looking at? (Something I realised was important after the eggsperiment) and: What are we looking for? The answers to these questions weren’t always obvious, which is why it was important to regroup during the initial phases of the investigations and share initial findings with each other.”*

"During the broken eggs practical, I realized that too many times, suggestive ideas were given to the whole group that were modified continuously throughout the analysis. It became clear that there was a lack of decision making and sticking to it until the end."

"Because of the complexity of evidence, good collaboration and team work is required to achieve results. The egg crash lecture gave good insight in how difficult it to research data obtained from evidence, to find patterns and draw conclusions."

Student realise, with the benefit of hindsight, that having the evidence and looking for patterns, using critical thinking, it was very easy to achieve the goal of finding the answers. However, the reflections show another particular, related to group dynamics and collaboration. Students initially were very competitive, working together in their own team only, even though there was NO competition element in the Eggcercise. During the theory lectures the importance of collaboration and teamwork was elaborated and shown, but students still tended to fall back into the competitive "solitude team" mode. Rather than choosing to communicate with other groups and have the opportunity to get more information or a different insight. On several occasions this hindered students to reach the desired goal and get the answers efficiently within the set time.

"The last practical I would like to mention is the "egg investigation". During that task every group was supposed to analyze crashed eggs pictures and the data provided. Again, the key was communication, however in this exercise it was more focused on the communication between the teams. At the end of the time, the atmosphere was pretty nervous and everyone was frustrated as we were not able to figure out what happened with eggs. In my opinion it was very valuable lesson for everybody."

Having student frustrated during lectures seems to be bad, however, during the end-of-lecture debrief the students were very keen in pointing out what they did wrong and what could be improved. The lecturers were pleasantly surprised in the following lecture when all teams showed collaboration and a structured way of working together. The progress was remarkable and presented challenges for the lecturers as the students were able to more effectively crack the presented cases and challenges in the following lectures.

When running this workshop with educators an interesting difference was observed in the fact that more diverse teams (that is teams with a make up spanning multiple fields of academia) were far more effective in working out what happened despite some of them having no technical knowledge whatsoever. It was interesting to see that the willingness to work together and their ability to listen to one and other was higher which resulted in more effective teamwork. This shows the value of this exercise for lecturers and have students experience this aspect in a safe educational environment.

Finally, it was observed by the participants that staff had as least as much fun (if not too much fun) observing the participants during the exercise. The differences before and after are in some cases very real and confirm to the authors the justification of using these type of exercises.

4 CONCLUSIONS AND RECOMMENDATIONS FOR CURRICULUM DEVELOPMENT

During the designing and running of the course on Forensic Engineering the lecturers found that the integrated learning approach offered them an opportunity to expose students to the real life world of forensic accident investigation combining engineering knowledge with the training in personal skills such as investigation and critical thinking skills. It allowed staff to encourage students to be curious, to challenge their preconceptions and to learn whilst making mistakes about a topic they were all very curious about.

In its execution students used their combined engineering knowledge as well as their team working and synthesis skills to deduce what may have occurred. The use of small, somewhat out-of-context workshops to train individual skills such as this workshop, allowed students to practice this type of thinking before having to apply it to their final challenge the actual final exam investigation. The students rate this course highly and are keen to assist in maintaining the myth by alluding to all the unexpected "Easter eggs' in this course but never giving anything away to the next year of students embarking on the course. In fact, graduates of this class volunteer in great numbers to assist in the course to teach their successors.

For colleagues who are considering doing something similar in their courses we would like to encourage you to do so. Students indicate this is the best learning experience they have ever had and you will find you will have a lot of fun creating these type of exercises. The golden rules in creating these exercises are:

1. What is your objective with the exercise, what would you like students to take away from it?
2. How would you train them in this skill if you were in the real engineering world (practically)?
3. Take that training to the absurd by taking it out-of-context of your course but within the imagination of your students by applying it to something more trivial
4. Trial it in-class (or on your PhD students first) and be prepared for it to go wrong the first time
5. Have a good close out in which you explain what the take-aways of the exercise were and stress the main learning points
6. Ask students to reflect on what they have learned
7. Adapt, Expand and Rerun the next year until you feel you have reached your objectives

Finally, to all those who call for more skill training in engineering curricula: you are right. However, it is the believe of the authors that this is best done by converting existing classes into integrated learning experiences allowing for the gaining of knowledge and the training in skills to go hand-in-hand whilst increasing student motivation and increasing their deeper learning.

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