Role-play experience through virtual reconstruction of accident investigation

Graham Schleyer¹ and Rui Fang Duan¹ and Nicola Stacey²

University of Liverpool¹ and The Health & Safety Laboratory (HSL)², UK

ABSTRACT: The health and safety agenda is becoming increasingly important in engineering education as employers expect graduate engineers to be risk aware and have an appreciation of their professional responsibility for their own safety and the safety of others. Active experiential learning methods in the form of role-play in real-life scenarios engage students to consider the wider implications of their activities as professional engineers in society. To this end, a real-life accident investigation has been developed into a virtual laboratory exercise for year 1 engineering students. In this lab, students take on the role of the accident investigation team sorting through information and analysing evidence in support of an expert witness statement. The exercise encourages team working and communication, and is accepted as an important element of the student’s active learning experience in safety risk issues. The lab serves to emphasise that human factors have a large part to play in the underlying cause of accidents. Elements of risk education are embedded in the exercise: professional responsibilities for managing risk, risk considerations for design, hazard identification, underlying causes of accidents and linking accident investigation with risk assessment. A re-construction of the scene is created with a 1/100th scale model that was used in the actual court prosecution and a file of data is provided comprising photographs, witness statements and other technical documents mainly taken from the accident investigation report. Future developments will explore the use of virtual 3-D software to re-create a walkthrough of the accident scene with interactive elements.

1. INTRODUCTION

The need for formal implementation of risk education is addressed by the Health and Safety Executive’s (HSE) strategic business aims. Action point 34 states, “The government and the Health and Safety Commission (HSC) will act to ensure that safety-critical professionals such as architects and engineers receive adequate education in risk management. This will be delivered through a programme of direct approaches relevant to higher and further education and professional institutions” (HSE and DETR, 2000). However, in Lee’s scoping study on education of risk concepts (Lee, 1999) there is a finding that the concepts of hazards and risk are not well understood or differentiated by new graduates. One comment from an external source suggests that “a graduate engineer’s knowledge of hazard and risk varies from discipline to discipline and from university to university.” For example, chemical engineering students, on balance, receive more hazards training than do mechanical engineering students. HSL in collaboration with the University of Liverpool is working on generating a template to incorporate risk education into the new ‘Liverpool Engineer’ curriculum of an undergraduate engineering degree course. An overview of
the project was presented at the 2006 engineering education conference in Liverpool (Schleyer et al, 2006).

Employers expect graduate engineers to be risk aware and have an appreciation of their professional responsibility for their own safety and the safety of others. Role-play in real-life scenarios engages students to consider the wider implications of their activities as professional engineers in society. A distinction was made between risk education at the academic level and the practical application of it in real context. Universities are believed to be better placed to deliver the theoretical aspects of risk education than industry. However, hazards and risk becomes more relevant when it can be related to aspects of daily life and business closely affecting the general public. The role-play exercise aims to merge the theory with practice and highlight how close to home risk and hazards can be. It is not practical or realistic in terms of timing and safety to take a group of students to an accident scene but it is possible to bring the accident scene to the students. The development of the new laboratory exercise was based on a similar exercise run by the University of Sheffield. A case study based on the walkway collapse at Port Ramsgate with embedded safety risk elements was developed with the help of the HSL. Through the laboratory, students are expected to learn about the general accident investigation procedure; recognize and analyze key information about the accident; perform a simple risk assessment; and to have safety risk concepts, formally presented in lectures, reinforced.

2. EMBEDDED RISK CONCEPTS

2.1 Accident investigation principles

The HSE funded a survey (Henderson et al, 2001) to gain a comprehensive and nationally representative overview of accident investigation practices and procedures. This consisted of a large-scale telephone survey with some 1500 participants. The results showed that there was a range of approaches to incident investigation, from system-based (which examine all potential contributory factors) through to wholly traditional methods (that focus on the individual concerned and the most immediate cause). The majority of companies involved in accident investigation work, operate closer to the traditional approach rather than the system-based approach. In 2004, the HSE published new guidance on how to investigate accidents and incidents, including near misses (HSE, 2004). There are four principal steps featured in the guidance, namely:

1. The gathering of information;
2. The analysing of information;
3. Identifying risk control measures; and
4. The action plan and its implementation

These steps were used in the development of the worksheets that the students would use in their role-play investigation.

2.2 Learning outcomes

The laboratory exercise is expected to achieve the following learning outcomes as part of the engineering undergraduate curriculum, namely:

Students should be able to:
1. Understand the engineer’s professional responsibilities for safety and managing risk

2. Demonstrate the ability to collect, analyze, and interpret data, and to support conclusions

3. Learn the underlying causes of accidents, and the link between accidents and risk control

4. Identify hazards

5. Provide protective measures

6. Work effectively in teams, including assignment of roles, monitor progress, meet deadlines, and integrate individual contributions into a final deliverable

7. Communicate effectively about work with colleagues, both orally and in writing

3. ROLE-PLAY DESCRIPTIONS

Traditional undergraduate engineering laboratory exercises have mostly been designed to verify specific theoretical concepts which have been delivered during formal lectures. This type of laboratory practice is characterized by a set of sequential instructions given to students on how to apply specified laboratory equipment and to observe expected phenomena under specified conditions. In contrast to the traditional engineering laboratory, students in this role-play exercise will explore basic information and evidence to find answers to what happened and how and why it happened. When the exercise was first launched in the 2005-06 academic year, it was structured around five stages of the investigation. Each stage was tackled by a different tutor group each week, drawing on findings from the previous group, as would be done in real life investigations. The lecture material was also timed to synchronize with the particular stage in the investigation. This way there was also less chance of groups copying from week to week. It became evident, however, that some students were missing out on key aspects of the investigation by conducting the lab in different stages each week. Furthermore, with changes to the timing of the linked module, now delivered over 12 weeks rather than 24 weeks from 2006-07, synchronization of the lecture material with the various stages of the lab was impractical. Consequently, from 2006-07, the exercise was re-structured, based on the jig-saw model, to allow the group each week to tackle all stages of the investigation now reduced to 4 from 5. This also encouraged more team working as the group had to be divided up into smaller teams to work on each of the stages.

Evidence from student feedback indicated that the students liked this structure better giving every member of the group the opportunity of linking with all stages of the investigation.

The accident scene was reconstructed using the following resources:

**Wooden scale models**
(1) The 1/100th scale model used in the court prosecution, Fig. 1, gives a clear layout of the accident scene with model people representing witnesses on display and each with a reference to an actual witness statement in the file. This however gives an unfair advantage to the group as the investigation team would not have such a complete view of the accident scene upon arrival. The new interactive ‘walk-through’ being developed could make this part of the investigation more realistic. (2) A full-
scale model of the critical components that failed, Fig. 2, is also available for inspection.

Fig. 1: 1/100th scale model of accident scene

Fig. 2: full-scale model of critical component

Photographs
Photographs taken at the accident scene showing different views, forensic evidence, and condition of equipment are available.

Information folder
This contains background information mainly taken from the official accident investigation report (HSE, 2000) and the paper by Chapman (1998). Project plans, witness statements and description of good practices provide students with sufficient information to investigate the accident. Data like engineering stress calculations and material properties can also be found for reference purposes.

3.1 2005-06 format

For the 2005-06 academic year, the accident investigation was divided into five stages and every stage ran twice over a 10 week period. Students working in tutor groups of around 6-10 tackled one of the stages each week, with subsequent groups drawing from the findings of the previous group. The initial idea was to synchronize material taught in the mechanics of solids lectures with the appropriate stage of the lab exercise. A summary of the whole investigation was covered in the last weeks of the lecture course thus allowing students to get an appreciation of the entire investigation and connection of the different stages.

Stage 1: recording the accident
This stage aims to bring students to the accident scene. The first accident investigation team collects evidence for the investigation and establishes what happened. The tasks for the students are to (1) examine the accident scene by way of the model re-construction, witness statements, together with the information folder, (2) work out what happened, who were the main parties involved, and (3) suggest what factors could have contributed to the accident.

Stage 2: design considerations
This stage takes the students back to headquarters and gets them to examine the design aspects. Starting from the information gathered from stage 1, students will review the design concepts: specifications, decomposition of the product, sources of
loads, movements, articulation systems and failure modes. Students are encouraged to consider how to design against failure. This particular aspect of the investigation is especially emphasized in the lecture course.

**Stage 3: risk management**
Following the design considerations, the next group is given a risk assessment to perform until the risk is “as low as reasonably practicable”. The main tasks of this stage are (1) to identify hazards associated with the original design of the walkway and modifications to the design, (2) to consider what risks have been affected by the new design and what precautions could be taken to ensure the risks are adequately controlled by the designers, operators and contractors. (3) Finally the students are directed to the previous stage to comment on the safety of the design.

**Stage 4: material assessment**
This stage is about detailed metallurgical examination of the failed components. Students examine details of the broken parts together with analysis of the welds from the critical parts that failed. This part of the investigation takes the group closer to the root cause. They are encouraged to think of ways in which this could have been prevented.

**Stage 5: stress analysis**
After reviewing the previous stages’ work, students determine the strength of the failed part on their own and compare their results with the calculations produced by the designer and the classification society. This stage links well with the theory given in the lecture course.

**3.2 2006-07 format**
For the 2006-07 academic year, the five stages were condensed into one three-hour session. A condensed version of essential data was provided as well as modified worksheets.

Students work together in two teams. Each team complete two worksheets on different aspects of the investigation: design appraisal (C), stress analysis (D), metallurgical inspection (I) and operational risk management (O). Apart from finishing the worksheets, each team presents their findings with sufficient background information to the rest of the students. This enables some discussion and constructive criticism. A personal witness statement based on the findings during the lab is completed individually, which is handed in the next day covering the topics of why the accident happened, the root causes of the accident and who was responsible. Half of the marks are given for the completed worksheets (average of two worksheets) and half for the personal statement as expert evidence.

**3.2.1 Instruction to students**
They are asked to provide expert evidence in an accident investigation in which field data has been gathered and requires to be analyzed.

They work together in two teams, ‘CD’ and ‘IO’. Each team completes two worksheets on different aspects of the investigation: design appraisal (C), stress analysis (D), metallurgical inspection (I) and operational risk management (O).

Each team presents their findings to the other team. They need to allow one hour for the presentations and discussions. Their expert witness statement should cover (in no more than one side of A4) the root causes of the accident, why the accident happened, and who was responsible.
3.2.2 Demonstrator's role

The lab demonstrator plays an important role in assisting the completion of the investigation. The laboratory is organised in such a way so as to include a warming up exercise, team work and individual contribution.

Warming up
Students are first given an icebreaker to get them thinking and talking to one another while they are signing in. A good demonstrator will notice if there is lack of participation and encourage interaction with discussion and questions. Several icebreaker exercises have been developed specifically for this lab.

Team work
After the warming up, the lab then commences with a brief introductory talk. The first task is for the groups to choose a group leader whose responsibilities are to allocate tasks for each team and coordinate activities. Thereafter the students will follow the instructions given to them by the demonstrator and/or worksheets. The main role of the demonstrator is to facilitate the groups. Students are encouraged to search for clues on the accident scene model and follow them up using the file of information, use white boards and mind-maps, Fig. 3, for discussion. Mind-maps turn out to be very helpful for task allocation, information gathering, discussion and note taking.

Fig. 3: mind-map

Individual contribution
An element of independent contribution is made through completion of the expert witness statement at the end of the lab. This is submitted the following day of the lab and assessed individually.

4. ACTIVE EXPERIENTIAL LEARNING

The exercise encourages team working, communication, engagement of the students from the start through icebreakers, and the use of white boards and mind-maps for discussion. Elements of risk education as described above in 2.2 are embedded in the exercise.

4.1 What students learn in 'IO' team

The following points are what the students are expected to learn from their part in the exercise:

- There were justifiable safety reasons for introducing a double deck linkspan, some risks were reduced, and others were increased by the new design
Most significant hazard in the new design was the elevated passenger walkway (30 m above ground) that had no safety backup system or tolerance to the failure of just one point of attachment.

The designer and the fabricator made a series of gross errors in carrying out their work for which there were adequate standards and guidance.

The incident demonstrated the need for effective project management.

The design should have allowed for lifelong maintenance and appropriate safe fixed access to do this.

The support feet were ‘safety critical’ items; appropriate fabrication and welding procedures should have been used and monitored.

Sensible quality assurance and monitoring procedures should have been applied during fabrication and installation.

Failure of the walkway could have been avoided if the operators, Port Ramsgate, had responded to defects which became apparent during operation.

### 4.2 What students learn in ‘CD’ team

The following points are what the students are expected to learn from their part in the exercise:

- The main load points on the walkway would come under additional stress due to the rolling action of the pontoon.

- The support feet are high maintenance components.

- Failure of any one of the support feet could lead to catastrophic collapse.

- Fatigue cracking is a critical failure mode due to dynamic loads and environmental factors.

- Assumptions for the load path and static analysis were unrealistic and incorrect.

- Using realistic values for the load path and for the loads results in unacceptably high stresses in the critical component.

- Due to the high risk nature of the design, a high factor of safety should have been used.

- There was no safety backup system should the walkway collapse.

### 5. CONCLUSIONS

Feedback from students indicates that the lab is succeeding in promoting role-play learning by engaging students to consider the wider implications of their activities as professional engineers.
– The exercise encourages team working, communication and discussion as well as the practice of presentation skills

– The exercise has raised the profile of health and safety risk integration in engineering education and is accepted as a valuable learning experience in safety risk issues

Acknowledgements

The authors wish to thank the HSE and the University of Liverpool (Studentship Awards) for funding this work. Dr S Joel and G Norton for their technical support and Mr N Ruston for the idea of the icebreaker exercise for the material examination stage and feedback from the lab demonstrators are gratefully acknowledged.

References


