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# Application of Case Study Material in Undergraduate Learning

Trish C. Kerin[a,*], Michaela Pollock[b]

[a]Insitution of Chemical Engineers Safety Centre, Level 7, 455 Bourke St Melbourne VIC Australia, 3000
[b]Department of Chemical Engineering, University College London, Torrington Place, London, WC1E 7JE, United Kingdom
tkerin@icheme.org

When we review a case study it can be very tempting to judge the actions of the people involved with the benefit of hindsight. Because we know the outcome, it seems obvious what decisions led there. This hindsight inhibits our ability to learn from the event because we fall into the trap of justifying why we would not make the same decision. To counter this, the IChemE Safety Centre started to develop some case studies that try to minimise hindsight bias. These case studies were developed with a non-technical workforce audience in mind, and have been successfully employed in a variety of industrial and commercial settings containing wide-ranging audiences. Furthermore, this has enabled them to be utilised at universities to impart process safety knowledge at an early stage in undergraduate studies and bring a realistic industrial setting into an academic environment. University College London is one such university, where they have adapted the case studies to gain other additional insights and support learning outcomes of introductory safety courses given to second year undergraduates who are still developing their core chemical engineering knowledge and have had limited exposure to industrial settings. This paper will explore the basis for the case study development and they key requirements to reduce hindsight bias. It will then explain different options for how they can be used in an educational setting to give students the experience of a process safety incident as well as an understanding of the varying demands on a worker in an operational facility. Reflections upon how the case studies have already been used in academia and some suggestions on further ways in which the case studies can be used in an academic setting are made. Finally, some recommendations for additional support material that could be developed by the IChemE Safety Center to further encourage the use of the case studies in academia are made.

## 1. Introduction

Think about a movie you saw with a surprising twist in the plot. Did you identify the twist before it became obvious? Or did you get a surprise with the twist but then said to yourself “I knew that was going to happen”. Once we know the outcome, our perspective of the events changes. The next time you saw the movie, you could pick out very early on what the different clues were that gave the plot away. This is because we can’t “unknow” what we already know. This phenomena is called Hindsight Bias, and is one of the many cognitive biases that impact how humans respond to events.

Now think about the last incident investigation report you read. It would have detailed the sequence of events that took place leading up to the loss of control and flowing onto the consequences. Think about your response when you read about a vessel with a faulty level indicator being overfilled and a loss of containment occurring, which then ignited. Filling a vessel with a faulty level gauge seems like a silly thing to do, and an overfill scenario seems to be very logical in hindsight. But in that situation there are many factors that may have impeded the decision making of the individual who decided to fill the vessel in those conditions.

As defined by Blank, Nestler, von Collani and Fischer (2008), there are three levels of hindsight bias; Memory Distortion, Inevitability and Foreseeability. Roese and Vohs (2015) go on to explain these. Memory Distortion is where a judgement was made prior to an event but remembered differently after the event, to align with the outcome. Inevitability suggests that the outcome was predetermined, or a belief that it just had to happen. This is partly related to how hindsight bias impacts learning from incidents. Lastly Foreseeability is about believing

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that you would have predicted the outcome in the same circumstances. It involves making judgements about our own capability and knowledge. It is this form of hindsight bias that largely impacts our ability to learn from incidents, as we judge the actions of others while believing that we would have seen the incident outcome as a real possibility and therefore prevented it occurring. This is because when we consider the incident report we know the outcome that did occur. We then fall into the trap of thinking that we would never have made the same obvious mistake that led to the incident occurring. This then becomes a blocker to learning from the incident. We are subconsciously justifying that our behaviour would have been different rather than thinking about what we need to do to prevent a similar incident. This leads to an over confidence in our own abilities.

## 2. Case studies to minimise hindsight bias

### 2.1 How the case studies were developed

The IChemE Safety Centre (ISC) set about developing some case studies to try and minimize the impact of hindsight bias on the audience, in an effort to create better learning from incidents. A key step here was also to involve the participant in the experience, so the learning was active.

Once an incident was selected for this treatment, research was conducted into the findings to dig deep into the context of the sequence of events that took place. It was vital to understand the context as this provided reasons why the decisions were made. It was also vital to tell the story without disclosing the actual incident and hence consequence at the start, this allowed people to be immersed in the context without having the foreseeability, and thus minimising the impact of hindsight bias.

The next step was to actively involve the participants in the decision making, giving them a chance to contribute to critical events as they unfolded. This was done by establishing a consistent decision point, that would be asked at three times throughout the development of the story to the eventual conclusion.

A significant challenge in developing the materials was to take a complex and nuanced incident that had several technical aspects to it and present it in such a way that technical knowledge of the subject matter was unnecessary to participate in the story and decision points. Engineering concepts needed to be simplified, and the inherent technology explained.

Once the story had been established and simplified, the decisions were inserted at three points within the case study to provide the interactive experience. This then allowed the participants to understand the context and make the critical decisions. This led to participants having the experience of making the decisions which led to the incident, without having to suffer the consequences personally. While this is not a replacement for having the real experience, it does go some way to providing insight into their own thought and decision-making processes as well as generating some of the emotional response you would see in the real incident. For this reason, it is critical that the activity is facilitated, as like in any incident, people need to discuss their feelings and debrief. The facilitation notes focus on the emotional response of the audience at the end of the exercise and then bring it back to how you can take this experience back into your workplace to help you make better decisions. There have been some instances where participants have complained that they were led to making the decision that resulted in the incident, by the context development. This is usually a defensive response to realizing they have caused the incident and a great example of how hindsight bias actually works. When they only see the context and not the outcome they can easily make similar decisions. In this instance the facilitator would discuss this as a key learning, if a person has been led to make a particular decision by watching a short video, they have shown that they are capable of making a similar decision when surrounded by work pressures and context.

There are two versions of each case study. The first containing the three decision points, where the participants make a key decision at three points in the story line. The second version contains some additional exercises, where the concepts of lead process safety metrics and process safety competencies across the whole organisation are explored. These exercises allow the participants to consider what metrics may have been the most useful in the developing incident, resulting in detailed consideration of metrics they may not normally have been exposed to. It also allows them to consider specific process safety competencies and think about who in the organisation should be involved at each level of the competency.

As at July 2018 there were six case studies available, covering a wide range of industries. Each case study also has a specific story and theme. The theme of the case study can be more useful to understand than the industry setting, as the learnings can be applied across multiple industries.

Table 1 details the Case Studies.

*Table 1 Case Study details*

| Title | Story | Theme |
|---|---|---|
| Gas Plant | Set in a gas process plant, the participant plays the role of a plant operator responding to the events of the day. | Management of Change. |
| Tank Farm | Set in a tank farm, the participant plays the role of a plant operator responding to the events of the day. | Safe operation of tank farms and shift handovers. |
| Coal Mine | Set in a coal mine, the participant plays the role of advisor to the mine manager during the design and construction of the mine. | Safety Governance and design and construction decision making. |
| Offshore Platform | Set on an offshore platform the participant plays the role of an incident investigator, investigating a gas leak. | Permit to Work systems. |
| Lift Off | Set in a space agency the participant plays the role of an engineer in the launch assessment team. | Organisational culture and ethical decision making. |
| Tidal Wave | Set in a power plant the participant plays the role of the plant supervisor. | Natural hazard triggering technological disaster (Natech) and emergency plan resilience. |

These case studies were designed for use in the workplace. So far they have been run in a variety of settings, including large conferences, small work teams from one company and audiences made up of different companies and or roles. They have worked for groups as senior at the company directors all the way to the front line operations teams. Where they have been run in very large audiences, mobile phone polling technology has been used to gather people's decisions and guide the facilitator's discussion with the group. In smaller audiences, there are suitable handouts allowing people to mark their decision and then contribute to the conversation led by the facilitator. The full case study experience takes between 90 and 120 minutes, depending on which version is run. The 90 minute activity explores the decision points, while the 120 minute exercise explores the decisions and the exercises around lead process safety metrics and process safety competencies. As noted above, the case studies have their own facilitation notes, so they can be run internally or with an external facilitator. The ISC runs several facilitated programs each year, and uses the case studies within several of its public training offerings. Feedback from both facilitators and participants has been very positive. The following quotes have been received in feedback forms:

*"every person in an organisation needs to experience this to build their understanding of culture" – participant*

*"I knew I had them in the story when they all fell silent at one point, when they realized what was about to happen next and that their decisions had led to it" – facilitator*

Given the success of the case studies in the wide-ranging settings and formats described above, one of the next aims of the ISC was to further extend the use of the case studies to an academic environment. It was felt that the manner in which the engineering concepts were simplified for a non-technical audience made the case studies easily accessible to an undergraduate academic setting where students are building up their core chemical engineering knowledge. The application in academia is discussed below.

## 3. Applying the case study material in an academic setting

In an undergraduate academic setting there are a number of challenges and constraints faced by educators with regards to how to effectively teach safety to large cohorts of students who are still developing their core chemical engineering knowledge. Furthermore, many students, particularly at the undergraduate level, will have limited, if any, site experience. As such, hindsight bias is not the main obstacle in a student's analysis of a past accident. Instead a lack of understanding of the context of a past accident, the decisions that led to the accident and the key learnings from the accident is the challenge faced by educators. Moreover, in an academic context educators are limited by the pre-defined learning outcomes of the course, the lecture theatre

or classroom environment in which teaching takes place and the timeslot provided in which to teach safety, potentially as little as 1 hour a week to cover a specified amount of material. However, as outlined by Shallcross (2013) employing learnings from past accidents within an academic context are a valuable and useful tool in teaching safety in an academic environment.

Within the context of the challenges and constraints of an academic environment the ISC case studies are a valuable resource. Each of the ISC case studies not only highlight how hindsight bias can impact the learnings from an accident, but also focus on different themes and industries as shown in Table 1. Furthermore, the interactive nature and focus on accessibility of the ISC case study videos to a wide-ranging audience lends well to engaging students and enhancing their understanding of often complex and unknown situations. It is by utilising these variations in themes and industries that the ISC case studies can effectively be used in an academic environment by providing well-researched, real-life examples of safety accidents that can support students in the learning of particular safety concepts or technologies that are being examined within a lecture context. In the next section of this paper the use and adaption of the ISC case studies to highlight certain points within a series of lectures on introduction to safety as part of the lecture course entitled 'Design and Professional Skills II (DPS II)' for second year undergraduate chemical engineering students on the Integrated Engineering Programme (IEP) at UCL are exemplified. For further information and examples on how teaching safety is embedded throughout the chemical engineering IEP teaching framework see Pollock and Sorensen (2018).

### 3.1 Examples of specific adaptations of case studies for an academic environment

*Risk evaluation and decision making*

One of the learning outcomes of the second year Design and Professional Skills II course is to gain an understanding of issues important to engineering designers including decision-making. This is framed within a design context in 4 week-long mini design projects, called Scenarios, and also exemplified in a safety context in the introduction to safety lectures, which is one of the topics included in the lecture course that forms part of DPS II. Students are introduced to the definition of risk (AIChE CCPS, 2008) and the contribution to the evaluation of risk firstly through the expected frequency of an incident and secondly through the impact or severity of the incident. Risk matrices are introduced to students together with categories of different levels of risk, frequency and severity and their respective descriptions similar to those shown in AIChE CCPS (2008).

The ISC coal mine case study whose theme is safety governance and design and construction decision making is used to contextualise the learning objectives to a real-life industrial setting with a safety focus. A six minute video extract from the ISC case study is played to students in the lecture theatre where different methods by which to build a second ventilation shaft are examined and commented upon from the perspective of different stakeholders. Following the video, students are asked to discuss and complete a decision point worksheet developed by the ISC which asks students to decide if different stakeholders would recommend each of the methods by which to build the second ventilation shaft. This exercise exemplifies decision-making to students in a real-life safety context. In order to support the learnings on risk matrices which had just been introduced in the lecture, the ISC decision point worksheet was further extended to ask students for their evaluation of the risk matrix category for each ventilation shaft construction method.

In the same lecture hazard evaluation methods and how they can be used effectively at different stages within the process design cycle are introduced. To conclude this part of the learning, students are once again reminded of the ISC coal mine case study and are asked to discuss and recommend appropriate hazard evaluation studies that should have been performed on the recommended method for building a second ventilation shaft. During in-class discussions students are encouraged to identify in which part of the process design cycle the ISC coal mine case study video is set and what would be appropriate hazard evaluation methods and why.

*Inherent safety*

A further learning outcome from the Design and Professional Skills II course is an understanding of the concepts of inherently safer design. The principals of inherent safety are initially introduced to students in the first year Design and Professional Skills I course. These are further built upon in DPS II with a particular focus on inherently safer design within the process industries. Approaches to design which are inherently safer and contrasting approaches to design which are not inherently safer are discussed within the lecture.

These learnings on inherently safer design are then emphasised on a real-life example by examining the design and operation of a tank farm as described in the ISC case study tank farm. Again an extract of the ISC case study video is shown to the class, in this case up to 12 minutes of video, which describes the layout and operation of the tank farm and the events leading up to the incident. In this case however, the decision point worksheets and exercises developed by ISC are not given to the students. Instead, before watching the video students are asked to observe and note down where principals of inherent safety could have been used to

improve the design and operation of the tank farm. To aid students' understanding of the tank farm described in the video, the schematic overview of the tank farm developed by ISC can be handed out. Students then discuss in small groups where inherent safety principals could have been used to improve the design and operation of the tank farm and then with the class as a whole in a discussion led by the instructor.
There are many benefits to this exercise where students can consider inherent safety on a real-life industrial problem. They can observe the impact of inherent safety not only on design but also on operation and how this can contribute to a safety incident. Furthermore, for students in only the second year of their undergraduate studies it is very valuable opportunity to bring a realistic, operational setting into the lecture environment.

### 3.2 Reflections on how case studies can be applied in academic setting

From the two examples outlined it can be seen that the ISC case study videos have been effectively used and adapted for an academic setting. One of the main benefits of the ISC case studies is that they enable well-researched, real-life industrial examples to be brought into an academic lecture theatre environment through well-made, clear and accessible videos of past incidents. The format of the ISC case study videos, decision point worksheets and exercises are also very accessible to educators to adapt for their specific needs and can deviate from the original intention of the ISC which was to remove hindsight bias. This is because of the richness of content within the well-researched case studies where different industries and themes within safety are examined. Educators teaching safety can easily adapt the ISC case studies to focus on specific themes within safety or examine safety issues within specific industries. In advanced safety courses, the case studies can be used to demonstrate the original intention of ISC developers, namely examining removing hindsight bias. For example, final year or postgraduate students with a firm grasp of chemical engineering fundamentals and introductory safety concepts, who may already have studied some past accidents and feel that they would not make the same mistakes as have been made in the past, may enhance their learning of past accidents through the removal of hindsight bias. Moreover, educators can even use the ISC case studies in fundamental chemical engineering lectures, where safety is not the main focus of the entire lecture course, to highlight a specific safety aspect of a given technology in just one lecture. Furthermore, the decision point worksheets and other exercises that have been developed by the ISC can be used directly in an academic setting, modified to highlight additional learnings or completely new exercises can be developed by educators to emphasis other learnings that can be gained from the ISC case studies.
Reflecting back on how the case studies were incorporated into second year introduction to safety lectures at UCL, it was found that incorporating the ISC case studies into an academic setting was easy and indeed very relevant at highlighting specific concepts. However, this could only be achieved once the material within the ISC case study had been studied in detail by educators in charge of the course. To further aid educators in incorporating the ISC case studies into an academic setting the ISC could develop further support material in the form of a brief synopsis of each case study. This could include information on the actual incident being studied, the safety themes addressed within the case study and which video extracts within the full range of case study videos developed exemplify the different safety themes.

## 4. Conclusions

The case studies were originally developed for use within companies and designed to be run as a complete activity, focused on attempting to remove hindsight bias from the participants to generate a higher quality experience. However given the approach that was taken, by simplifying complex process safety concepts so all aspects of a business could participate, using short video segments, setting context and drawing out specific themes, they have proved useful in other areas such as the academic environment, as exemplified by their use in introductory safety courses at University College London.
The richness of the content within the ISC case studies, in terms of well-researched past accident material and accessibility of the format of the ISC case studies videos to a wide-ranging audience lends itself very well for use in a variety of academic settings from introductory to advanced safety courses as well as specific technical lectures. As has been outlined in this paper, the focus of application within an academic setting can deviate from the original intention of removing hindsight bias and can instead focus on particular safety themes or specific technologies. The ISC decision point worksheets and exercises can be used as originally developed, adapted or completely new exercises can be developed to further support learning. Overall, there is a significant benefit to students to support their learning outcomes in an academic environment by bringing well-researched, real-life situations, in an accessible and clear format into the lecture theatre.

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**References**

American Institute of Chemical Engineers, Center for Chemical Process Safety (AIChE CCPS), 2008, Guidelines for hazard evaluation procedures, 3rd Ed, New York, N. Y., CCPS, Center for Chemical Process Safety, Hoboken, N. J. Wiley-Interscience.

Blank, H., Nestler, S., von Collani, G., and Fischer, V. 2008, How many hindsight biases are there? *Cognition,* 106, 1408-1440.

Pollock, M., and Sorensen, E. 2018, Reflections on embedding safety throughout the process engineering program, Proceedings of the 13th International Symposium on Process Systems Engineering PSE 2018, July 1-5, San Diego, California, USA.

Roese, N J., and Vohs, K D. 2015, Hindsight Bias. Perspectives on Psychological Science, 7(5) 411-426.

Shallcross, D. C., 2013, Safety education through case study presentations, ECE, 8, e12-e30.