Process Safety Not Guaranteed: The Need for New Learning Approaches

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The concept of process safety has been around a long time but a spate of major accidents in the last decade has further emphasised the need for more effective training and education. This paper presents a range of novel approaches to help develop knowledge and competence in process safety, including:

- A new national degree apprenticeship at master's level in Risk and Safety Management for high hazard industries, co-designed by employers, universities and professional bodies.
- Postgraduate education that meets the knowledge and understanding requirements for IChemE's Professional Process Safety Engineer qualification.
- Game Based Learning covering common process safety themes such as layers of protection and safety-critical systems, taking the message out of PowerPoint and broadcasting it interactively in short, fun sessions.
- Harnessing the potential of new graduates by introducing them to asset integrity initiatives such as improving the reliability of engineered systems.

Keywords: Process safety competence, MSc, degree apprenticeship, game based learning, graduate development.

Introduction

Process safety is a blend of engineering and management skills focused on preventing catastrophic accidents associated with loss of containment of energy or dangerous substances such as chemicals and petroleum products. These engineering and management skills exceed those required for managing workplace safety (Energy Institute 2016) and, as a consequence, much has been done in recent years to define the required competencies and improve process safety training. For example, the IChemE Safety Centre has introduced a generic process safety competency framework for different types of roles in an organisation, from front line personnel, through discipline engineers and support functions, to management and executives (ISC 2015). Cogent Skills provides three process safety courses developed around national training standards content, aimed at front line operators through to senior executives (Cogent Skills 2016), and for process safety engineers the IChemE has introduced its Professional Process Safety Engineer qualification (IChemE 2012).

The purpose of this paper is to present four new and novel approaches that have been applied to help develop knowledge and competence in process safety, each one suitable for a different 'target audience':

A new national degree apprenticeship at master's level in Risk and Safety Management for high hazard industries, targeted at new graduates as well as experienced engineers and scientists looking to cross-skill into process safety.

Postgraduate education that meets the knowledge and understanding requirements for IChemE's Professional Process Safety Engineer qualification, generally targeted at graduates with several years of work experience.

Game Based Learning covering common process safety themes such as layers of protection and safety-critical systems, which is ideally suited for workforce groups from front line personnel to senior managers.

Harnessing the potential of new graduates with little work experience by focusing them on asset integrity initiatives.

Degree Apprenticeship

Apprenticeships have long been recognised as an important way to develop the skills needed by employers, and the government is increasing the quality and quantity of apprenticeships in England, targeting three million starts in 2020. Nobody understands the skills that employers need better than the employers themselves. As a result the government is placing employers in the driving seat when it comes to designing apprenticeships so that they focus on those knowledge, skills and behaviours that employers require from their workforce of the future. A levy will put employers at the heart of paying for and choosing apprenticeship training, and place the funding of apprenticeships on a sustainable footing. Employers will choose between high quality education and training providers, or be able to train their apprentices themselves (HM Government 2015).

The apprenticeship levy comes into force in April 2017 and requires all employers operating in the UK, with a pay bill over £3 million each year, to make an investment in apprenticeships of 0.5% of their annual pay bill. The levy will be paid through the employer's PAYE system alongside tax and National Insurance contributions. Overall government funding of apprenticeships for 2015-16 was about £1.5bn and the new levy will raise funding to around £2.5bn by 2019-20. In England, for every £1 an employer contributes to the fund, government will pay £2 up to a cap of £18,000 for an apprenticeship, bringing the maximum joint investment from the employer and government to £27,000. Small and Medium Enterprises (SMEs) not required to pay the levy will still benefit from government funding for apprenticeships (DfE 2016, HEFCE 2016). Clearly employers have a significant commercial incentive to make the best use of the funding to meet the training and education needs of their workforce.

Degree Apprenticeship in Risk and Safety Management

Degree apprenticeships entitle apprentices to achieve a full bachelor's (level 6) or master's degree (level 7). They are co-designed by employers, universities and professional bodies and combine university education and work experience. For the apprentice they are a great alternative to the traditional university-only route in that the apprentice receives a salary, incurs no tuition fees, gains vocational training as well as an academic education and has the chance to gain professional accreditation and membership. The employer gains an employee with a directly relevant academic qualification, practical experience and who has been assessed as meeting the competence requirements of their role.

Risktec is currently facilitating an employer group to 'trailblaze' a new national master's level degree apprenticeship standard in Risk and Safety Management for high hazard industries (Risktec 2016). The employer group includes large employers from the nuclear, defence, rail, aerospace, aviation, oil and gas, petrochemical and renewables sectors, as well as SMEs. The group has passed the first government 'gateway' and received approval to proceed to the next stage and develop the standard. The group has been working, along with universities and professional engineering institutions including IChemE, to develop the standard which will be submitted for the second gateway. When that is achieved the group will work on the assessment plan to be submitted for the third and final gateway. The assessment plan describes the end-point assessment (EPA) for the standard - a holistic assessment of the knowledge, skills and behaviour that have been learnt throughout the apprenticeship.

Occupational Profile

The standard is for the occupation of 'Risk and Safety Management Practitioner' in high hazard industries. Typical job roles include process safety engineer, technical safety engineer, safety and reliability engineer, nuclear safety engineer, railway safety engineer and air safety engineer. Such job roles involve focusing on establishing the context of the problem, identifying all hazards including those with the potential to cause a major accident, analysing the associated risk, evaluating the risk against acceptance criteria and proposing ways of treating the risk such that it is eliminated, reduced and maintained as low as reasonably practicable. They are also required to address means of monitoring and reviewing the actual risk and safety performance, and communicating and consulting risk issues with all relevant stakeholders.

Whilst the emphasis on certain aspects of the risk profile and use of specific techniques may differ slightly between high hazard industries, the overriding risk management process is the same for all. Whether practitioners work in 'systems' sectors such as nuclear, defence, rail and aviation, for example, or in 'process' industries such as oil and gas, petrochemical and chemical, the risk management processes, safety management systems for design and operations, and organisational and human factors are all fundamentally the same. Furthermore, a greater understanding of approaches adopted in each other's industry will avoid costly reinvention and also increase diversity in the risk and safety toolbox.

The degree apprenticeship aims to create rounded professionals capable of working competently in their chosen industry but with the risk and safety management knowledge, skills and behaviours (KSBs) that are transferable across high hazard industries, as shown in Table 1.

Table 1. Knowledge, Skills and Behaviours of the Risk and Safety Management Degree Apprenticeship

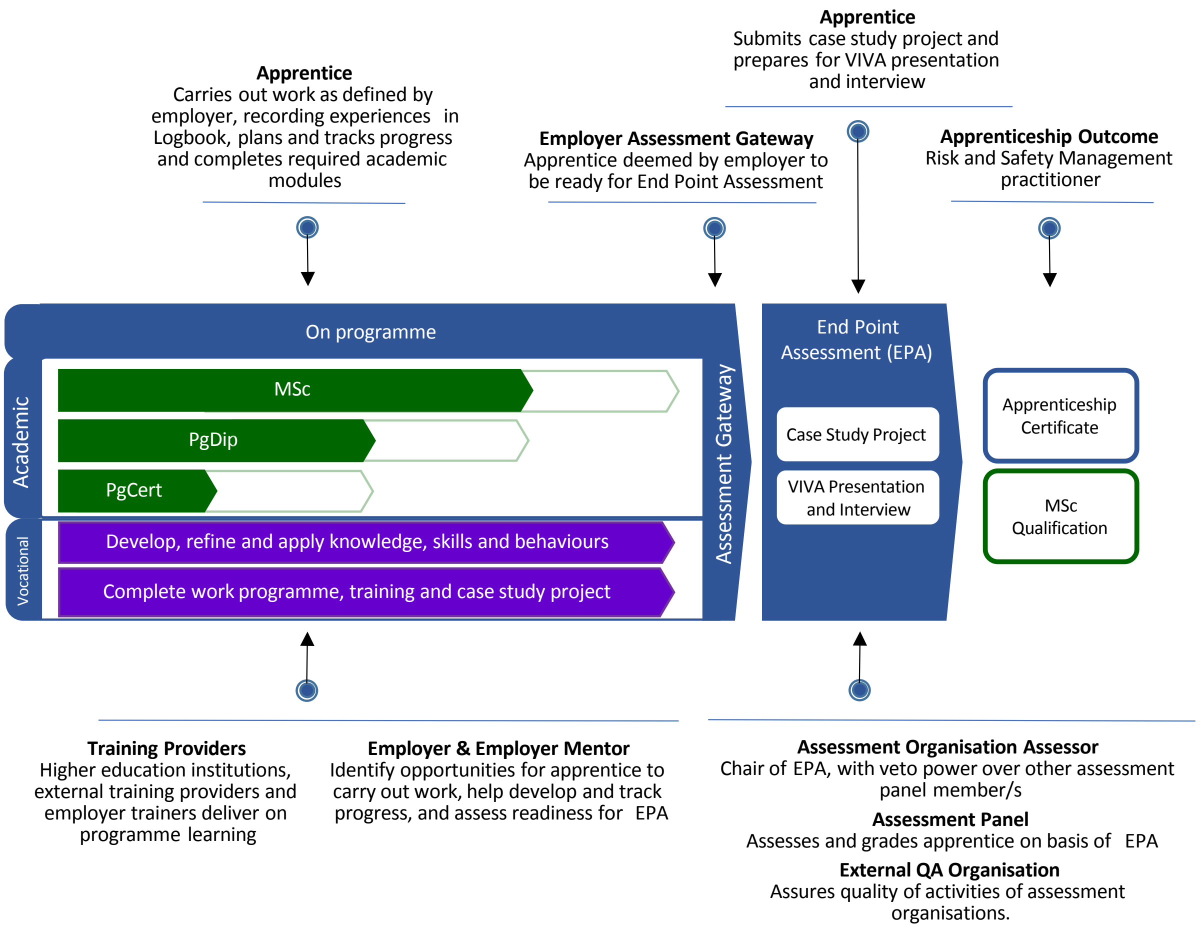
Knowledge	Skills	Behaviours
Risk management principles and practice Risk assessment techniques Industry domain Employer specialisms	Risk and safety management Lifecycle view Leadership Effective communication Problem-finding and creative problem-solving	High reliability mindset Change, adapting and visualising Improving Professional participation

Assessment Approach

The assessment plan will set out objective review criteria for each of the KSBs. Once the apprentice has completed an MSc in risk and safety management (180 credits at level 7) or equivalent and sufficient 'on programme' (on-the-job) training such that the employer believes the apprentice is ready for the EPA, the apprentice is assessed by an assessment panel. The panel will comprise an assessor from an approved assessment organisation selected by the employer as well as an assessor from the employer. The EPA will involve at least two types of assessment, for example a case study project and a combined presentation and structured interview. The successful apprentice will receive an apprenticeship certificate alongside their MSc qualification. External quality assurance of the activities of the assessment organisation will be provided by an approved independent organisation.

An overview of a typical on programme and assessment approach is illustrated in Figure 1:

Figure 1. Illustrative On Programme and Assessment Approach



Whilst any entry requirements will be a matter for individual employers, typically an apprentice might be expected to have already achieved a relevant science, technology, engineering or mathematics (STEM) bachelor degree or equivalent. Apprentices without level 2 English and Maths will need to achieve this level prior to the EPA. The typical duration for the degree apprenticeship will be three years, depending on the amount of academic study and relevant vocational experience achieved each year. It is understood that some learners will already have some knowledge and therefore accredited prior learning (APL) can be applied, making a shorter apprenticeship possible.

As well as the apprentice achieving the standard of risk and safety management practitioner, the apprenticeship is intended to provide evidence of KSBs in line with the professional registration requirements for Chartered Engineer. The apprenticeship may also align with relevant professional registration requirements, e.g. IChemE Professional Process Safety Engineer, and other relevant professional bodies regulated by the Engineering Council.

The whole approach of this apprenticeship is to provide a highly efficient and cost-effective means of developing the required skills of UK risk and safety management practitioners, including process safety engineers, making best use of the levy paid by employers and the financial assistance provided by the government.

Postgraduate Education

When it comes to process safety competence, the IChemE recognises that "Knowledge and understanding of process safety are important components of professional competence. Formal education is the desirable, though not only, way of demonstrating the necessary knowledge and understanding." (IChemE 2012).

The process safety field faces a problem with regards to formal education, as there are no first degrees (level 6) in process safety engineering taught at UK universities (although there may be an element of process safety within the curriculum of some chemical engineering degrees). The usual solution to this lack of formal education is for most 'process safety engineers' or 'technical safety engineers' to have degrees in science, technology, engineering or mathematics (STEM) subjects and then, by necessity, they learn on the job under the supervision of more experienced personnel and fill in knowledge gaps through short training courses in specialist topics. It is fair to say that much of this learning is of an ad-hoc nature rather than following a fully structured programme.

For many engineering disciplines, such as mechanical or chemical engineering for example, the professional competencies that need to be met and maintained are well defined and governed with undergraduate courses and long-recognised Chartered Engineer schemes. However, for those engineers and scientists working in the field of process safety engineering, the required competencies are less well established. The IChemE has perhaps done the most to provide guidance on what this relatively new discipline encompasses, with the introduction of its globally recognised Professional Process Safety Engineer competence standard (IChemE 2012). The standard is recognised and positioned at the same professional level as Chartered Engineer and Professional Engineer and provides useful guidance on the key areas of knowledge that need to be demonstrated, as summarised in Table 2.

Table 2. The IChemE Competence Standard for Professional Process Safety Engineers

A	Ably apply knowledge and understanding of technical process safety to practical engineering situations (in design and/or in operations) and ably apply appropriate theoretical and practical methods to the analysis and solution of process safety problems.	
A1	Hazard identification	Able to identify hazards using recognised hazard identification techniques.
A2	Assessment of consequences	Able to assess hazard consequences using recognised consequence modelling techniques.
A3	Control of hazards	Able to assess and implement safeguards appropriate for the hazard being considered in an operations or design environment.
A4	Risk assessment	Able to undertake risk assessment to determine whether safeguards are adequate to mitigate hazards.
B	Ably handle the wider implications of work as a process safety practitioner	
B1	Understanding and application of relevant Regulations	Able to demonstrate effective understanding and application of regulations appropriate to the industry and geographical area(s) in which the engineer practises.
B2	Protection of the public	Able to demonstrate understanding and application of process safety principles in reducing public risk.
B3	Incident investigation	Able to demonstrate understanding and experience of incident investigation and implementation of lessons learned.
B4	Emergency planning	Able to demonstrate understanding and experience in defining emergency actions for hazards identified.
C	Ably provide effective process safety leadership and communication	
C1	Process safety management	Able to demonstrate understanding and personal experience of process safety management.
C2	Influencing process safety culture	Able to demonstrate direct influence of process safety culture during professional practice.
D	Ably demonstrate personal commitment to high standards of professional conduct related to process safety, recognising obligations to society, the profession and the environment.	
E	Ably demonstrate effective continuing professional development.	

By claiming credit for their on the job learning and experience as part of the registration process, individuals in process safety roles can now gain a formal process safety qualification. However, the breadth and depth of the Professional Process Safety Engineer competencies are, necessarily, substantial and require significant experience in a range of roles to demonstrate the required knowledge and skills. Unless the employer has a very well developed and structured training programme, many process safety engineers often find themselves specialising in a few areas, for example hazard identification and risk assessment, and do not gain experience of other required competencies, for example incident investigation and emergency planning.

Although there is a scarcity of first degrees in the subject, there are several postgraduate qualification process safety programmes available (for example Aberdeen 2016, Sheffield 2016, LJMU 2016), and gaining such a qualification would clearly benefit the individual when applying to become a Professional Process Safety Engineer with the IChemE. The learning is across a formal, structured curriculum covering the principles and practice of process safety, and the relevance and use of theories, processes and techniques that a process safety engineer is likely to encounter, meaning that the entire breadth of competencies is addressed. Furthermore, gaining a postgraduate qualification demonstrates the ability to think independently, critically analyse situations and creatively solve complex risk and safety problems.

Case Study - Meeting the Knowledge Requirements of IChemE's Professional Process Safety Engineer Registration

Since 2009 Risktec has been delivering its MSc in Risk and Safety Management in partnership with Liverpool John Moores University (LJMU) in the UK. The MSc programme has been developed by practising consultants and is intended for practitioners working within high hazard industries. It is available via face-to-face, distance learning and blended learning (a combination of both).

To meet the knowledge requirements of the IChemE's Professional Process Safety Engineer registration, Risktec created a specific process safety pathway through its MSc programme. This pathway was successfully approved by IChemE in June 2016 as meeting the knowledge and understanding requirements for the qualification. This means that students successfully completing the MSc will be able to apply for registration as a Professional Process Safety Engineer with just additional evidence of their professional competence.

Each of the MSc modules is assessed by a few short online activities and a longer, formal written assignment. The MSc is completed by submission of a process safety-related dissertation of about 15,000 words. The student is guided to select a state-of-the-art topic in process safety engineering that is of real interest to current and prospective employers. During the dissertation the student is supported by an academic supervisor from LJMU as well an industrial supervisor from Risktec.

The full MSc programme lasts three years but students can achieve a Postgraduate Certificate (PgCert) after one year or a Postgraduate Diploma (PgDip) after two years.

To support the IChemE approval process for the MSc, the module topics of the process safety pathway were mapped against the competencies of the IChemE's Professional Process Safety Engineer registration. Table 3 shows the percentage of each module's content which is directly applicable to each IChemE Professional Process Safety Engineer competence.

The iterative mapping process resulted in valuable improvements to the MSc modules, ensuring sufficient process industry-specific content alongside material for other high hazard industries, and resulting in a well-rounded, cross-industry programme of formal academic, postgraduate study in Risk and Safety Management. The process also demonstrated that the MSc programme can be translated into the European Credit Transfer System (ECTS), with each module being worth 5 credits.

Further, as can be seen from Table 3, the resulting programme is highly efficient at meeting the IChemE competencies, with 100% of ten of the twelve MSc modules being directly relevant to the Professional Process Safety Engineer qualification.

Table 3. Mapping of MSc Modules to IChemE Competencies

	MSc Module												
IChemE Competencies for Professional Process Safety Engineers	Principles of Risk Management	Research Methods in Risk & Safety Management(Note)	Hazard Identification	Risk Analysis	HSE Management Systems	Risk Reduction & ALARP	Bowtie Risk Management	Human Factors in Design & Operations	Culture, Behaviour and Competency	Physical Effects Modelling	Incident Investigation & Analysis	Emergency Response & Crisis Management	MSc Project(Note)
A1 Hazard Identification			100%					40%					
A2 Assessment of Consequences	20%									100%		20%	
A3 Control of Hazards						20%	100%				20%		
A4 Risk Assessment	40%			100%									
B1 Understanding and Application of Relevant Regulations	40%												
B2 Protection of the Public						80%							
B3 Incident Investigation											80%		
B4 Emergency Planning												80%	
C1 Process Safety Management					100%								
C2 Influencing Process Safety Culture									100%				

Note: The Research Methods in Risk & Safety Management module, and the MSc Project, both provide an opportunity for the candidate to demonstrate the necessary breadth and depth of knowledge and competence to meet the key areas required to successfully qualify as a Professional Process Safety Engineer.

Game Based Learning

A perennial frustration within high hazard industries is that incidents continue to happen even though organisations go to great time, cost and trouble to train their personnel. Making learning “stick” is clearly not a *trivial pursuit*. Game Based Learning (GBL) provides an innovative solution to this problem and can be used to get across any message in the workplace. But it is in high hazard industries - where, generally speaking, improvement is about small margins - that GBL comes into its own.

Learning by Doing

GBL uses a fun, every-day analogy or metaphor for a traditionally technical subject, making the training more memorable and accessible to all personnel across the organisation. Through playing the game, trainees develop an appreciation of how the analogy/metaphor relates to their specific roles and responsibilities. When people participate in an interactive, hands-on activity, their retention of knowledge is much better compared to traditional training methods.

This claim is supported by the work of Edgar Dale, an American educationist, who developed the concept of the 'Cone of Experience' (Dale 1969), which provides an intuitive model of the concreteness of various audio-visual media. Whilst Dale included no numbers in his model, it is commonly suggested elsewhere that people remember 90% of what they 'do' when they simulate, model or experience a lesson. Whatever the validity of such percentages, most people would generally agree that they remember more about something they do rather than what they read or hear for example. This is the fundamental basis of GBL and its advantage over traditional training by PowerPoint.

In conjunction with some of its key clients, Risktec has developed a series of games (some examples are shown in Figure 2) which instil a fundamental understanding of key process safety themes at all levels of an organisation. The games are designed to align with the root causes of the majority of process safety incidents and instil a fundamental understanding of key process safety themes.

Figure 2. Example Games

Disadvantages

The only commonly encountered barrier when adopting GBL is a reluctance to embrace what can be viewed as a potentially flippant approach within the serious environment of a high hazard industry; “safety is not a game!” However, given the highly visual, hands-on nature of the games, a quick demonstration is usually all that is needed to show the benefits of this innovative approach. Having fun within the serious environment of a high hazard industry should never be taboo, particularly when it enhances learning and therefore the process safety competence of a workforce.

Case Studies

GBL sessions are short, typically lasting 30 to 45 minutes. They are extremely flexible and can be delivered in a number of ways, for example:

- To provide a diverting, energising break from a traditional classroom session.
- To deliver a serious message (e.g. a process safety improvement) in a short, high-impact memorable session.
- As an entertaining ice-breaker within a meeting, workshop or conference, that can also convey relevant learning.
- As part of the roll-out of a new initiative or operation, e.g. to support the use of a new facility safety case.

The low cost and significant flexibility and effectiveness (in terms of impact, coverage and knowledge retention) of GBL presents a hugely compelling business case. Some case studies are described briefly below:

1. A tailored version of *RiskJet* was played as part of a two day classroom safety case training course for sixteen design engineers at a large European energy operator. Having introduced bowtie analysis as an excellent technique for identifying safety-critical equipment, the trainees played RiskJet in groups of four for about 45 minutes to reinforce the understanding that safety-critical equipment is designed to prevent or mitigate major accidents and that processes need to be in place to ensure they continue to function as designed.
2. Tailored sets of *Tipping Point* were provided to support safety case roll-out in the recreation rooms of an offshore oil and gas installation. Each game comes in a box with instructions, requires no additional materials and no expert facilitation. It therefore allowed mass roll-out by the operator and avoided expensive trainer mobilisation and delivery costs. Also, given its simplicity and flexibility, it was played around operational commitments and thus reached crews on different shifts who would most likely have missed out on more traditional training.
3. A bespoke version of *Tipping Point* was played as an ice-breaker at a two day formal conference of about one hundred engineering managers from a multi-national provider of electrical and electronic products for the aerospace, defence and transportation sectors. The managers played the game for about 30 minutes in five groups of twenty. The focus of the learning was on the main causes of failing to integrate safety into the design process.
4. GBL has been used for a process safety awareness programme at onshore plants and various offshore plants, with a wide range of audiences (Hanza 2016). The first session focused on layers of protection and the second on functional safety-critical equipment and instrumentation. The training gathered support and popularity from the leadership and the workforce and the feedback was overwhelmingly positive.
5. As well as engaging the operational workforce, GBL has also been used to inspire the workforce of the future. GBL was run at STEMS (Science, Technology, Engineering and Mathematics) school career events to help illustrate the careers available in the oil and gas industry. School leavers played games which highlighted the roles that discipline engineers and operational personnel have in ensuring that engineered barriers are in place and are functioning, to ensure continued production whilst preventing major accidents.

GBL gives all employees an enjoyable experience whilst delivering a serious message in a high impact and memorable way. It makes much more effective use of training budgets, ensuring the message that needs to be communicated is received, understood and implemented quickly and efficiently, providing a long-term benefit to the business.

By linking process safety themes to every day analogies or metaphors, GBL is industry agnostic. With the messages it seeks to communicate transcending industry and discipline boundaries, GBL provides clear benefits to all industries.

Future Developments

Whilst the games discussed above have delivered significant value to organisations already, the process behind their development also offers significant benefit to the organisation. Process safety concepts can be readily combined and metaphors developed to create a bespoke game which delivers the intended message in an effective, memorable way to suit a specific application, operation or asset.

Drawing upon a bank of ideas, new games continue to be developed to extend the benefits this technique offers in enhancing learning efficiency and effectiveness with the ultimate objective of improving process safety performance.

Harnessing the Potential of Graduates

Graduate training schemes are common in most large organisations and can be a good way to attract talent and provide a basic grounding in the business. Traditional graduate training schemes typically last one or two years and involve rotation through a number of departments within the business. In each, the graduate is introduced to operations, following a structured training plan, often shadowing experienced colleagues, before moving on to the next department. Whilst this broad understanding of the business can be beneficial to a future career, the graduate emerges from the scheme with limited practical experience or formal qualifications and may be ill-equipped to make a meaningful contribution to the business for some time. Moreover, many graduates can become frustrated or disillusioned by constant work-shadowing, fuelling the risk of dropping out.

Companies often underestimate the capabilities of recent graduates and assume tacitly that, until they have completed the graduate training scheme and have gained experience, they are of limited benefit to the business. However, given the right opportunity and a degree of freedom, graduates can contribute in a way that established employees cannot. The significant advantage of graduates over employees is that their lack of preconceived ideas can challenge the basis of accepted working practices by asking simple questions. Further, they are a lower cost resource for the organisation, and can often undertake 'nice-to-have' projects that more senior employees are not able to prioritise. By concentrating on a needy area of the business and harnessing the enthusiasm of a small team of graduates, it is possible to deliver significant tangible benefits.

Some organisations foster a natural reluctance to embark on such an endeavour in the belief that it will create more work downstream - but this barrier evaporates if the graduates are also empowered to implement agreed solutions. Additionally, if a structured training scheme is operated in parallel, the graduates will emerge fully trained, with a thorough understanding of a critical business area, a sense of ownership and significant practical experience.

Case Study - Graduates Improve Reliability of Ageing Plants

Risktec, in partnership with a major UK power generation company, conceived the idea of the graduate 'Equipment Reliability Acceleration Team' (ERAT). With the green light to progress the project, Risktec and other providers recruited several graduate teams. The teams are "ring-fenced" to target improvements in the equipment reliability and maintenance regime. With the initiative having starting in 2009, the current 2017 programme includes a total of 25 graduates from Risktec at 8 stations focused on important asset integrity management measures such as:

- Reducing equipment maintenance backlog by eliminating unnecessary work.
- Introducing more advanced inspection techniques.
- Increasing equipment reliability.
- Identifying plant systems susceptible to single component failure.

Each year, graduate selection involves initial screening by interview followed by assessment centre evaluation, designed to identify graduates with excellent interpersonal and influencing skills, as well as proactive working methods. All successful graduates are enrolled in Risktec's Risk and Safety Management training programme.

At the power stations, the graduates are overseen by a client team leader, with offsite support from a Risktec consultant mentor. Each ERAT is given the freedom to troubleshoot problems, propose and investigate potential solutions, and ultimately implement changes in accordance with station procedures. Strong management support from the client ensures that the teams are given a high profile and the results of their work communicated throughout the business. Based on the application of these measures, significant cost savings have been demonstrated over the years.

The introduction of modern and often novel techniques, coupled with more streamlined scheduling and a reduction in high-frequency low-value maintenance tasks has brought substantial benefits. Improvements quoted include:

- Over 85,000 man-hours per year of unnecessary maintenance released across the fleet.
- Over 11,000 hours per year increase in essential plant availability (improved safety).
- Identification of single point vulnerabilities and development of corrective action plans.

Moreover, the talent pool has been widened, by preparing graduates with practical site experience and relevant qualifications. This has led to a number of ERAT graduates transferring to substantive posts within the client organisation.

The key success factors for this type of scheme may be summarised as follows:

- Graduate selection is fundamental; although academic grades are important, the graduate should have drive, enthusiasm, and strong interpersonal and influencing skills.
- An area of business should be identified that is ripe for improvement and relevant to graduate development. Asset integrity and process safety management are fertile grounds for identifying possible initiatives.
- The graduate team should be free from outside distractions, i.e. the team must be "ring-fenced".
- Strong leadership and support should be given to the graduates, whilst affording them the freedom to identify improvements, propose solutions and implement agreed changes.

- Structured training should be carried out in parallel, with an integrated training schedule that aligns with the tasks being undertaken.

Conclusions

Four new and novel approaches have been applied to help develop knowledge and competence in process safety:

1. A new national degree apprenticeship at master's level in Risk and Safety Management for high hazard industries, co-designed by employers, universities and professional bodies, is working its way through the government's trailblazer process. Once available (targeted for the second half of 2017), employers in England will be able to access apprenticeship funding and place apprentices on the programme.
2. Process safety is increasingly recognised as an engineering discipline in its own right, alongside more traditional disciplines such as mechanical or chemical engineering. That is why the IChemE has established a global, professional registration for process safety engineers to recognise and demonstrate their competence and commitment to the profession, and Risktec's MSc in Risk and Safety Management (Process Safety Pathway) is one of the first to meet the IChemE's requirements.
3. Game Based Learning (GBL) provides an innovative solution to the problem of making learning "stick". Although having fun in the workplace may still be seen as taboo by some, especially those within the serious environment of high hazard industries, when it enhances learning, competence and process safety, perhaps we all need a bit of GBL?
4. Graduates have huge untapped potential. Rather than being an initial burden on an organisation, they can be an asset in their own right if focused on an area of business that is ripe for improvement such as asset integrity and process safety management and, under strong leadership, given the freedom to think for themselves and take action.

References

Energy Institute (2016), *Process safety*, Available at https://www.energyinst.org/technical/safety/process-safety (Accessed: 9 December 2016).

ISC (2015), IChemE Safety Centre, *Process Safety Competency – a Model*.

Cogent Skills (2016), *Process Safety Management Courses*, Available at http://www.cogentskills.com/courses/process-safety-management-courses/ (Accessed: 9 December 2016).

IChemE (2012), *PEng (Process Safety) Standard for professional engineering competence in process safety*.

HM Government (2015), *English Apprenticeships: Our 2020 Vision*, Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/482754/BIS-15-604-english-apprenticeships-our-2020-vision.pdf (Accessed: 9 December 2016).

DfE (2016), *Apprenticeship funding: how it will work*, Available at https://www.gov.uk/government/publications/apprenticeship-levy-how-it-will-work/apprenticeship-levy-how-it-will-work (Accessed: 9 December 2016).

HEFCE (2016), *Degree apprenticeships*, Available at http://www.hefce.ac.uk/kess/apprentice/faq/ (Accessed: 9 December 2016).

Risktec (2016), *Degree Apprenticeship in Risk and Safety Management*, Available at http://www.risktec.co.uk/training-and-education/apprenticeships.aspx (Accessed: 21 December 2016).

Aberdeen (2016), University of Aberdeen, *Process Safety MSc*, Available at https://www.abdn.ac.uk/study/postgraduate-taught/degree-programmes/249/process-safety/ (Accessed 20 December 2016).

Sheffield (2016), The University of Sheffield, *MSc(Eng)/Diploma Process Safety and Loss Prevention*, https://www.sheffield.ac.uk/postgraduate/taught/courses/engineering/chempro/process-safety-loss-prevention-msc (Accessed 20 December 2016).

LJMU (2016), Liverpool John Moores University in partnership with Risktec, *MSc in Risk and Safety Management*, http://www.risktec.co.uk/training-and-education/msc.aspx (Accessed 20 December 2016).

Dale (1969), Dale, E., *Audio-visual methods in teaching*, New York: Dryden, 1969.

Hanza (2016), Hanza, A., *Two-Way Safety Training*, The Chemical Engineer, November 2016.