KNOWLEDGE AND SKILLS RETENTION IN SUSTAINING E-LEARNING CAPABILITY

Marie Cahillane, Piers MacLean, and Victoria Smy
Centre for Cyber Security and Information Systems
Cranfield University, Defence Academy of the UK
United Kingdom

Abstract

Cognitive science suggests that periods of no practice in performing tasks may impact on the retention of the requisite Knowledge and Skills (K&S). This paper reports a study that predicted the retention of the K&S required for the effective design and delivery of e-learning content in *virtual learning environments* (VLEs). A predictive retention model was applied to VLE requisite K&S resulting in a series of indicative retention curves. Outputs from this research can inform the development of targeted training to mitigate skills fade and maintain institutional capability to sustain effective e-learning content organisation activities.

Introduction

The design and delivery of effective e-learning content within virtual learning environments requires staff with relevant knowledge and skills (K&S). The literature indicates that the more skilled personnel are, the more likely an organisation is to be successful in the provision of e-learning (Rogers, 2003). Past research has identified organisational processes and practices as being indicative of e-learning capability. The e-Learning Maturity Model (e-MM), for example, provides a means of benchmarking and comparing capabilities for the development, deployment and support of sustainable e-learning in higher education (Marshall, 2010). Whilst the e-MM addresses some of the people components of capability in terms of organisational practice, it focuses on processes and tools and does not provide sufficient information to support the development and maintenance of competence within the organisation. Competence analysis is an example of a process area aimed at directing the people component of capability. To demonstrate this process area has been achieved organisations need to document and maintain competence descriptions (Marshall, 2012). *Competence* can be defined as the knowledge, skills and underpinning attitudinal dispositions that must be acquired and maintained by individuals and teams in order to effectively perform tasks to a pre-defined standard of proficiency (Deighton, Wells, McGuiness, Page & Mills, 2011a). It follows that an individual who successfully performs a task is perceived as demonstrating competence in the application of the required knowledge or skill (Stothard & Nicholson, 2001). However, details regarding competence requirements are not addressed within the e-MM, and therefore the underpinning K&S required for competence management within the field of e-learning are not clearly identified.

When considering training and refresher training priorities for a task or job role, it is necessary to have an understanding of the type of knowledge and/or skills that must be retained to competently perform a task to the standard required. This is because cognitive science has shown that different types of K&S decay at different rates (e.g., Bryant & Angel, 2000; Deighton et al., 2011a; General Medical Council, 2014). Best practice within industry (Bonsall, 2012; Deighton, Wells, McGuiness, Page, & Mills, 2011b) and defence (JSP822, 2012) recommends a Knowledge, Skills and Attitudes (KSA) analysis be performed where a task is broken down into its constituent KSA, the acquisition and retention of which is required for successful performance. Without such a task analysis, the accurate consideration of the retention of knowledge and skills underpinning competence and the variables that determine how it can best be trained and maintained is constrained (MacLean & Cahillane, 2015). As KSA suggests, attitudes also play an important role in behaviour; however, they are arguably not subject to decay over time as are knowledge and skills. Rather, training can result in attitudinal shifts or change, and therefore the present study addresses the retention of VLE requisite K&S.

E-learning content design and delivery tasks encompass the effective organisation of e-learning content within a VLE. They involve a combination of the following activities: posting learning material, designing and generating learning activities, including summative and formative assessment (e.g., quizzes); accessing and commenting on submitted assignments. Execution of such activities is underpinned by the successful retrieval of procedures. Such tasks are therefore representative of procedural skills requiring memory for discrete sequences of steps. The application of procedural skills can involve the application of motor skill, although this element is typically minimal, such as moving a mouse to select items within a visual display (Goodwin, Leibrecht, Wampler, Livingston, & Dyer, 2007). Within VLEs, navigating through a series of menus and submenus to set parameters and execute commands provides an example. Unlike perceptual-psychomotor skills, for which greater retention is observed over extended periods of non-application (Swezey & Llaneras, 1997), memory for procedural skills is highly perishable over periods of non-use (Cahillane & Morin, 2012). The ability of an individual to retrieve the steps required in applying a procedural skill and more importantly, the order in which they must be performed, is a strong predictor of performance (Goodwin et al., 2007; Sanders, 2001; Wisher, Sabol & Ellis, 1999). Skills fade is particularly salient when individuals receive initial training in the requisite K&S, which they may not use for an extended period of time (Sabol & Wisher, 2001; Wisher et al., 1999). A meta-analysis performed on 189 independent data points derived from 53 research papers found a strong correlation between retention interval and skill fade (Arthur, Bennett, Stanush, & McNelly, 1998).

Predicting Skills Retention

The User Decision Aid (UDA) is a model developed by the United States (US) Army Research Institute (ARI) to predict skill retention and provide unit commanders and trainers with an evidence-base to inform the scheduling of refresher training (Rose, Radtke, Harris, Shettel, & Hagman, 1985). The UDA was developed with a focus on procedural tasks, since most military task involve some sort of procedural element from performing drills to following

Standard Operating Procedures. The model is theoretically-based and includes 10 of the most important *task-related* factors known to influence skill retention, according to the psychology literature (see Table 1, p.4).

As a survey-based task rating method, the UDA can be applied by Subject Matter Experts (SMEs) wishing to rate the characteristics of individual tasks in order to generate predicted retention curves. Whilst subsequent research has identified other moderating factors, such as frequency of application and the contextualisation of the training environment to the performance context, (see Cianciolo, Crabb, Schaefer, Jackson, & Grover, 2010), to date the UDA is the most developed scientific predictive model of skills retention; it has also received some validation (see Rose, Czarnolewski et al., 1985).

The UDA does not predict individual skill retention scores but instead predicts the percentage of personnel within a work force that are able to perform a task successfully (to criterion) after a period of time has elapsed since the requisite K&S were last applied. The skill retention curves generated by the UDA predict retention up to 12 months of no practice in applying the K&S. In addition, the retention curves generated are based on the assumption that 100% of personnel within a task force (sample) were competent at the end of their last training session. For 100% of personnel within a task force to remain competent, the UDA model assumes that all personnel are regularly and frequently applying the required knowledge and skills.

Aims and Objectives

To our knowledge, no empirical evidence exists regarding the retention of the K&S required by individuals within training and education institutions responsible for the effective organisation of e-learning content within VLEs. An evidence base would enable such institutions to understand and develop capability for sustainable and effective e-learning content organisation activities. To address this knowledge gap in the literature, the present study applied the UDA predictive skills retention model to a set of activities representative of the procedural skills required for effective organisation and delivery of e-learning content on a VLE.

Method

Participants

Two Cranfield University SMEs with approximately 25 years of collective experience in the administration and use of proprietary, bespoke, and open-source VLEs (all of which are underpinned by procedural skills) took part in this study.

Procedure

The e-learning SMEs conducted a task analysis to decompose content organisation within VLEs into its constituent subtasks, which represent the requisite procedural skills. A total of 15 subtasks, which describe key VLE management, use, and learning design activities, were identified along with the conditions under which each subtask is performed and the standards to be achieved by staff performing the task. Facilitated by the research team, the SMEs applied the UDA survey-based skills retention model to each subtask.

The model consists of 10 questions for which a number of prescribed responses are possible (see Table 1). Each response is associated with a weighting value which is lower for tasks that are harder to retain.

Table 1

The UDA Questions, Responses and Response Scale Values

UDA Questions	**Response**	**Value**
1. Are job or memory aids used by the individual in performing (and in the performance evaluation) this task?	Yes No	1 0
2. Are job or memory aids used by the individual in performing (and in the performance evaluation) this task?	Excellent Very good Marginally good Poor	56 25 2 1
3. Into how many steps has the task been divided?	1 step 2-5 steps 6-10 steps >10 steps	25 14 12 0
4. Are the steps required to be performed in a definite sequence?	None are All are Some are and some are not	10 5 0
5. Does each task provide built-in feedback so that you can tell if you are doing each step correctly?	For all steps For most steps For only a few steps No built-in feedback	22 19 11 0
6. Does the task or part of the task have a time limit for its completion?	No time limit Fairly easy to meet Difficult to meet	40 35 0
7. How difficult are the mental processing requirements of this task?	Almost none Simple Complex Very complex	37 28 3 0
8. How many facts, terms, names, rules, or ideas must an individual memorize in order to do the task?	None A few (1-3) Some (4-8) Very many (>8)	20 18 13 0
9. How hard are the facts, terms that must be remembered?	Not applicable Not hard at all Somewhat hard Very hard	34 31 12 0
10. What are the motor control demands of the task?	None Small Considerable Very large	2 0 16 3

Both SMEs were given an adapted copy of the UDA rating form, which provided examples defining and differentiating the prescribed responses. Since the UDA was developed to enable the prediction of skills retention for military tasks, some of these examples were specific to the military. These examples were tailored to the current context to aid in their interpretation and ultimately, the application of the model. Where military terms such as *soldier* were used we sometimes replaced them with *individual* or *staff*. Where task examples were adjusted, the amendments were superficial and terminological and did not alter the intended meaning behind the prescribed responses. For example, assembling the M16 rifle (a multi-step task) is replaced by "creating a pop-up window for a book item."

The research team talked through all the possible responses and their associated scale values. When all 10 questions were completed, the scale (weighting) values were totalled to produce an overall UDA score for each subtask. This overall score was then fed into a formula to predict skill retention at different time intervals (for full detail see Rose, Manning, Radtke, & Ford, 1984). The total time take to conduct the task analysis and apply the model was three hours. It was not possible to resolve differences in the UDA responses by calculating the arithmetic mean, since only the values provided in the UDA model are acceptable. Such differences could reflect factual matters (the presence or absence of a job aid) or differences in judgement (e.g., 'how good is the job aid?'). Therefore, any differences in the responses selected by the SMEs, for each subtask, were resolved through discussion.

Results

The e-learning content organisation task analysis revealed 15 subtasks, all of which were deemed by the SMEs as representative of procedural skills. Differences in indicative refresher training intervals for the e-learning content organisation subtasks were defined by the point at which 50% of staff are predicted to no longer be able to perform an activity without practice. Application of the UDA to the 15 subtasks resulted in a series of indicative retention curves as shown in Figure 1. There is a clear distinction between those tasks which fade rapidly and those which fade to a much lesser extent, with 11 out of 15 activities predicted to be rapidly forgotten, in contrast to only four activities indicated to be retained at a better rate during periods of no practice or application of the skills. Figure 1 indicates the following refresher training intervals for the e-learning content organisation activities which are predicted to be rapidly forgotten:

- Setting up a quiz – 2 weeks
- Using completion tracking – 7 weeks
- Adding a book activity – 10 weeks
- Using conditional release and news forums for communications – 11 weeks
- Using Turnitin or Grademark - 15 weeks
- Using Quick Mail for communications, adding a URL and adding an HTML page – 16 weeks
- Managing a folder on a page – 17 weeks

For those activities predicted to decay at a much slower rate, the following refresher training intervals are indicated in Figure 1:

- Setting up a discussion forum – 47 weeks
- Managing page sections – 55 weeks
- Adding files to a page – 67 weeks
- Displaying and hiding individual items on a page; and making a page visible to students – 90 weeks

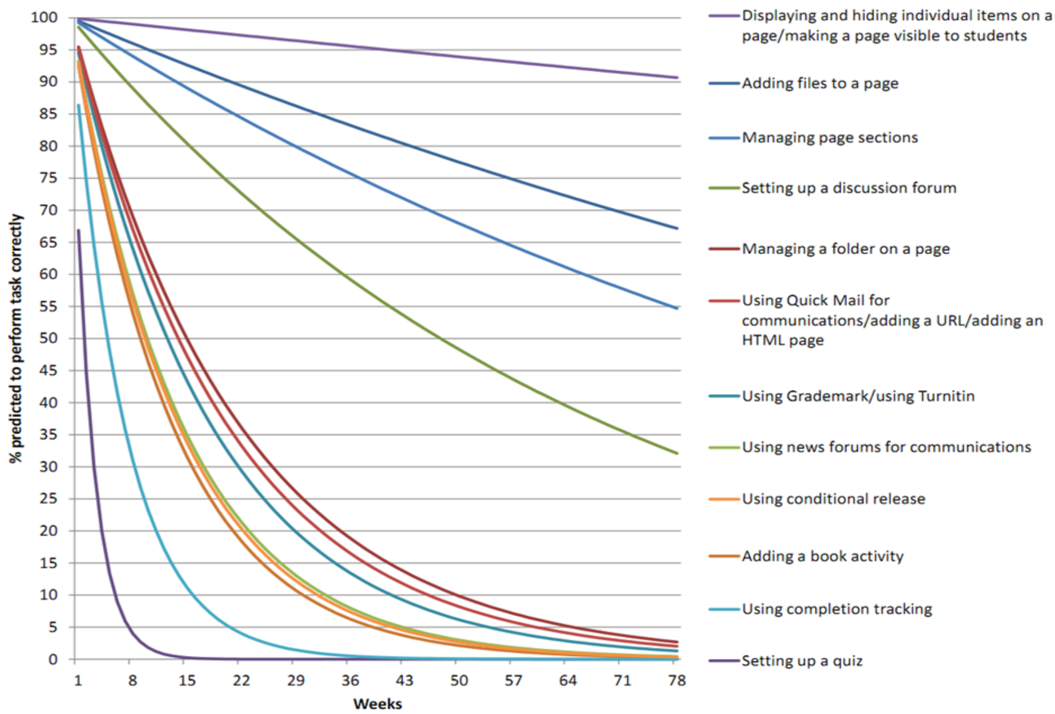

Figure 1. UDA indicative retention curves for e-learning content design and delivery procedural skills. (Note that three tasks are represented by a single curve; using Quick Mail, etc.)

Discussion

The findings of the present study indicate that it is feasible to use the UDA predictive skills retention model as a tool for differentiating and prioritising key e-learning content organisation activities. Application of the UDA demonstrated variability in retention rates for e-learning content organisation activities and their underpinning procedural skills. Two task characteristics: (a) the absence of a job aid; and (b) the complexity of mental processing requirements, account for the low subtask UDA ratings and thus differentiate those e-learning activities which are more susceptible to skills fade from those which are less susceptible. Job aids have been shown to reduce operator memory capacity load and help retention of information by externalising the steps that are required for successful task performance. Examples of job aids include quick reference guides, mnemonics, and technical manuals (Arthur, 1998; Bryant & Angel, 2000; Rose et al., 1985; Stothard & Nicholson, 2001). Less apparent forms of job aid are encountered in technology design where functions are set up such that the steps have to be performed in a particular order.

At the time of conducting this study, no job aid was available to assist staff in performing seven of the e-learning content organisation activities. These included: setting up a quiz, adding a URL or HTML page, using Quick Mail and news forums for communications, using completion tracking and conditional release. In addition to the absence of a job aid, *setting up a quiz and using completion tracking* were also rated as having complex mental processing requirements. *Mental processing requirement* complexity refers to the difficulty behind the thought processes an individual must apply during task performance. Such cognitive processes are often described as analysis, judgment, reasoning, decision making and problem solving. A task requires very complex mental processing requirements if it requires rapid decisions based on complex technical information under conditions of uncertainty and stress (Rose, Czarnolewski et al., 1985). The activities *setting up a quiz and using completion tracking* were predicted to fade the most. Excluding '*using Turnitin and Grademark* the activities most prone to skill fade also required memory for a definite sequence comprising up to five steps, because no job aid was available.

In contrast, the four activities which faded the least: *displaying and hiding individual items on a page; making a page visible to student; adding files to a page; managing page sections and setting up a discussion forum'* were characterised by simple mental processing requirements and the availability of a quality job aid which externalised memory for task procedures. Job aids are known to improve retention for procedural tasks requiring rote memory. However, they are generally found to be less helpful in optimising the retention of higher order cognitive processes such as decision-making. For example, managing information within a VLE requires the successful application of decision-making. In the case of this study, where activities such as *managing information on a pag*' were characterised by complex mental processing requirements, use of a job aid was not predicted to help retention. Conversely, use of a job aid was predicted to optimise skill retention where simple mental processing requirements underpinned information management tasks, for example *managing page sections*'.

The UDA model indicates that retention for those tasks predicted to fade the most could be improved by simply having a quality job aid made available for use while performing the task. Job aids not only externalise memory for tasks steps but also the facts and principles that need to be retained for successful task performance. Facts buried in multiple job aids are difficult to find let alone remember in context therefore, where tasks have eight or more facts to be memorised, these can be summarised in a condensed list which staff can more easily review. If the same facts are applicable to other activities, a list of these facts can be prepared to enable staff to see how the facts and principles generalise across e-learning content design and delivery.

The model also suggests that retention of tasks requiring the application of higher order cognitive processes can be optimised by reducing the complexity of mental processing requirements. This could be achieved by teaching staff how to reason and make decisions in situations so that the behaviours become internalised and more representative of gross mental comparisons characteristic of simple mental processing requirements (Kim, Ritter & Koubek, 2011). However, skills fade resulting from 'mental processing requirements' cannot be mitigated unless those requirements are accurately and operationally defined. The task analysis for e-learning content organisation used for the purposes of this study only provided a descriptive summary of the sequence of steps to be undertaken and the principles to be memorised; no distinctions in the action verbs used to describe the activities were observed. The targeted use of action verbs to describe activities would serve not only to better emphasise the process heavy procedural nature of these activities but also to articulate the level of mental processing required in their execution.

Limitations of the UDA

To our knowledge, only one study has compared UDA predicted scores to actual performance scores obtained by participants at multiple time intervals (i.e., 2, 5, and 7 months) (Rose, Czarnolewski, et al., 1985). Here the UDA was found to be effective at predicting retention across several field artillery tasks and the predicted skills retention curves were fairly consistent with actual performance data for these tasks. However, in comparison to the actual performance data, the UDA curves predicted on average that at a two month retention interval a smaller proportion of soldiers would able to perform the task to criterion, although across tasks this difference was only five percent. At other retention intervals the difference between predicted and actual performance was as great as 30 percent for some tasks, a difference which increased over longer retention intervals. This suggests that the UDA model may over predict skill fade across varying time intervals. The UDA has therefore been viewed as pessimistic in its projected predictions, such that the decay rate is potentially predicted to be somewhat worse than might be observed if actual performance data were collected. The potential over estimation of the level of skills retention has important implications for the application of the UDA to the organisation of e-learning content on VLEs when evaluating refresher training intervals. Although the UDA's forward projections of skill fade are potentially pessimistic, it can be argued that they indicate the 'worst case scenario', which, if considered along with other factors known to influence skills retention, can help inform refresher training decisions.

Additional moderators of skill retention that are not accounted for in the ARI UDA model include the effect of practice (Cianciolo et al., 2010) and the level at which individuals originally acquired knowledge and skills during initial training (Sabol & Wisher, 2001). Practice may occur with individuals having maintained knowledge and skills at a different level which is determined by the number of refresher training sessions they have completed in the past. Consequently, the predicted rate of skills decay would not be as pessimistic if the impact of practice was addressed. Where the level of original learning is concerned, research has shown that, at least in the short-term, skills that are acquired to a higher level tend to decay to a lesser extent compared to skills acquired after one demonstration of accurate performance (Driskell, Cooper & Moran, 1994; Sabol & Wisher, 2001). Moreover, individual differences in level of original learning have been found to predict skills retention to a higher degree than do individual differences in forgetting rates across skills such as perceptual motor and procedural skills (Swezey & Llaneras, 1997).

Conclusions

Application of the UDA predictive skills retention model identified e-learning content organisation activities that are most susceptible to skill fade. The results indicate approaches to training delivery that could increase skill retention for these activities. During training, having a quality job aid available for tasks characterised by definite sequences of steps would optimise their retention, since the memory requirement is situated in the job aid, and therefore knowledge for the job aid is not forgotten as long as it is used.

Furthermore, emphasis should be placed on encouraging staff to be able to locate and use existing job aids. Mental processing requirement complexity can be reduced by teaching staff how to reason and make decisions so that the underpinning cognitive processes become internalised and thus more representative of gross comparisons characteristic of simple mental processing requirements. The next step for future research will be to calculate how much retention would increase for those activities predicted to fade rapidly with the provision of quality job aids and a reduction in mental processing requirement complexity.

References

Arthur, W. Jr., & Bennett, W. Jr., Stanush, P.L., & McNelly, T.L. (1998). Factors that influence skill decay and retention: A quantitative review and analysis. *Human Performance, 11,* 57-101.

Bonsall, K. (2012*). Non-technical skills for rail: A list of skills and behavioural markers for drivers with guidance notes*. RSSB Report. Research Programme Operations and Management.

Bryant, D. & Angel, H. (2000). *Retention and fading of military Skills: Literature Review* Guelph, Ontario: Human systems Incorporated. (PWGSC Contract No W7711-9-7539/001/TOR).

Cahillane, M.A., & Morin, C. (2012). Skills Retention in a Complex Battlefield Management System. *Journal of Battlefield Technology, 15* (1), 65-72.

Cianciolo, A.T., Crabb, B.T., Schaefer, P., Jackson, S. & Grover, J. (2010). *Sustainment of individual and collective future combat skills: Modelling and research methods* (ARI Research Report 1918). US Army Research Institute for the Behavioral & Social Sciences. Arlington, VA.

Deighton, C., Wells, L., McGuiness, B., Page , H., & Mills, A. (2011a). Optimising competence retention in safety critical roles: influencing factors and management strategies. *Presented at the 1st World Congress on Rail Training*: Madrid, 6 – 8 April 2011.

Deighton, C., Wells, L., McGuiness, B., Page , H., & Mills, A. (2011b). *A model for optimising competence retention in the rail industry (skills fade)*. RSSB Report. Research Programme Operations & Management.

Driskell, J., Copper, C., & Moran, A. (1994). Does Mental Practice Enhance Performance? *Journal of Applied Psychology, 79* (4), 481-492.

General Medical Council. (2014). *Skills fade: a review of the evidence that clinical and professional skills fade during time out of practice, and of how skills fade may be measured or remediated*. Access at: http://www.gmc-uk.org/about/research/26013.asp

Goodwin, G., Leibrecht, B., Wampler, R.., Livingston, S., & Dyer, J. (2007). *Retention of selected FBCB2 operating skills among infantry captains career course (ICCC) students*. (1872). US Army Research Institute for the Behavioral & Social Sciences. Arlington, VA.

JSP822. (2012). *The Design and Delivery of Training*. Part 5: Chapter 1, DTSM 1. The Governance and Management of Defence Training & Education. Training Education Skills and Resettlement Division.

Kim, J., Ritter, R., & Koubek, R. (2011). An integrated theory for improved skill acquisition and retention in the three stages of learning. *Theoretical Issues in Ergonomics Science*, *14* (1), 22-37.

MacLean, P., & Cahillane, M. (2015). The human factor in learning design, research, policy, and practice. *International Journal of Information and Learning Technology. 32* (3).
Marshall, S. (2010) A quality framework for continuous improvement of e-learning: the e-learning maturity model. *Journal of Distance Education, 24,* 143–166.
Marshall, S. (2012). Improving the quality of e-learning: Lessons from the eMM. *Journal of Computer Assisted learning, 28*, 65-78.
Rogers, E. M. (2003). *Diffusion of innovations* (5th Ed.), New York, NY: Free.
Rose, A., Czarnolewski, M., Gragg, F., Austin, S., Ford, P., Doyle, J., & Hagman, J.D. (1985). *Acquisition and Retention of Soldiering Skills*. (671) US Army Research Institute for Behavioral & Social Science: Arlington, VA.
Rose, A., Manning, C., Radtke, P., & Ford, P. (1984). Acquisition and retention of soldiering skills: Report of Year 2 progress. DTIC Document.
Rose, A., Radtke, P., Shettel, H. & Hagman, J. (1985). *User manual for predicting military task retention*. (AIR FR 37800)U.S. Army Research Institute for Behavioral & Social Science: Alexandria, VA.
Sanders, W. (2001). *Cognitive psychology principles for digital systems training* (ARI Research Report 1773). U.S. Army Research Institute for the Behavioral and Social Sciences. Alexandria, VA.
Sabol, M., & Wisher, R. (2001). Retention and reaquisition of military skills. *Military Operations Research. 6*(1), 59 – 80.
Stothard, C., & Nicholson, R. (2001). *Skill acquisition and retention in training: DSTO Support to the Army ammunition study*. DSTO Electronics and Surveillance Research Laboratory DSTO-CR-0218.
Swezey, R., & Llaneras, R. (1997). Models in training and instruction. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (pp. 514-577). New York: Wiley.
Wisher, R., Sabol, M., & Ellis. J. (1999). *Staying sharp: Retention of military knowledge and skills*. (Final Special Report 39). US Army Research Institute for Behavioural & Social Sciences. *Alexandria*, VA.

Author Details

Marie Cahillane
m.cahillane@cranfield.ac.uk
Piers MacLean
p.j.maclean@cranfield.ac.uk
Victoria Smy
v.smy@cranfield.ac.uk