CONTENT AND CONTEXT: UNDERSTANDING THE COMPLEXITIES OF HUMAN BEHAVIOUR IN SHIP OPERATION

Claire Pekcan, Warsash Maritime Centre, Southampton Institute, UK
David Gatfield, Warsash Maritime Centre, Southampton Institute, UK
Professor Michael Barnett, Warsash Maritime Centre, Southampton Institute, UK

SUMMARY

The maritime training establishment at Warsash Maritime Centre is moving toward the delivery of novel courses that concentrate on non-technical or human behavioural aspects of ship operations. This paper describes the philosophical underpinnings and the evidence-based process upon which one such course, being run at the Centre, was developed. The authors explain how and why the course is designed for the specific development of social and cognitive skills or 'crew resource management skills' in ships' officers. The paper concludes with an outline of future research that will consider how the training context, full-mission simulator or desktop scenario, in which the social and cognitive skills of the ships' officers are exercised, influences the successful development of these non-technical skills

AUTHORS BIOGRAPHY

Claire Pekcan

Claire Pekcan is a Senior Research Fellow in the Maritime Research Centre at Southampton Institute. After an earlier career in the health services, she has gained significant valuable experience over the past 10 years in human factors, safety management, risk management, and human resource management in the UK ports, international merchant shipping, and offshore environments. Her particular research interests are in organisational safety culture, organisational competence, professional competence, and human performance influencing factors in the merchant shipping and port operations arena.

David Gatfield

David Gatfield is a Senior Lecturer and Unit Manager of the Machinery Space Simulator at Warsash Maritime Centre. After serving at sea as a Marine Engineering Officer, he was appointed Technical Superintendent for Shell Tankers and was responsible for the support of the instrumentation and control systems onboard all vessels in the fleet. He joined Warsash Maritime Centre in 1996 and lectures in Engineering Systems Management, Risk Management, Petrochemical Tanker Engineering Systems and Gas Tanker Reliquefaction Systems. He is currently conducting research for a PhD in behavioural markers for the assessment of competence in crisis management. David is an Associate Member of the Institute of Marine Engineering, Science and Technology (IMarEST) and a Member of its Council.

Professor Mike Barnett

Professor Mike Barnett is Head of the Maritime Research Centre at Southampton Institute, which incorporates the Warsash Maritime Centre. After a seafaring career of fifteen years, he studied at the University of Wales, Cardiff and in 1989 was awarded a PhD for his work on human error and the use of simulation in training for emergencies. He joined Warsash in 1985 as a lecturer in tanker safety and has been Head of Research at Warsash since 1991. His current post encompasses responsibility for the management of research and welfare of postgraduate researchers at Warsash and on the Southampton campus. Mike is a Chartered Marine Scientist (CMarSCi), Fellow of the Nautical Institute, Fellow and current Vice-President of the Institute of Marine Engineering, Science and Technology (IMarEST) and a Member of its Council.

1. INTRODUCTION

A recent review of accident databases from the USA, UK, Canada and Australia confirms that human error continues to be the dominant factor in maritime accidents and reveals that in 70% of recorded incidents attributed to human error, failures in non-technical skills such as situation assessment and awareness predominate (ABS, 2004).

Historically maritime training has addressed the development of technical and procedural skills. Until recently, providing solutions to the problems of developing non-technical skills and the optimal use of crew resources has been neglected in maritime training.

Simulator-based training courses were introduced primarily to train the skills of passage planning and the importance of the Master/Pilot relationship (Gyles and Salmon 1978). This training initiative developed into the Bridge Team Management (BTM) courses that are conducted today on many simulators world-wide and, although not taught directly, they contain some of the elements to be found in Crew Resource Management (CRM) courses developed in other industries, such as aviation. These aviation courses were developed to focus on the non-technical skills of flight operations and include group dynamics, leadership, interpersonal communications, and decision making (Helmreich and Merritt 1998). Bridge Resource Management (BRM) courses are a more recent initiative, adapted directly from the aviation model for training the non-technical skills of resource management, and are not always based on the use of simulators.

The 1980s saw the introduction of Engine Room simulators and, towards the end of that decade, cargo operations simulators also became available. However, it is only recently that the combined use of bridge and engine room simulators to provide a total ship simulation environment has been undertaken.

In summary, resource management training has become established in the curricula of many maritime training establishments. Courses take a variety of forms and cover both deck and engine room disciplines. The courses are often simulator-based, but not always, and their syllabuses reflect CRM training in other industries. As can be seen from the history of this development, most major training initiatives have resulted from the lessons learnt from a succession of casualties. The next section reviews one casualty and the resource management issues it raises and why technical training alone is insufficient.

2. A CASE STUDY: THE "GREEN LILY"

2.1. The Circumstances

On 18th November 1997, the 3,624 grt Bahamian registered vessel "Green Lily" sailed from Lerwick in the Shetland Islands with a cargo of frozen fish for the Ivory Coast. The weather on departure was bad with wind speeds increasing to severe gale force 9. The following morning, while hove to about 15 miles south-east of the island of Bressay in the Shetland Isles in storm force 10 winds, a sea water supply line fractured in the engine room. The engineers controlled the flooding and pumping out had begun when the main engine stopped. Unsuccessful attempts were made to restart the engine while the vessel drifted northwards towards Bressay. Shetland Coastguard was advised and three tugs, the Lerwick RNLI lifeboat and a coastguard helicopter prepared to proceed to the casualty.

Attempts were made by two of the tugs to secure a line and tow the "Green Lily" away from land but although initially successful, each line parted. The starboard anchor was released and the third tug attempted to snag the cable and pull her head to wind, but the cable parted. At this time, the lifeboat rescued five crewmen, including two injured, from the ship's deck. The ten remaining crew members were rescued by the Coastguard helicopter but the winchman, who had remained on the deck of the ship, was swept into the sea and lost. The "Green Lily" went aground and started to break up. The investigation by the Marine Accident Investigation Branch (MAIB), published in June 1999, advised the cause of the grounding was:

"the lack of propulsion and failure to restart the main engine to arrest the drift of the vessel towards the shore in the prevailing environmental conditions. of the towage attempts and inadequate teamwork" Contributory causes included flooding of the engine room, failure to reset the mechanical over-speed trip, inadequate knowledge of the cooling water system, failure" (MAIB, 1999; pp. 9)

2.2 The Analysis

- An initial technical failure precipitated events and was compounded by a hostile environment and further technical problems and failures. The situation was escalating in severity. An emergency was becoming a crisis, but the actors in this tragedy did not have the benefit of hindsight to read the 'script'.
- The available emergency plans, which tended to be procedures based on single failures, were not applicable. The individuals involved were forced to fall back on their experience to cope with an increasingly complex and unpredictable set of circumstances.
- Initial diagnosis of the technical failure was incorrect and led to a faulty but persistent mental model of the situation. In this case, the chief and second engineers, together with the electrical engineer, failed to understand why the main engine stopped and were consequently unable to restart it. They believed that the main engine failure was due to the effect of the flooding, previously caused by the fracture of the sea suction pipe. The probable reason for the main engine stoppage was actually due to the mechanical over-speed trip either not being reset or reset incorrectly.
- Awareness of the overall situation by individuals was based on incomplete or inaccurate information. In this case, both the Master, based on his calculation of drift, and the engineers, were over optimistic in their belief that a tow would be available before the ship ran aground. Meanwhile, the skippers of the rescue craft had unexpressed reservations about various aspects of the operation including the appropriateness of some of the towing gear, the weather conditions and sea room, and the ability of the ship's crew to handle the towlines.
- Individuals and units were separated physically and several agencies were interacting through various forms of communication. In these circumstances, it was

very difficult for the key players to communicate meaningfully and maintain a shared and agreed awareness of the rapidly changing situation.

3. PHILOSOPHICAL UNDERPINNINGS

As the above case study illustrates, the majority of accidents and incidents are *not* caused by technical problems but by the failure of the crew to respond appropriately to the situation. Arguably, most maritime professionals would agree with Helmreich *et al.*, (1998) that in order to ensure safe and efficient operations there is a need to understand the behaviours of effective error detection and management. However, while other safety critical industries and the military have heeded this message and have been training and assessing resource management skills as a way of ensuring that errors are effectively detected and managed (Flin & Martin, 2001; Cannon-Bowers & Salas, 1998; Brabazon & Conlin, 2000; Flin et al., 2000), the maritime industry continues to lag behind.

The only mandatory requirements in the maritime domain for the development of the non-technical skills of resource management are those of the International Maritime Organization's (IMO) Seafarer's Training, Certification and Watchkeeping Code (International Maritime Organization, 1995). Table *A-V/2* of this code specifies the minimum standard of competence in crisis management and human behaviour skills for those senior officers who have responsibility for the safety of passengers in emergencies. The competence assessment criteria detailed within the Code are not based on specific overt behaviours, but rather on generalised statements of performance outputs, and as such are highly subjective and open to interpretation (Barnett et al, 2003). Although these standards of competence indicate that IMO recognises the need for non-technical management skills, both the standards and their assessment criteria are immature in comparison with the understanding of non-technical skills, and their assessment, within an industry such as civil aviation.

At the Maritime Centre in Warsash, courses are now being developed that go beyond STCW 95. One such course, the Crew Resource Management (CRM) course, is almost entirely concerned with teaching human behavioural or non-technical aspects of ship operations. Technical aspects of ship operation, such as ship navigation or power generation, are not covered as separate items. Rather, the course curriculum is devoted to social and cognitive aspects of seafarers' performance, i.e. it is devoted to those skills thought to be important in assisting in the detection and management of errors.

A further novel approach of the Warsash course is the incorporation of human behaviour research findings in the training philosophy. The recognition primed decision-making theory (Klein, 1993; Orasanu, 1997) suggests that there is a generic metacognitive skill that can be developed to be applied to handle any unpredictable situation. One aspect of this theory that is put into practice on the course is the enrichment of mental models through the building of repertoire patterns. Another aspect is the development of critical thinking skills through the practice of specific techniques in simulated scenarios (Barnett, 2004).

4. CONTENT: THE EVIDENCE-BASED PEDAGOGICAL PROCESS

4.1 Course Aims and Objectives

Taking as a starting point the aviation industry's model for CRM training as outlined in CAP 737, the course at Warsash aims to

- enhance the operational safety of the client company's vessels
- reduce the likelihood of an incident to a vessel
- reinforce the client company's Vision and Mission

These aims are met by emphasising skills that will increase shipboard officers' abilities to act responsibly to health, safety, and environmental concerns.

Table 1. below identifies the types of skills that are taught on the CRM course.

Social Skills	**Cognitive Skills**
Co-operation	**Situation Awareness**
Open communication	Situation assessment
Consideration for others	Risk assessment
Team working	
Leadership and Managerial Skills	**Decision Making**
Situational leadership	Problem diagnosis
Assertiveness	Option generation
Planning and coordinating	Option selection

Table 1. Crew Resource Management Skills

Table 2. in the Appendix maps the course objectives against the Crew Resource Management skills displayed in Table 1.

Understandably, purchasers of education and training for seafarers are asking questions about the value-added of the courses that their officers attend. They want to know that at the end of a course, an officer will have learnt what he or she needed to learn, and can apply the skills practised at the training institution, onboard ship. The purchasers' wish is to be assured that they have spent company money to best effect.

Lecturers, on the other hand, are acutely aware that to achieve attitude or behaviour change in days is an inordinately difficult task, especially when presented with a class of officers of differing rank, experience, and nationality. Unfortunately, the trap into which lecturers fall is to equate value for money with value added. Rather than adopting a teaching strategy that focuses on how students learn, they adopt a strategy that focuses on what the teacher teaches (Biggs, 2003). The result is that the expert lecturer transmits as much of his or her expertise as possible in the time given (value for money) rather than changing the attitude or behaviour of their class (value added).

The philosophy underpinning the crew resource management course delivered at Warsash Maritime Centre is student centred as opposed to lecturer centred, and thus represents a course that seeks to add value to the participating officers through attitude, behaviour, and cognitive change. The instructional system or process employed at Warsash to bring about these changes draws on theories of learning e.g. Operant Conditioning (Thorndike, 1898), the main tenet of which is behaviour that is rewarded will be repeated and behaviour that is punished will cease, i.e. the consequences of one's actions (rewards or punishments) drive behaviour (Rescorla, 1987).

4.2 The ABC of Learning

However, just allowing the students to 'behave' on the course with the lecturers providing no more than feedback (consequences) would be unlikely to beget the safety behaviours associated with effective error detection and management. The students need to be presented with new ways of thinking, new techniques, and new ways of behaving that will facilitate their abilities to handle problem situations.

In the language of behaviour based safety management, these new ways of thinking and behaving are the antecedents to safe behaviour. However, antecedents, such as safety rules, procedures, instructions, toolbox talks, and risk assessments, are ineffective in bringing about change on their own. Krause explains,

"Many well-intentioned safety programs fail because they rely too much on antecedents – things that come before behaviour…All too often these same antecedents have no powerful consequences backing them up." Krause (1997, p. 37)

In the same way, training courses that concentrate on instruction (antecedents) where the emphasis is on what the teacher teaches and not on how the student learns, are unlikely to bring about behaviour change. As Krause states:

"both antecedents and consequences influence behaviour, but they do so differently:

- *consequences influence behaviour powerfully and directly*
- *antecedents influence behaviour indirectly and serve to predict consequences."*

The authors maintain that both are important and thus have designed the crew resource management course in accordance with Antecedent-Behaviour-Consequence (ABC) principles. The course provides the opportunity for the students to practice the behaviour (B) that has been learnt in the lectures (A) and through the debrief session after an exercise receive feedback on their actions (C).

4.2.1 Antecedents

Within the Warsash training course, the lecturer inputs are descriptions and explanations of the following:

- models of human error
- error chain analysis
- situational leadership
- interpersonal influence
- cultural awareness
- situation awareness
- effective communication

These teacher led activities are antecedent to student-centred activities described under the behaviours section below.

4.2.2 Behaviours

There have been a number of training programs produced that aim to improve the higher order cognitive skills of the students within specific context (Woods, 1983; Wales & Nardi, 1985; Resnick, 1987). These techniques have been adapted at Warsash to try and improve the students' social skills such as communication and co-operation. Some of the techniques used are:

- having students justify their solutions to one
- another;
- having students evaluate other students solutions;
- allowing students to make and correct errors;

Other studies have been directed at trying to generate training techniques to improve general problem solving skills that would be transferable into different contexts of application (de Bono, 1985; Covington, 1987; Resnick, 1987). These techniques have also been adapted at Warsash to improve the students' cognitive and metacognitive skills:

- considering multiple sides of an issue (lateral
- thinking);
- considering consequences;
- selecting goals and planning strategies;
- prioritizing factors involved in a situation;
- generating and evaluating evidence;
- using perceptual rather than logical thinking
- extensive practice of solving problems;
- teaching the use of heuristic strategies;
- use of graphical representations to show the
- structure of problems;

4.2.3 Consequences

"Debriefing is the key to the entire learning process, during which trainees' knowledge and attitudes are applied, tested, analysed and synthesised." (Ellman, 1977)

A student-centred debriefing technique has been shown to be more effective because students learn better through self-discovery and self-analysis than by lecture. The student-centred debriefing technique draws upon students' professional expertise and motivation to perform well, and it helps the lecturer understand the students' performance.

Until students have the opportunity to reflect on that which they have experienced during a simulator exercise, it is doubtful that any real learning will take place. The 'debrief' integrates the simulation experience into the learning environment. Debriefing is the critical phase of learning, where the individual begins to understand events experienced. These accommodations of new information form the essence of meaning. Students learn to tie things together, to connect part to part to whole. Students may, or may not process their newly acquired information correctly. Through the debriefing process, the lecturer can ensure that new learning is processed in the correct manner. The debriefing process should provide feedback to the lecturer on the students' value of, and understanding of, the simulation. It also provides feedback to the students about the consequences of their behaviours. Lecturers need to ascertain whether the students' experiences matched those of the real world and whether they believed that the experiences were useful.

Although the course at Warsash is student-centred, considerable thought is given to the instructional design to ensure that the students have a sound conceptual framework to guide them towards achieving the course objectives. Good instructional design also includes aspects of the mode and medium of instruction, i.e. the context in which the training is delivered. The next section reviews the results of some recent research to determine the likely effectiveness of different forms of simulation in CRM skill development.

5. CONTEXT: WHAT ARE THE MOST EFFECTIVE WAYS OF TRAINING CRM SKILLS?

In the year 2000, the Maritime Coastguard Agency (MCA), following a recommendation of the Marine Accident Investigation Branch (MAIB) in response to the loss of the "Green Lily", awarded a project to a research team at Warsash Maritime Centre. The remit of the project was to investigate the potential use of simulators for training in the handling crises and escalating emergencies. This project enabled the researchers to review current concepts and models in the field of resource and crisis management across a range of safety critical industries and to conduct a survey of expert opinion on the optimal training and assessment regimes (Barnett et al 2002).

In order to ascertain the optimal types of simulation to provide training and assessment of non-technical skills, the Warsash research team used a panel of 15 experts drawn from marine simulation resources as well as researchers and practitioners from other similar safety critical industries. Within this project, the Policy Delphi Method (Turoff 1970) was used . The Policy Delphi process is a form of policy analysis that provides a decision maker with the strongest arguments on each side of the issue. A range of future implementation scenarios were proposed as training policies that could meet the perceived training requirements relating to the exercising of resource management skills. These policies were presented to the panel of experts. A subsequent workshop involving some of the panel experts was also used to confirm and develop their responses.

The following is a summary of the responses received from the panel of experts in reply to 19 questions sent to them in order to further clarify the main arguments for and against the proposed training policies.

Training Policy 1: The Use of Full Mission Simulators for Team Based Exercises

The panel of experts believed that the strength of this option was the ability to undertake team-based activities in an environment that provided realism. However, the experts also thought that the cost of full-mission simulators was a significant disadvantage. The experts also made some important observations regarding team based activities and these were that:

- training and assessment of resource management skills should only ever be undertaken separately, and
- the tutor should never also be the assessor within the same time-frame

Training Policy 2: The Use of Full Mission Simulators for Single Trainee Exercises

There was agreement that this policy option was not generally beneficial, but could be useful in special circumstances such as remedial and pre-team training.

Training Policy 3: The Use of Virtual Environments

Although there was still a very positive response to this policy option, little empirical evidence was cited to support the opinions given.

There was general agreement that the communications systems used within this policy option could be embedded, as long as they allowed actual voice communications, and this could be used in a similar way to real communication systems.

Most responses indicated that the co-workers within virtual reality training environments should be real and not simulated in order to facilitate effective team training. However, the possibility was raised that simulated co-workers could be used to afford a greater variety of training opportunities for team members.

There was general agreement that a high level of fidelity was required for certain elements of the virtual environment, but there was a wide diversity of opinion as to what these elements were. The elements discussed were all part of the functional representation of the real environment, both physical and procedural. One response stated that virtual environment did not have to have a high degree of fidelity as long as it allowed for the replication of the skills inherent in the task being trained.

Training Policy 4: The Use of Desktop Computer Simulations

There was agreement that this policy option required a certain level of interactivity to be effective and that an increase in interactivity could improve effectiveness and efficiency up to a point, beyond which the trainee may start to feel confused.

A number of ways of improving interactivity were proposed including the:

- creation of multiple training paths
- provision of training scenarios with more than one acceptable outcome
- use of a facilitator to guide the trainee.

If this policy option could be team-based there was general agreement that this would be more beneficial, because it would allow trainees to discuss alternative solutions. However, one response indicated that if the simulation were more team-based it would become more difficult to control and it would be more difficult to carry out assessments.

Training Policy 5: The Use of Table-top Simulations

All participants agreed that this policy option could be used for training. However, there were arguments made both for and against the use of this policy option for undertaking assessment.

The argument against was based on the lack of fidelity provided by this type of simulation and the difficulty in observing relevant competent behaviour in a context that is very different from the actual workplace.

The argument for was based on assessment being undertaken against those relevant behavioural markers that could be observed within the context of the simulation.

Training Policy 6: The Use of Class Room Based Workshops

There was general agreement that this policy option is best suited to training only.

The following strengths were associated with this policy option:

- cost beneficial
- flexible
- gives the opportunity to discuss operational / emergency problems with others
- tutor guided

The following weaknesses were associated with this policy option:

- there is no environment to manage
- not suitable for the assessment of competence

One response suggested that any weaknesses associated with this policy option could be overcome by providing a good tutor and ensuring interactivity. There was a wide spread of opinion regarding which other methods of training this policy option could be usefully used in conjunction with. The overall range of opinion covered all of the remaining five policy options. One response suggested that classroom-based workshops followed by practice in context would allow increased transfer.

The following were proposed as being suitable to be trained using this policy option:

- appreciation of technical risks
- knowledge of systems
- knowledge of procedures
- theoretical knowledge
- planning
- risk management
- problem solving

The workshop concluded that the inclusion of full mission simulation was the only viable assessment option. This method is used extensively by the nuclear and aviation industries. The argument is that it is the only safe method that guarantees that the majority of the cues that seem important are present and that the perceived required skills may be demonstrated.

The search for a single cost-effective training option to deliver the required standard of competence may be misplaced. The principle enshrined in STCW95 and National Vocational Qualifications (NVQs) is that once the standard of competence has been defined, how an individual reaches that standard is irrelevant. Among a number of variables, it is the motivation of the learner and the ingenuity of the trainer that will determine the most cost-effective training option. In an ideal world, the trainer would select the most appropriate method from his/her training "toolbox" to suit the individual trainee, their learning style, and stage of development identified through continuous assessment.

Research conducted by Crichton and Rattray (2002) since this exercise describes the potential of Tactical Decision Games (TDGs) for crisis management training. TDGs are a low-cost, low fidelity classroom based simulation that focuses on improved decision making and heightened situational awareness. Evaluation of their effectiveness and their validity and reliability as a competence assessment tool is currently underway.

In summary, the most cost-effective training option will be determined by a number of "local" factors, including the ingenuity of the instructor. At present, however, the assessment of competence, particularly for marine certification purposes, through the use of currently available full mission simulations represents the most viable option.

6. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

As in similar safety-critical industries, the analysis of maritime accidents over the years has revealed shortcomings in the ability of operators to manage both resources and crises. CRM training has been seen increasingly as a fundamental part of the human error management philosophy. The International Maritime Organization recognises the need for non-technical or resource management skills, but both the standards of competence and their assessment criteria are immature in comparison with civil aviation. Although CRM training has become well established in the maritime curricula, as with civil aviation, there remains a question mark about how effective such training actually might be in improving safety performance. Analysis of recent casualties also suggest that CRM training, although important, may not be a panacea for prevention of accidents and that organisational factors, as well as operator error, must also be taken into account.

In setting an agenda for future maritime research in this area, the authors conclude that the following issues need to be addressed:

If the direct training of resource and crisis management skills is pursued, to what extent will such skills, learned in a simulated environment, transfer to the real world? What are the optimum training environments to ensure effective transfer? How can these non-technical skills be assessed most effectively, both at the level of the individual and at the level of the team? What behavioural markers, both at individual and team level, predict safe performance? In multi-national environments, how may cultural factors be characterised and what is the impact on overall safety performance of cultural differences?

However, as with any scientific endeavour, it is not sufficient to just ask questions. There is much that is still not known about human behaviour in response to unexpected, unplanned, and seemingly uncontrollable events. CRM training is a method that has been devised for preparing people to manage such events. The maritime community is to some extent playing 'catch up' with the research being carried out in the military and aviation arenas; and this is a privileged position. Maritime researchers are able to cogitate on the issues that their counterparts in other industries raise and it is their efforts that have inspired us to offer this maritime research agenda. It is offered, not as a guiding light for all now to follow, rather as a stimulus for debate. As a research community, interested in describing, predicting and ultimately, enhancing human performance, we need to make sure we are asking the *right* questions; questions that will lead us to conduct meaningful and fruitful research.

REFERENCES

ABS (2004) *ABS Review and Analysis of Accident Databases: 1991-2002 Data.* American Bureau of shipping Technical Report: SAHF 2003-5.1, March 2004.

Barnett, M. L., Gatfield, D., and Habberley, J (2002) *Shipboard crisis management: A Case Study.* Proc Int. Conf. Human Factors in Ship design and Operation. pp 131-145 RINA, October 2002.

Barnett, M. L., Pekcan, C.H., and Gatfield, D. (2003) *A Research Agenda in Maritime Crew Resource Management.* Proc Int Conf. on Team Resource Management, Embry Riddle, Fl. USA, October 2003

Barnett, M. L. (2004) *Risk management training: the development of simulator-based scenarios from the analysis of recent maritime accidents* Proc. Conf Advances in International Maritime Research. IAMU, Tasmania, November 2004

Biggs, J. (2003) *Teaching for Quality Learning at University Second Edition.* Maidenhead: OU Press.

Brabazon, P., & Conlin, H. (2000). *Assessing the safety of staffing arrangements for process operations in the chemical and allied industries.* Report for the Hazardous Installations Directorate of the UK Health and Safety Executive. London: HMSO

Civil Aviation Authority Safety Regulation Group (2003). *CAP 737 Crew Resource Management (CRM) Training: Guidance For Flight Crew, CRM Instructors (CRMIs) and CRM Instructor-Examiners (CRMIEs).* www.caa.co.uk.

Canon-Bowers, J.A. & Salas, E. (1998). Individual and Team Decision Making Under Stress. In: J.A. Cannon-Bowers & E. Salas (Eds) *Making Decisions Under Stress: Implications for individual and team training.*Washington D.C.: American Psychological Society.

Covington, M.V. (1987). Instruction for problem-solving planning. In S.L. Friedman, E.K. Scholnick & R.R. Cocking (Eds.), *Blueprints for thinking: The role of planning in cognitive development.* Cambridge: Cambridge University Press.

Crichton, M and Rattray, W (2002) "Tactical Decision Games: What are they and how can they help?" Proc. Critical incident Management Conference, Aberdeen, June 2002.

de Bono, E. (1985). The CoRT thinking program. In J.W. Segal, S.F. Chipman & R. Glaser, (Eds.), *Thinking and learning skills: Vol 1. Relating instruction to research* (pp. 363–388). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ellman, N., (1977) Before the simulation fails: Avoiding potential pitfalls. *The Social Studies,* 68(6), 251-253. Washington D.C.:Heldref Publications.

Flin, R., O'Conner, P., Mearns, K., Gordon, R., & Whitaker, S. (2000). *Crew Resource Management Training for Offshore Operations.* Factoring the Human into Safety: Translating Research into Practice. Volume 3 of UK Health and Safety Executive report HSE OTO 2000 063. London: HSE.

Flin, R., & Martin, L. (2001). Behavioral Markers for Crew Resource Management: A Review of Current Practice. *The International Journal of Aviation Psychology,* 11(1), 95-118.

Gyles J.L. & Salmon, D. (1978) *Experience of Bridge team Training using the Warsash Ship Simulator.* Proc First Int Conf. on Marine Simulation MARSIM (1978) pp 1-26 Nautical Institute.

Helmreich, R.L. and Merritt, A. (1998) *Culture at Work in Aviation and Medicine."* Ashgate, England.

International Maritime Organization. (1995). *Seafarer's Training, Certification and Watchkeeping Code (STCW Code).* London: IMO.

Klein, G. Orasanu, J. Calderwood, R. & Zsambok C. (1993) *Decision making in action: Models and methods.* Norwood, NJ: Ablex.

Krause, T. R. (1997) *The Behaviour-Based Safety Process: Managing Involvement for an Injury Free Culture. Second Edition.* New York: Wiley.

Marine Accident Investigation Branch (MAIB) Marine Accident Report 5/99 "Report of the Inspector's Inquiry into the loss of mv Green Lily on 19 November 1997 off the East Coast of Bressay, Shetland Islands".

Orasanu, J.M (1997). Stress and naturalistic decision making : Strengthening the weak links in 'Decision making under stress: emerging themes and applications' (eds: R Flin, E Salas, M Strub and L Martin) Ashgate.

Raths, J., (1987) Enhancing understanding through debriefing. *Educational Leadership.* 45(2), 24-27. Alexandria VA: Association for Supervision and Curriculum Development.

Rescorla, R.A. (1987) A Pavlovian analysis of goal directed behaviour. *American Psychologist. 42* 2, 119-129.

Resnick, L.B. (1987). *Education and learning to think.* Washington, DC: National Academy Press.

Thorndike, E. L. (1898) Animal intelligence: An experimental study of the associative processes in animals. *Psychological Monographs, 2* 8.

Turoff, M, (1970) "The Policy Delphi," Journal of Technological Forecasting and Social Change, (2:2), 1970.

Wales, C.E., & Nardi, A.H. (1985). Teaching decision-making: What to teach and how to teach it. In A.L. Costa, (Ed.), *Developing Minds: A resource book for teaching thinking.* Alexandria, VA: Association for Supervision and Curriculum Development.

Woods, D.R. (1983). Introducing explicit training in problem solving into our courses. *Higher Education Research and Development, 2*, 79–102.

	Social Skills		Cognitive Skills	
Course Objectives	Co-operation	Leadership & Managerial Skills	Situation Awareness	Decision Making
Develop a quality improvement orientated culture with respect to safety of operations, protection of the environment and achieving goals within acceptable limits.		✓		
Develop a pro-active methodical and systematic approach to the management of systems, operations and communications through teamwork and to evaluate any deviation from a specific operational objective plan and analyse the reasons for this deviation.	✓	✓		✓
Identify and analyse risk factors, this to include consideration of human behavioural factors, which contribute to human error and situational awareness.			✓	✓
Identify the priorities to which a manager must attend with respect to the safety of operations: i) within hours of joining the vessel; ii) during the commissioning of the vessel; iii) before the vessel gets underway;			✓	✓
Develop the skills and confidence of the more junior members of the team through appropriate briefing, guidance and de-briefing techniques.	✓	✓		

Course Objectives	Social Skills		Cognitive Skills	
	Co-operation	Leadership & Managerial Skills	Situation Awareness	Decision Making
Assess own performance and formulate objectives for 'Continuing Professional Development' purposes.		✓		
Develop fault diagnosis strategies and methodologies.			✓	✓
Identify and terminate the development of error chains.			✓	✓
Identify essential on-board training needs of both individuals and the team with regard to both operational, emergency and crisis situations.		✓		
Practice and develop critical thinking skills during emergency and crisis situations			✓	✓

Table 2. The mapping of course objectives against CRM skills.