COLLABORATIVE LEARNING FOR PROFESSIONAL DEVELOPMENT OF SHIPBOARD ENGINEERS

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Abstract:

A review of investigation reports concerning accidents occurring in ship machinery spaces has indicated that nearly one fifth of all accidents/incidents are attributable, at least in part, to the deficiency in knowledge and skills of shipboard engineers. Maritime education and training (MET) is based on the belief that the generic engineering and seamanship knowledge and basic practical skills imparted to / acquired by the prospective marine engineers during their pre-sea education and training period will be effectively transferred to their on job situations, notwithstanding the variability of work environment and continuously changing shipboard technology. This study identifies factors that have implications on shipboard safety *vis-a-vis* marine engineers' initial and continual learning. Through experimental research it confirms positive impact of collaborative learning. It addresses issues that need consideration for developing a suitable mechanism to channelize the natural process of on-the-job learning for continual professional development of shipboard engineer officers.

Key words: Human factors, competence, social skills, collaborative learning.

1. Introduction

Standards of ship design for safety, use of better materials in construction, advanced construction techniques and production under sound quality control have steadily reached a plateau of high quality engendering higher reliability and consequent diminished frequency of technological failures. Consequently the role of human element in accident causation is becoming more prominent [1,2]. It is a common place to come across statements that human error is responsible for 80% of accidents in most industries. Competence of seafarers is built on comprehensive background knowledge and understanding, rather than surface knowledge acquired by rote learning. Setting adequate standards of knowledge, understanding and proficiency for development of competence as demanded by the International Convention on Standards of Training Certification and Watch-keeping for Seafarers (STCW) is paramount but equally important are the methods to facilitate comprehensive understanding. Prospective marine engineers are required to transfer their knowledge and skills from their learning environments to their work situation. This transfer is much easily achieved if the learnt knowledge is comprehensive [3]. The techniques of knowledge transfer for major part of the curriculum delivery in most maritime education and training institutions conform to the behaviourist approach that potentiates surface learning through rote memorising. Save for a few mandatory practical training courses the prevailing academic and competence assessment methods also support surface learning as the incentive is to pass examinations at the end of various courses. Prospective marine engineers with such learning are deprived of longer retention of knowledge and skills of learning. Learning of professional acumen continues during their shipboard professional careers and it is imperative that the methodologies for knowledge transfer implemented during their MET inculcate in them the skills of learning to transform them into lifelong learners.

Techniques of 'collaborative learning' are student-centred learning approaches that actively involve them in critical thinking, expressing their ideas, explaining, reflecting, enquiring to clarify their doubts and thus developing deep understanding of concepts. Literature search and our own experimental exercises have shown that collaborative methods have positive learning achievements. Application of collaborative learning techniques in MET institutions, while enhancing comprehensive understanding of the subject matter and acquisition of social skills, can also help the future marine engineers in developing attributes of lifelong learners, essential for them to learn from dynamic work situations on job and for professional development along with their peers.

2. Multiple Skills Demand

Shipboard engineers are at the centre stage of operations interacting with machines, technology and the machinery space work environment. They are required to prevent undesirable operational deviations through appropriate controls and to apply appropriate counter measures to maintain safety and efficiency of operations if and when unacceptable deviations do occur. Through their timely preventive actions and quick recovery processes they mitigate the consequences of incidents or accidents. However the cognitive processes which enable operators to make decisions, judgments and plans of actions to achieve desired objectives are the very processes which can fail and lead to error [2]. The factors responsible for errors on part of the engineers encompass personal attributes of knowledge, skills and experience as well as their physical, physiological, psychological and psycho-sociological characteristics [4].

Ship operation is a socio-technical system comprising seafarers on board as well as operators ashore at different hierarchical levels. Irrespective to their position in the system all of them are prone to committing errors with ultimate consequences of failures or accidents. Consequences of operational failures at the human-machine interface or the 'sharp end' resulting in what has been termed as 'active failures', and of the failures in the management of planning and control termed as the 'latent failures', are jointly responsible for undesirable incidents or accidents [5]. Figure 1 illustrates the hierarchical levels and the types of failures.

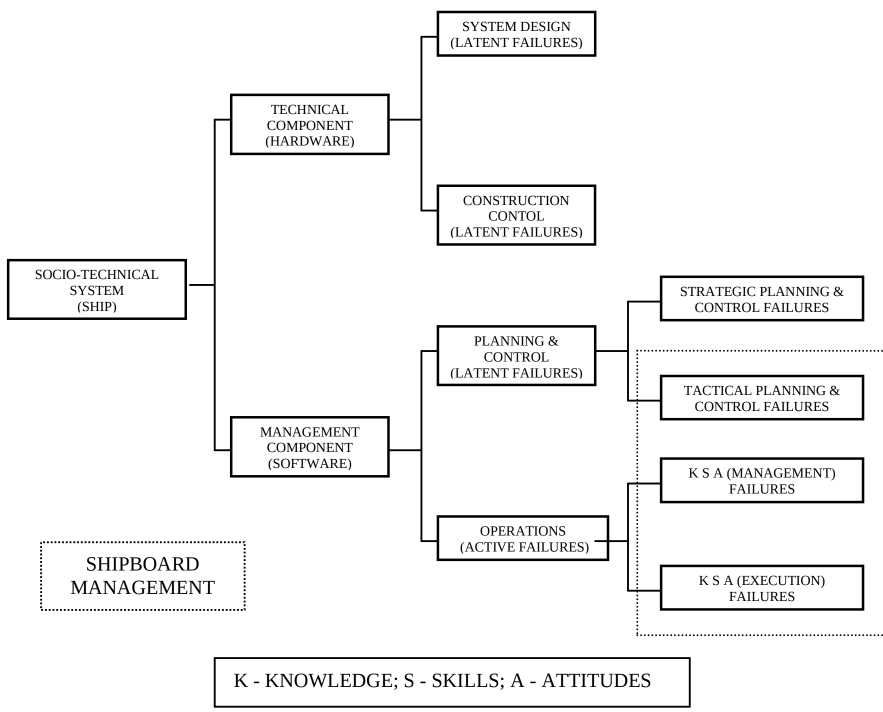

Figure 1: Ship Socio-technical System Management Components

The management component or the (software) of a socio-technical system, like a ship, comprises planning and control at two levels. Upper or the shore management of a shipping company or a ship management company is responsible for design, construction control and strategic planning, where most latent failures occur. The lower level comprises the shipboard management which is responsible for the tactical day to day planning, controls and shipboard operations that involve interactions at the human-machine interfaces. Shipboard operations are therefore prone to both, the latent as well as active failures. The shipboard engineers are responsible for planning of operations as well as for executing them and are therefore required to possess a combination of management and operational competence commensurate with each individual's hierarchical position on board. Emphasis of either type of competence changes as they gradually move up the management hierarchical ladder from support level to the operational level and finally to the management level as each one moves through his/her respective career path.

3. Human Element at the Human-machinery Interface

3.1 Competence mismatch

Competence of shipboard engineers refers to the application of knowledge, understanding and skills in a manner that their duties can be performed in a safe, efficient and timely manner [6]. Shipboard engineers' professional knowledge, technical skills, abilities, aptitude, social skills and attitudes must match the required level of competence for a particular ship's systems and its work environment. A mismatch occurs when the ship technology changes and demands engineers' corresponding upgraded expertise. It also occurs when there is need to replace the experienced engineers who have to inevitably leave the ship [7]. Employment of shipboard staff in commercial shipping is increasingly marked with high turnover and short term employments. Change in a ship's flag or its managing owner affects a change in the company's organizational structure, policies and procedures demanding changes in crews' behavioural responses to meet such new requirements. According to the mandatory International Safety Management Code (ISM Code) a ship's safety management system must be implemented afresh upon change of the company. The transportation safety board (TSB) of Canada, based on their random sampling of Sea-web database of vessels ranging between 8000 and 50,000 deadweight tonnes and constructed in 1997, have reported that 55% of such vessels, on an average, had almost three managers per vessel over the intervening 10-year period [8].

Continuously changing shipboard technology, crews comprising multinational seafarers, short tenure of service on board, shortage of trained seafarers, diversity in standards of MET in different countries contribute to a mismatch between the available expertise and the desired levels of competence. Unsafe acts committed by the operators leading to failures have been summarised by Cacciabue as the failures of planned actions in achieving their desired ends and he has termed them as 'lapses', 'slips', 'mistakes' and 'violations' [9]. Mistakes are the errors in selection of suitable rules, plans or procedures and occur, among psychological and other factors, due to lack of knowledge, skills and experience of the operators.

3.2 Accident causation factors

Several accident causation models and human error taxonomies have been developed by researchers for systematic reporting of accidents, aetiological analysis and for predicting failure modes and mechanisms. Some researchers have used the terms organizational factors, job factors and individual factors for categorising error causation mechanisms leading to unsafe acts [10]. In this context the individual factors subsume mental & physical abilities and capabilities comprising *inter alia* professional knowledge, skills, training and experience. While some of the taxonomies are fairly explicit in specifying inadequacy of knowledge, skills or training of operators the others use terms such as mental limitations, lack of awareness, ignorance etc.

Most national maritime administrations maintain their individual databases of accident investigations reports and some make them available in the public domain on their websites. Accident investigations reports from the following sources were reviewed for this research:

Australian Transportation Safety Bureau (ATSB)
Transportation Safety Board Canada (TSB)
Danish Maritime Authority (DMA)
Marine Accident Investigation Branch UK (MAIB)
National Transportation Safety Board USA (NTSB)

Numbers of reports from each of the above organizations are different depending on their availability in the electronic format and the year of commencement of posting of the reports on their respective websites. For this review the reports of accidents involving fishing vessels, pleasure crafts and vessels less than 500 gt or those with propulsion machinery of less than 750 kW were not considered. From the remaining 782 accident investigation reports a total of 113 reports pertaining to accidents in machinery spaces or resulting into occupational injuries to the engineering staff were shortlisted and further reviewed for this analysis. Distribution of investigation reports from five accident investigating authorities are shown in Figure 2.

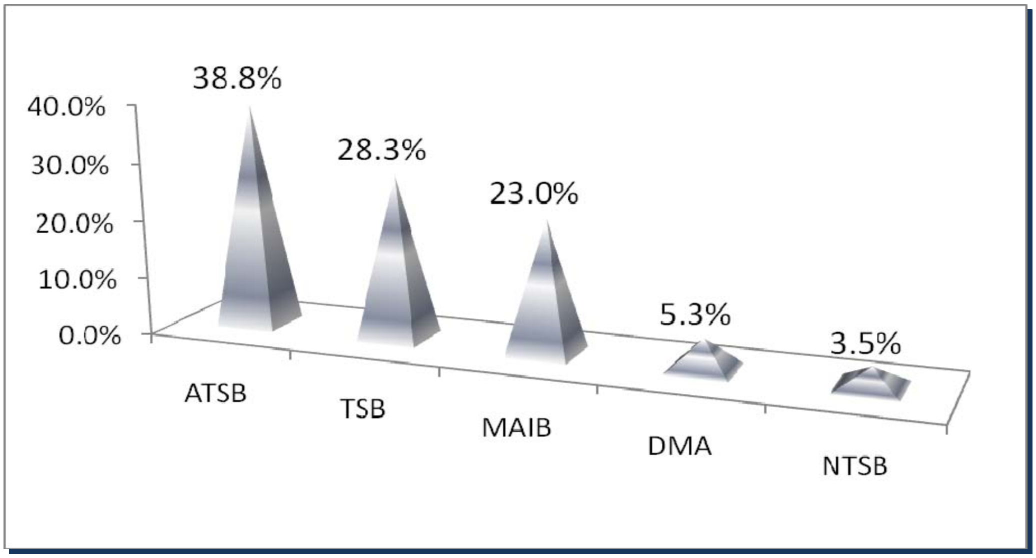

Fig. 2 Distribution of Machinery-Space Accidents Reports among five Investigating Authorities

Each accident investigation report in its final conclusions or findings has indicated the most probable causal factors identified by the investigators. In these 113 reports a total of 288 probable causal factors have been identified. Individual factors pertaining to the shipboard engineering staff have been considered for this analysis and it is noted that:

- Deficiency of knowledge of engineers has been identified as one of the probable causation factors in 31.8 % accident investigation reports
- Number of causes attributed to the deficiency of knowledge, experience and training apportion 19.1% of the total number of causes identified by the authorities

In another similar study conducted by Makoto Uchida [11], reviewing court judgement reports of accident enquiries from Japan Marine Accident Inquiry Agency spanning from year 1995 to 2003, a similar distribution is noted. In his study 173 judgement reports of accidents related to the marine engine management on merchant ships were statistically analysed on the bases of methodology vide IMO Resolution 884 (21). The study revealed that the accident attributed to human error related causes due to knowledge-based mistakes amounted to 20.7% of total causes.

4. Professional Knowledge and Competence

4.1 Diversity in Technical Competence

In spite of acceptance of the STCW Convention by overwhelming number of member states, the standards of maritime education and training still elude preciseness that is needed to be attained on global basis. Save for the limited guidance in the form of specified competencies, the actual contents and the standards of MET syllabus are still shrouded with vagueness. Rapidly changing technology has always created a gap between the static model of competence standards set by MET institutions and the dynamic nature of competence model demanded by the changing technology. There is a perpetual time lag in bridging this gap and as a rapid and short term measure there are increasingly high demands for proactive training measures e.g. training in the electronic controls on intelligent engines. This inevitable gap varies amongst MET institutions on national as well as on international scale.

4.2 Social competence

Present crewing pattern characterised by multinational crew has introduced variances not only in the standards of technical skills of seafarers on board ships but also in the standards of interpersonal skills. Seafarers with diverse ethnic and cultural backgrounds are required to work together in cohesive teams on board which calls for pertinent social skills on part of the seafarers [12]. Developing amicable human relations, team work and leadership skills are legitimate and valuable classroom goals not just the extracurricular ones [13]. The STCW Convention requires marine engineers to be proficient in sixteen specified competencies before they are considered competent for shipboard engineering operations. None of these competencies specifies or implies development of social skills.

4.3 Transfer of learning to shipboard work environment

The main focus of education and training in the MET institutions, as also mandated by the STCW Convention, is on development of professional skills on a firm foundation of theoretical knowledge. The philosophy of MET is based on the belief that once the prospective engineers have acquired the minimum requisite knowledge and practical skills they will be able to apply the learnt knowledge with necessary modifications to meet the varying demands of operations on board. Transfer of learning and its application to work situation is context sensitive and is easier if the learning takes place in same or similar conditions of the actual work environment. The learning that occurs during onboard training, practical exercises in simulated conditions and during on job training is more easily transferred than that learnt in the class room [3]. The extent of knowledge and skills transfer to work situations also depends upon the ease with which learning can be retrieved, which in turn, is a function of how well the material was learnt. Stronger is the understanding and comprehensive is the learnt knowledge more readily does the transfer occur. Conceptual learning that occurs with deep understanding is more likely to be transferred than the material that is merely committed to rote memorisation [14]. Critical thinking at the level of abstraction not only helps transfer but also helps developing skills of adaptation to dynamic work environment.

4.4 Knowledge transfer in the MET environment

Over three and a half decades ago Swedish researchers, Marton and Saljo, on basis of their study, suggested a need for shift of focus from teachers to learners for better learning achievements. Delivery of course curricula in educational institutions, and the MET providers being no exception, continues to be the traditional teacher-centred [15]. This traditional method relies on classroom delivery of lessons in a linear fashion and has been referred to as a ‘push’ method, where the teacher is pushing the learning material to students in logical step by step fashion [16]. In such teacher-centred learning activity the learners play a passive role expecting to be provided with new knowledge that they can add to their existing repertoire. Learning does occur provided the learners are thinking and making connections with their own ideas and experiences and are thus actively involved [17]. However if the learner is not able to make necessary cognitive connections due to his/her limited knowledge and experience, if the new information is too complicated, if it is delivered too quickly for him/her to assimilate or if there are environmental distractions the learner may not be able to keep himself/herself actively involved. This type of passive learning is therefore inflicted with a strong likelihood of learners’ cognitive dissociation with the discourse and their mentally wandering off in spite of physical presence in the class. Such students then need to put in extra efforts for learning through self reading, tutorials or peer help, failing which they may resort to rote learning for clearing the examinations.

Research over half a century espouses that ‘teachers cannot simply transfer readymade knowledge to students’ [18] and that the students have to create their own knowledge from the new information either to form new concepts or modify existing ones. When confronted with new information a learner’s curiosity causes an intrinsic state of mental tension that makes him/her strive for more information. This kind of intrinsic motivation to learn is stronger than the extrinsic motivation engendered from threats of examinations or enticement of rewards [19]. To potentiate comprehension and deep learning the learners are required to be kept engaged in the process of interpretation and interrelation of information; overt questioning the teacher/author or covert self interrogation, reflection and critical thinking. Acquiring skills for learning is a prominent feature of an educational process and has a lifelong implication on the professional lives of people. MET institutions in addition to ensuring that their students learn how to perform their tasks also need to inculcate, through application of suitable teaching techniques, the skills of learning that they could apply during their professional careers as well.

5. Active Learning Process

5.1 Collaborative learning

Some of the educational techniques that keep students engaged in the process of learning are characterised as group based learning methods under the term ‘collaborative learning’. These student-centred learning processes essentially require students to actively involve themselves, as members of small groups, to seek and assimilate relevant information on a particular subject matter, a query or a problem through interactions among themselves or at times also involving the teacher. They are required to engage themselves intellectually to discuss, reflect, argue, convince and disagree/agree to comprehend the concepts or look for solutions depending on the preset targets of learning. The students are responsible for their own learning and the built-in interdependence feature of the group-work makes them responsible for other group members' learning as well. Such an approach, based on the theory of constructivism, not only engenders deep learning but also helps the students in developing skills of learning. As the group members have to interact with each other for a common purpose development of social skills like effective communications, respecting other's ideas, putting forth one's ideas convincingly without offence or annoyance to others and teamwork is also achieved [20].

Collaborative learning is an umbrella term that encompasses a variety of group-based educational approaches in which students collaborate to apply their intellectual efforts jointly to search for solutions, constructing meanings or creating something new with information and ideas [13]. Number of variations on the basis of learning objectives, organisational structure of groups, extent of teacher involvement, incentives for group work, methods of assessments etc, has been developed by teachers and researchers. Various group-based learning methodologies have been implemented under different names. These group-based learning techniques are known by terms such as seminar, tutorial, buzz group, brain storming, snowballing, problem solving, case studies etc. Such group learning processes provide exposure to diverse view points where the learners are challenged socially and emotionally requiring them to propound and defend their ideas which help them in creating their unique conceptual framework of subjects/topics/events discussed. The group atmosphere promotes learning as well as satisfaction in such learning processes [21].

5.2 Cooperative learning

Cooperative learning is a form of collaborative learning which is characterised by a more structured format of group work for learning. Teacher's role is quite prominent in cooperative learning since s/he is responsible for designing and assigning the group learning tasks, providing resources, managing time and other resources, guiding the students, monitoring the progress and ensuring that the students do not stray away from the tasks. S/he also ensures that each member in each group effectively contributes in the group learning process. Johnson brothers, the pioneers in the implementation and research of cooperative learning, have identified five elements for accomplishment of common goals by the group members through a cooperative learning endeavour [22]. These five elements are:

- Positive interdependence: It is the essence of cooperation wherein each group member is obliged to rely on one another for achievement of the set goals. Failure of any one in doing his/her part has a negative consequence for the whole group, 'float together or sink together'.
- Individual accountability: All the group members are accountable for doing their share of work and for achieving mastery in all the material to be learnt, 'no hitchhiking'.
- Face to face positive interaction: Although some of the work may be done individually some must be done interactively with the group members providing feed back to each other, challenging one another's conclusions and most importantly, teaching and encouraging one another.
- Appropriate use of collaborative skills: Group members are encouraged and helped to develop and practice trust building, leadership, decision making, communication and conflict management.
- Group processing: Group members set the group goals, periodically assess the progress achieved as a team and to identify changes they need to make to function more effectively in future.

Number of research studies, particularly in the USA, has been conducted at the primary, secondary and tertiary level including engineering colleges. All these studies based on the cooperative learning methodologies rely on systematic comparison of academic achievement of students who participated in collaborative learning versus those in reference groups having attended same courses separately through the traditional class room instructions. Majority of such studies have shown that the students who participated in the collaborative learning process had enhanced learning achievements. In a review based on 29 studies, conducted at the elementary and secondary grade levels, positive achievement effects were noted in 63 % cases with 32.6 % indicating no improvement and 4.4 % cases showing a negative effect [23]. Johnson and Johnson of the Minisota University on the basis of their research involving eight different cooperative learning methodologies covering 158 studies have concluded that though there are variations in the achieved levels all of them show a positive achievement trend [24]. A review in 2008 of fourteen studies conducted in five Asian countries conducted at three academic levels and covering diverse subjects of basic sciences, engineering and social sciences concluded positive achievement effects in 53.3 %, no effect in 20 % and negative effect in 26.7 % cases [25]. Although the positive achievements have been noted in only 53.3 % of cases it is noted that positive achievement effects were comparatively higher (in 75% cases) at the college level. This is indicative of the regional culture traditionally holding teachers in high esteem even with reverence at the primary and secondary levels but the students at higher educational levels gradually realising the importance of critical thinking in the process of learning rather than just being passive learners. Different techniques of collaborative learning are used in all global regions as well. However in the field of MET no research on the positive achievement, effectiveness or usefulness of collaborative learning are traceable.

5.3 Research study at our university

5.3.1 Objectives of the study

Techniques of collaborative learning in a cooperative learning format were applied during the final year of MSc programme at our university. The student body at this university comprises international maritime professional of mixed backgrounds. The objective of the study was to find: if there is a difference in learning when applying collaborative learning methodology as compared to that achieved through individual learning. If so what is the extent of comparative positive gain and how does the extent of learning in recall items compare with the critical thinking items achieved under two methods.

5.3.2 Treatment group

The students who had enrolled in two of the elective subjects delivered during their final semester were treated through six specially modelled exercises for this study. Seven students had enrolled for the first subject titled ‘Advanced Maritime Technology’ and thirty students for the second subject titled ‘Ship Acquisition and Maintenance Management’. All the students enrolled in the first subject had technical background except one; however that student was a science graduate and over the past three semesters had acquired substantial technical knowledge. The students of latter course were of mixed academic and professional backgrounds. Both the subjects comprise two modules each. In all three modules, both modules of the first subject and one module of the second subject, were selected for this study. The subjects are of technical nature and while the former subject deals purely with contemporary shipboard technology the latter has more of management bias.

5.3.3 Methodology

The students enrolled for the first subject were divided into two sets of four and three students respectively. Each set of students was alternately put through the ‘individual learning’ and ‘group learning’ exercises in such a way that the set that worked individually in first exercise worked in a group in the second following similar treatment for the following two exercises. Thus each student worked twice individually and twice in group in the first four exercises. Students of the second subject were treated in similar fashion. Fifteen students worked individually and fifteen in three groups of five students each for the fifth exercise. The students who had worked individually in the fifth exercise worked in groups and vice-versa for the sixth exercise. This provided each of the students an opportunity to work individually as well as in group obviating treatment bias. In order to eliminate any element of subjectivity the groups for first four exercises were formed by random selection through lotteries and for the fifth and sixth exercises through Nth name selection technique.

Each of the six exercises had the same format. All the students enrolled for each module attended lectures together prior to their treatment through the exercises. Exercises were arranged midway and at the end of each module delivery. Each student was given a one page common text related to a part of subject matter previously covered through lectures. Each learning exercise was of 45 minutes duration in which one set of students worked individually and those in the other set worked in their allocated groups. The students working individually had to read, comprehend and assimilate the contents of the text on their own using their lecture notes, handouts and other reading material. Those working in groups had to learn and expand their understanding with the help of one another, sharing their understanding of the text, lecture notes, handouts and other reading material to reach common understanding of the concepts. While working in groups they were observed and encouraged to actively involve themselves in discussions, exchanging views, questioning and seeking clarifications from each other. At the end of the learning period of each exercise the students, whether they had worked individually or in groups, were given a common written test specific to each exercise. Each test had the same format; comprising eight recall type short answer questions and a long essay type question. The marks obtained by each student in the tests formed part of his/her final grades for respective subjects. The six exercises provided marks from forty four answer scripts of students working in groups and equal number working individually and were used for assessing effectiveness of the two learning methods.

The marks scored by students who worked in groups and individually in the assessment tests following each exercise were separately tabulated. The tabulation of marks was done for each student under three headings, namely 'all questions', 'recall type questions' and 'essay type questions' for each test on respective datasheet. The aggregate average marks under the three headings from each datasheet are tabulated for six exercises as shown in Tables 1, 2 and 3 respectively. Statistical analysis on the data from the six rest results was carried out using the SPSS software.

Table 1 Marks scored by both set of students in all questions

TEST No.	COMPLETE SET OF QUESTIONS AVERAGE MARKS				
	WHOLE CLASS	ALL STUDENTS WORKING IN GROUPS		STUDENTS WORKING INDIVIDUALLY	
	(X)	ALL GROUPS	GAIN, % OF (X)	ALL INDIV-DUALS	GAIN, % OF (X)
1	6,3	6,7	+6,3	6,1	-3,2
2	5,5	5,6	+1,8	5,4	-1,8
3	6,9	7,7	+11,6	6,3	-8,7
4	7,3	7,0	-4,1	7,7	+5,5
5	6,3	6,5	+3,2	6,1	-3,2
6	6,3	6,9	+9,5	5,7	-9,5

Table 2 Marks scored by both set of students in recall type questions

TEST No.	DRILL AND PRACTICE QUESTIONS (RECALL QUESTIONS) AVERAGE MARKS				
	WHOLE CLASS	ALL STUDENTS WORKING IN GROUPS		STUDENTS WORKING INDIVIDUALLY	
	(Y)	ALL GROUPS	GAIN, % OF (Y)	ALL INDIV-DUALS	GAIN, % OF (Y)
1	3,4	3,4	0,0	3,0	-11,8
2	2,1	2,0	-4,8	2,2	+4,8
3	3,3	3,5	+6,1	3,1	-6,1
4	3,7	3,4	-8,1	4,2	+13,5
5	3,0	3,1	+3,3	2,9	-3,3
6	2,7	2,9	+7,4	2,6	-3,7

Table 3 Marks scored by both set of students in questions requiring critical thinking

TEST No.	CRITICAL THINKING QUESTION (ESSAY QUESTION) AVERAGE MARKS				
	WHOLE CLASS	STUDENTS WORKING IN GROUPS		STUDENTS WORKING INDIVIDUALLY	
	(Z)	ALL GROUPS	GAIN, % OF (Z)	ALL INDIV-DUALS	GAIN, % OF (Z)
1	3,0	2,7	-10,0	3,1	+3,3
2	3,4	3,6	+5,9	3,2	-5,9
3	3,6	4,2	+16,6	3,1	-13,9
4	3,6	3,7	+2,8	3,5	-2,8
5	3,3	3,4	+3,0	3,2	-3,0
6	3,6	4,0	+11,1	3,1	-13,9

5.4 *Findings*

Analysis of scores from the assessment of answer scripts indicated:

Total aggregate scores:
In 83.3% tests the average group marks are higher than the average individual marks.

Marks scored by set of students who worked in groups are 8.4 % higher in relation to the average marks scored by the set of students who worked individually.

Recall questions:
In 66,6 % tests the average group marks are higher than the average individual marks.

Marks scored by set of students who worked in groups are 1.66 % higher in relation to the average marks scored by the set of students who worked individually.

Critical thinking questions:
In 83,3 % tests the average group marks are higher than the average individual marks.

Marks scored by set of students who worked in groups are 12.5 % higher in relation to the average marks scored by the set of students who worked individually.

A consistent behavior is observed in the group marks of all tests indicating a better performance of students working in groups as compared to individuals, a fact augmented by group mean of 6.72 compared to individual mean of 6.21.

The t-test conducted at an acceptable alpha level of 0.05 was found to be significant at 1.2 with $p < 0.002$. The hypothesis that groups perform better than individuals was further strengthened by the analysis of the covariance based on which the F value was significant at 1.06 at the same alpha level where p was < 0.02

Each student undertook the group learning and individual learning exercises alternately and the element of chance in performance is obviated. Thus it is safe to conclude that group performance is much better and learning is enhanced as compared to individual efforts. Learning achievement was higher in critical thinking items compared to recall type items. Even in the exercise No. 4, where individuals scored better aggregate marks in comparison with group marks, it is noticed that they did better in groups in the critical thinking items. This confirms that better learning is achieved through discussions, exchanging views, seeking clarifications from peers in groups of mixed professional backgrounds.

6. Applicability for Professional Development of Shipboard Engineers

6.1 On-the-job learning in the social setting on board

Successful completion of mandatory pre-sea courses at their MET institutions is only the initial phase of professional education and learning for marine engineers. The second phase of learning, rather the professional learning phase, through application of learnt knowledge and skills in actual work environments starts when the prospective marine engineers take on the role and responsibilities of operators aboard ships. This phase of professional development through on-the-job learning occurs through their participation in a social practice. This social environment is disparate than the one at the educational institutions. Akin to apprenticeship, at least in the initial stages of shipboard employment, professional learning is formalised by a progression through tasks of increasing accountability [26]. Through their successively widening responsibilities for operating equipment of greater complexity or performing task where wrong actions can have significant consequences, they are gradually exposed to the unique characteristics of various shipboard engineered systems, normal working parameters and deviations thereof. Maintaining currency of safe operations requires them to routinely assess the operating conditions and the influence of work environments, select the course of action in cognizance with specific rules, procedures and traditional practices peculiar to their ship. This allied with demands for continuous confirmation or modifications of previously learnt concepts progressively adds to their repertoire of knowledge, skills and experience, an essential element in professional development.

6.2 Need for collaboration in the machinery spaces

Performance goals, activities and the social setup are unique to each ship's machinery spaces. They are dynamic and under the organizational and environmental influences keep changing with time and get accentuated due to turnover of the engineering staff. This makes the socio-technical setup on each ship a unique and dynamic amalgam of varied levels of professional knowledge, skills and experience. Each technical problem even when occurring on an identical system, sub-system or a piece of equipment is unique because of its deterministic variants and situational characteristics caused by technical, organizational and environmental influences in that particular case. Operational action in a particular situation or on equipment on one ship is not necessarily applicable to the equipment of the same make on another ship due to its individual characteristics and asymmetric situational context. The mental model based on the previous knowledge and experience that the engineers hold needs to be recreated or modified in the changed work environment.

When joining the next ship, after completing tenure on the previous one, the marine engineers are continually required to assimilate nuances of their new setup. This occurs formally as well informally through familiarisation, instructions, guidance, formal or informal talks, over hearing, observing other's actions, self exploration and through interaction with peers. However if the exchange of information and knowledge is formalised they can create a structure, a blueprint or a mental model for understanding of similarities or discrepancies enhancing their familiarity with various situations. Need for such exchange can hardly be disputed as it is almost unlikely that each one in the team of engineers has faced a particular situation in his/her past shipboard experience. Such an exchange increases the individual capacity of team members to act more appropriately in proximate situations for benefit of efficiency, personal safety and the shipboard safety.

6.3 Learning through collaboration in the work environment

In absence of guidance, mentorship or peer help through amicable social interactions in work place the learning of professional acumen by the incumbents is by hit-and-trial method i.e. learning through mistakes. An engineer faced with a novel situation or condition of an equipment or a part thereof makes his/her conclusions relying on personal repertoire of knowledge experience and available documented information and would like to seek affirmation to his/her conclusions. Without any feed back or reinforcements on the validity of his/her perception he/she is in a dilemma whether his/her conceptual assessment is right or wrong and the degree of its correctness or otherwise. That people are social creatures who like to talk with each other about topics of common interest [27] is squarely applicable to the engineers on board especially under such conditions of ambivalence.

Need of knowledge exchange on the engineered system, organizational set up and working environment specific to the ship through mutual coordination cannot be over emphasized. Formalized systematic collaboration among team members facilitates transfer of pertinent information from those who have to those who need it, with all the benefits of collaborative involvement. Such peer collaboration for learning, aside from sharing knowledge of systems characteristics, is also extended to solving technical problems, risk assessment and risk management utilizing the strength of varied knowledge and experience of all the team members. In absence of deliberate, systematic and formal transfer of knowledge through interactions the learning still occurs but in a fragmented manner, at uncertain pace and at times at the cost of efficiency, damages, personal safety and even ship safety.

If collaborative learning is to be applied on board it has to be conceptually different than that in a class room scenario. The team of shipboard engineers would need to assume the responsibility of leading as well as controlling the coordination activities within the group to achieve learning objectives, which are also to be set by the team. If the MET institutions do not apply collaborative learning techniques the engineers are not expected to have the desirable social skills necessary for application of collaborative learning process on board. Desirability of applying collaborative learning techniques in shore MET level is emphatically perceptible.

7. Conclusions

Research has identified that inadequacy of professional knowledge is one of the factors responsible for shipboard accidents. Diversity in MET standards, methods of curricula delivery, assessment procedures and employment pattern of marine engineers constrain the process of comprehensive understanding of engineering concepts as well as learning on the job. Objectives of MET generally confine to providing specified generic engineering and seamanship knowledge with some basic skills to perform tasks on board. The teaching methods adopted for achieving these objectives however fall short of the processes that could inculcate skills of learning.

Better learning is achieved through group-based learning methods. Application of collaborative learning techniques in the MET institutions would promote students' comprehensive understanding of subject matter which is an essential feature for transfer of learning to work situations. It will also help them in developing skills of learning, cooperation and team work, the desirable personal attributes for shipboard duties.

Specific knowledge of the engineered systems and influence of work environment are unique to each ship. All possible operational problems, machinery conditions and work situations cannot be perceived, documented or studied for prescribing solutions. Every engineer cannot get an exposure to all perceivable situations, however amongst the team of engineers on board there is a unique wealth of knowledge and experience that must be shared for mutual learning and sound professional development. This needs to be achieved through formal application of a suitable variant of collaborative learning on board ships.

Implementation of collaborative learning principles for marine engineers' learning and development on board will require a suitable strategy, a framework for its effective application, guidance and training. This calls for further research that would explore feasibility of its application, to develop suitable strategies and procedures for its application for the benefit of marine engineers and safety of ships, persons and the environment.

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