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Using a Low-Fidelity Wargame for Training Fleet-level Command and Control in the Classroom

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***Abstract*—Today, the military increasingly rely on simulators to support training and education. One reason for this is simulators are seen as a cost-effective to achieve realistic training. Modern simulators can replicate almost any aspect of the real world, a development in part driven by the implicit assumption that the better the simulator, the better the training. But does higher fidelity necessarily lead to better learning? Recent research point in an alternative direction - it is not the quality of the simulator that determines the quality of training, but rather how well the simulator is integrated in a larger training setting. This paper presents an attempt along these lines - the simple surface warfare model (SSM). SSM is a low-fidelity naval wargame that has been used for several years to train fleet-level decision making skills at courses on both junior and senior officers levels. The paper begins by discussing the use of simulators in training and education. The SSM is introduced, and its integration in fleet-level decision-making courses is presented. Evaluations of the use of the wargame are presented. The paper finishes off with a discussion of how low-fidelity simulators can be used to support training and education.**

***Index Terms*—Training, Low-fidelity, Wargame, Simulator, Command and control, Decision making, Naval Warfare**

I. Introduction

Today, the military increasingly rely on simulators to support training and education. One reason for this is that simulators allow for real-world problems to be brought into training, without subjecting the trainees to the dangers inherent in, for example, live fire exercises. Another reason is that the range of missions that the military must solve today is significantly wider than before. Still, the increased task complexity must be tackled within budget constraints that have remained quite stable. Simulators are seen as a cost-effective way to meet both these requirements.

Modern simulators can replicate almost any aspect of the real world, a development that in part has been driven by the implicit assumption that the better the simulator, the better the training (Salas, Bowers, & Rhodenizer, 1998). But does higher fidelity necessarily lead to better learning? Recent research point in an alternative direction (Salas et al., 1998; P. Alexander, Kulikowich, & Jetton, 1994; Ricci, Salas, & Cannon-Bowers, 2002) - it is not the quality of the simulator that determines the quality of training, but rather how well the simulator is integrated in a larger training setting. This paper presents an attempt along these lines - the simple surface warfare model (SSM). SSM is a low-fidelity naval wargame that has been used for several years to train fleet-level decision making skills at courses on both junior and senior officers levels. The system has purposely been designed to only include a minimum level of detail, with the rationale that that less detail means less development costs, less time to trains students in using the game, and less time for the instructors to set up a scenario.

The paper begins by discussing the use of simulators in training and education. The SSM is introduced, and its integration in fleet-level decision-making courses is presented. Following that, evaluations of the use of the wargame is presented. The paper finishes off with a discussion of how low-fidelity simulators can be used to support training and education.

Simulators as training tools have been approached from different points of view, but two major strains of research can be discerned: the engineering perspective and the psychology perspective. The engineering perspective have focused on developing the technology required to create simulators and have reached a level of realism that possible to recreate almost any artifact (Salas et al., 1998). Needless to say, it is the aviation industry that have been pushing towards more advanced simulators, but during recent years high-fidelity simulators are finding their way into every branch of the military - army, navy, and air force - which becomes evident if one visits military simulation and training conferences[1].

Psychologists have also approached simulators, but instead focused on trying to understand how people acquire knowledge in complex environments. Research in areas such as cognition, training, practice, feedback, and performance measuring have progressed (Brannick, Salas, & Prince, 1997; Ford, Kozlowski, Kraiger, Salas, & Teachout, 1997; Zsambok & Klein, 1997), and today there is a considerable amount of literature that describe the processes involved and what is required to learn complex tasks, both for individuals and teams (Salas, Bowers, & Cannon-Bowers, 1995).

Despite progress in both fields, there seems to have been little consideration of how the knowledge acquired within the field of learning should be applied to simulator based training. Apparently the focus has been on designing the simulators

[1] E.g the annual 'Interservice/Industry Training, Simulation and Education Conference'

to provide the maximum level of realism, with the implicit assumption that this would make the trainees learn, instead of focusing on how the simulators should be designed to support learning of the required skills and knowledge (Salas et al., 1998). During the last decade, however, researchers have started urging for a shift in perspective, from a focus on the simulator to a focus where the simulator is viewed as a tool for training. A tool that must be incorporated into a wider view of training that takes into account other principles derived from training research (Salas & Cannon-Bowers, 1997).

Training is a systematic way to acquire knowledge, and because of that one must realize that just spending time in the simulator is not enough. Several other aspects must be considered. First, feedback must be incorporated in the training (Brehmer & Joyce, 1988; Jacobs & Dempsey, 1993; Kluger & DeNisi, 1996). It must also be possible to measure the performance of the trainee to determine the effects of the training (Cannon-Bowers & Salas, 1997; Prince, Brannick, Prince, & Salas, 1997). If higher levels of expertise is required then deliberate training, or guided practice, must be allowed for (Smith-Jentsch, Payne, & Johnston, 1996; Ericson, Krampe, & Tesch-Römer, 1993). It is also necessary to design training scenarios that challenges the trainee with appropriate situations at an appropriate level of difficulty (Johnston, Cannon-Bowers, & Jentsch, 1995). Further, the simulator has limited capability on its own to teach new knowledge and skills to trainees (Gredler, 2004). For the training to be effective it is necessary that the trainees first have acquired basic knowledge in the field the simulator training is targeted at (P. Alexander et al., 1994; Clark, 1994; Dochy, Segers, & Buehl, 1999). This is especially important if the focus of training is on meta-cognitive skills, i.e., planning, evaluating, and monitoring one's own thinking (Davidson & Sternberg, 1998; Holyoak, 1995; Sternberg, 1998). It seems that a shift in focus from the simulator to the trainee allow for a new perspective on the simulator. Instead of designing it to replicate every bit of the target domain it can instead be designed to allow for the best possible learning.

Despite this observation, there are two assumptions that still govern the practice when using simulators as training tools (Salas et al., 1998). First, is the apparently firm belief that the higher the fidelity of the simulator, the better the training. The second assumption regards a misconception that training received in a simulator is good if a subject matter expert thinks the simulator is good. Beginning with fidelity, its relation to transfer was investigated in a review by Alexander, Brunyé, Sidman, and Weil (2005). They identified several aspects of fidelity, where each aspect of fidelity describe how well a simulator replicates the target environment on a particular dimension, e.g. physical, functional or psychological. (Alexander et al., 2005) points to studies, i.e. (Rolfsson et al., 2002; Repperger, Gilkey, Green, LaFleur, & Haas, 2004), that suggest that high fidelity haptic feedback can be effective when training laparoscopic skills and F-16 landing procedures. Despite these two observations of positive effects of high fidelity, Alexander et al. (2005) concludes on basis of the rest of their analysis that "if the level of fidelity captures the critical elements [and] properties of the skills [and] tasks you wish to teach, that level of fidelity is sufficient *even if* it noticeably deviates from the real world" (Alexander et al., 2005, p.6)[2].

This view on fidelity is supported by Salas et al. (1998) who also contests the assumption that high fidelity automatically transfers to better training (also pointed out by Dion, Smith, & Dismukes, 1996; Roscoe, 1980). They point to aviation studies that suggest that higher scene detail does not lead to better flight skills in the aircraft (Taylor et al., 1993) and that positive transfer is actually higher under conditions of low scene detail compared to medium detail (Taylor, Lintern, Koonce, Kaiser, & Morrison, 1991). Salas et al. (1998) follows Flexman and Stark (1987) and conclude that complete physical is rarely needed, but should instead "be dictated by the cognitive and behavioral requirements of the task"(p. 202). This opinion is further supported by Estock, Stelzer, Alexander, and Engel (2009) that showed no performance difference between training received in a high-fidelity simulator compared to a low-fidelty in a pre test-post test study of F-16 fighter pilots. Jentsch and Bowers (1998) and Koonce and Bramble (1998) also describe how low-fidelity simulators could be used effectively in aviation training.

The second assumption regards how to evaluate the training received in the simulator. Traditionally training has been evaluated by asking the trainees how they experienced the training (Salas et al., 1998), for an example see evaluation by (Lif, Frank, & Lundin, 2011). The problem with this kind of evaluation is that there is no significant relation between trainees reaction to a simulator and their subsequent performance (Tannenbaum & Yukl, 1992; Estock et al., 2009). Because of that Salas et al. (1998) suggest that training should be evaluated in relation to the learned performance instead of how well the simulator performed.

Salas et al. (1998) also points to early research regarding evaluation of training, i.e. Kirkpatrick (1959), that suggests that simulation based training programs should be evaluated on several levels - reaction, learning, behavior, and results. Reaction refers to the students own thoughts of the training. Learning refers to measured progression towards the training objectives specified beforehand. Behavior refers to determining if the student will perform the behaviors learned in training when doing the actual job. Finally the level results refers to the impact of the training in relation to organizational goals. This view of how to perform evaluation is also supported by Cannon-Bowers et al. (1989) and Stout, Salas, and Fowlkes (1997).

Despite today's general focus on simulator fidelity there are not much evidence to support the claim that increased fidelity would increase the quality of training. On contrary, when comparing the effect of fidelity to other aspects of training, such as pre-training, feedback, and performance measurement, it becomes evident that effort instead should be invested in how the simulator should be used as a tool to support the larger

[2][and] inserted to increase readability

training program - the simulator alone does not provide any learning, the training program does. Thus, current research seems to imply that a low-fidelity simulator integrated into a well structured training program would provide for better training than a stand-alone high-fidelity simulator. The focus of training should be on what the trainee should learn and then let those requirements govern the design of the supporting equipment.

This paper presents an attempt along those lines - the low-fidelity naval wargame SSM. SSM has been used for several years in training tactical thinking at junior and senior levels at the Swedish war college. The paper describes how the simulator is used as a training tool in courses that teaches tactical thinking to students, and our experiences from using it.

II. The wargame

SSM is a multiplayer naval wargame designed to let players take on the role as fleet commander and execute various missions assigned by higher command. The game focuses on the higher command levels of naval warfare, which means that the players face problems on squadron, flotilla, or fleet-level, rather than the tactical problems at group or ship level. Further, the game is designed to let the players engage in multi-sided encounters, thus experiencing the decision problems generated by facing one or more human opponents.

The current focus of SSM is naval warfare, but the gaming system itself is designed as an open sandbox. This means that it is they who create the scenario that decide which units to be defined and used in the game. All units are created using a flexible scenario editor and there is nothing that prevents, for example, that an armored vehicle, an infantry division, or a group of attack aircrafts are modeled and used as playing pieces in the game. Thus, it is possible to create land, air, and naval warfare games as well as any combinations of those.

To set up a game, the instructors have to decide on where the game should take place, what the missions are for each side, and what units each side are controlling. The instructors then uses the scenario editor to set up the map and the units to use, assigns units to each side, and drags the units to their starting positions. The scenario is loaded into the server and each side connects to the server through their clients.

In SSM each side only sees what the units on that side see. This means that the player must use the sensors on his or her units to survey the operations area and establish the location of the other players' units. To free the player from the nitty-gritty details of merging sensor data, the SSM automatically compiles a common operational picture for each side, using the data provided by the sensors on that side. At any moment, the common operational picture is the best possible view of the surroundings that a player has.

The SSM gaming system consists of three separate programs. There is the game server that runs scenarios and to which clients connects. There is the game client from which the players control the units on their teams. Any number of clients can connect to each team and if desired, different clients can be configured to handle only a smaller part of the units on the team. In that case the client only gets the COP created by the units controlled by the client. Finally, there is the game editor in which the games are set up.

In the game the player gives orders to subordinate units by pointing and clicking. A unit can be ordered to go somewhere, turn a sensor on or off, or fire a weapon. It takes about two hours for a player to learn the functionality of the game. After that they control the units effortlessly and can instead focus on the fleet level decision-making, i.e. what needs to be done to succeed with the current mission.

III. Context of use

The SSM has been used in several courses over a period of four years to give students theoretical and practical knowledge of how to plan and execute naval operations. In addition it has also been used as an experimental platform for investigating the decision-making strategies of experienced navy commanders and as an analytical simulation for supporting course of action development and evaluation in operational planning courses. The courses have been on junior level, i.e. cadets graduating as ensigns, and senior levels, i.e. lieutenants graduating as lieutenant commanders and lieutenant commanders graduating as commanders.

The courses have been designed with the purpose to give the students theoretical, as well as practical knowledge about naval operations. The level of the courses have of course differed depending on the level of experience of the students, but the general course arrangement is similar. The complete course stretches over eight weeks. During the initial four weeks, theoretical concepts from operational art and doctrine, together with leadership and international law are introduced and discussed in a classroom setting. After that, the students are divided into smaller teams of five to six people. Each team then use the theoretical concepts as guiding principles when designing a plan for naval operation during one week of planning. The plan is executed several times in one week of play in SSM. The last three weeks the students use the results from the the game week to analyze the practical experiences from the game in relation to the theoretical concepts discussed in the classroom, in a series of essays and exams.

A. Scenario

As said in the introduction, the SSM is an open sandbox, which means that virtually any naval mission including any number and types of units can be played. Different scenarios have been used in the courses, but to get a general appreciation of the task the students have to solve, one scenario will be presented. The scenario takes place in the Mediterranean, between the island of Sicily and the coast around Naples, Italy. The mission given to the naval component is to transport one armored brigade from the city of Palermo on Sicily and land it in ports in, and around, the city of Naples in Italy (see Figure 1). The purpose of the operation is to support an northward offensive on the Italian mainland. The naval component consist of about thirty ships - transport, surface warfare,

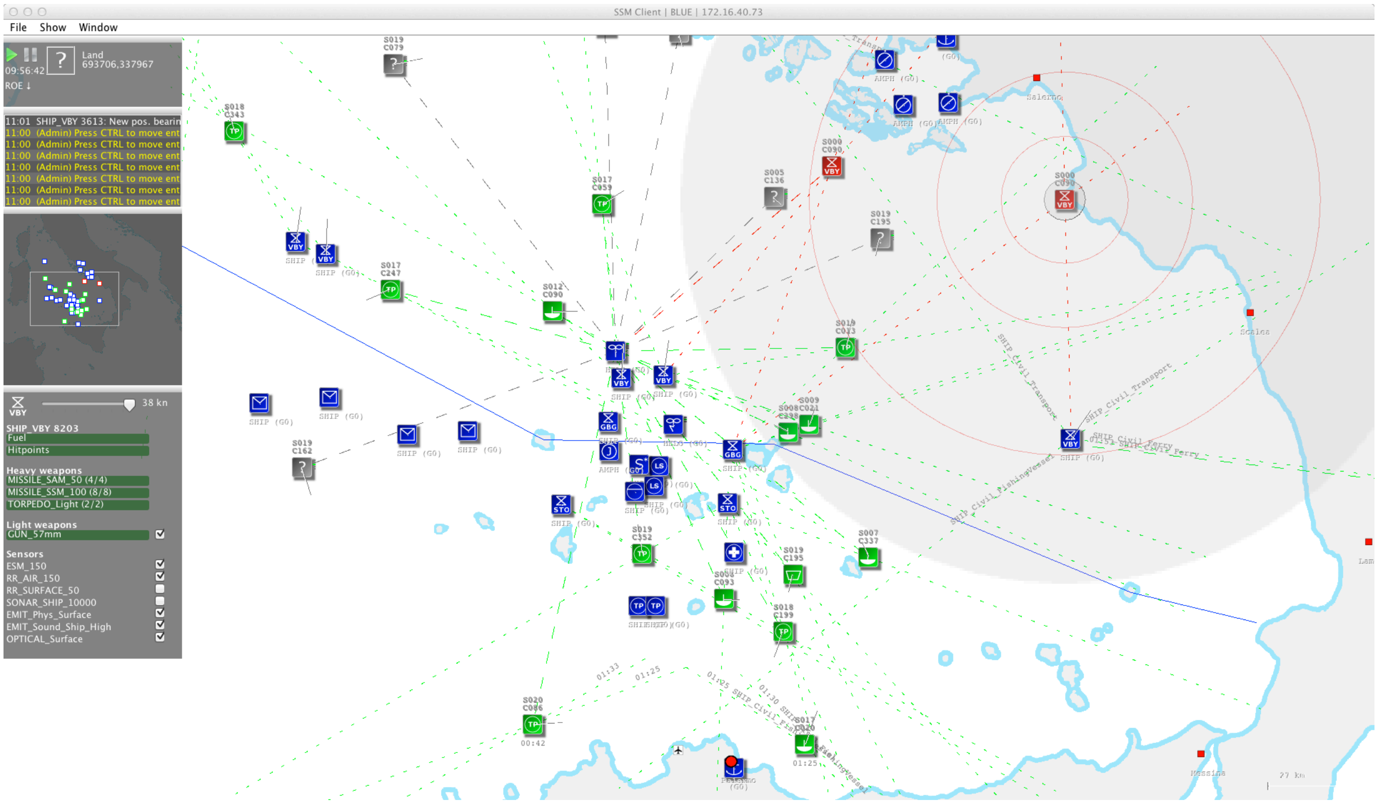

Fig. 1. The player sees only what the units on his or her side see. The information provided by the sensors on the units are compiled to provide the player with a common operational picture of the operations area. The mission for the player in the scenario is to escort an armored brigade from the city of Palermo on Sicily (on bottom of the screen) to ports in, and around, the city of Naples (at the top). The terrain around Naples and Sicily has been modified, archipelago regions have been added, to include problem associated with littoral environments in the scenario.

anti-submarine warfare, anti-air warfare, mine-clearance - supported by submarines and helicopters. Amphibious forces are loaded onto amphibious assault ships, their task is to secure a beachhead for the main transport. Intelligence states that red forces are present in the area, and that they have units of the same capacity as the blue force, but approximately only one-third in numbers.

B. Planning week

At the beginning of the planning week, each team receives the scenario description, intelligence reports, the order of battles, and a mission statement. They are instructed to prepare one blue course of action and as many red alternatives as they see fit. Usually they prepare one 'most probable' red course of action, and one 'most dangerous'. The focus of planning is, however, on the blue course of action. The decision making procedure they used is the 'planning under time pressure'-procedure (Thunholm, 2005) and an additional objective of the week is that the students become apt at using this planning method. The use of the method have been trained on another scenario in a step-by-step fashion in the weeks preceding the planning week, and the planning week serves as the students first

C. Execution week

The wargaming week starts with a general presentation of the SSM. The core functionality is presented during a one hour classroom session. Immediately following that, the teams go to separate rooms where they may organize the staff as they seem fit and are given time to setup maps and other documents they need. The rooms are each equipped with four SSM clients where at last one is displayed on a wide screen so the whole staff can see it. When they are ready, a two hour training session starts where the objective is to train the students in how to use the functions in the SSM.

After training, the first round of execution begins. The staffs are paired, one against another, where one staff plays blue side and the other plays red. Neutral units are played by the instructors. An experienced instructor follows each staff for the whole session, taking notes to be used in the debriefing and intervening with questions if necessary. The pace of the game is set to fit the blue staff, and in general it varies between real-time and an acceleration of 1:20 (one hour of game time takes three minutes). The game continues for about 3 hours, or to a point where it becomes evident if the blue side will succeed or fail.

Immediately after the game, the staffs are given fifteen minutes each for internal debriefing. During the debriefing they answer questions roughly resembling those proposed by

Pliske, McCloskey, and Klein (2001), e.g. What were the tough decisions? Why were they difficult? What would you do differently if you were in this situation again? Another set of question regarded the plan itself. Did you execute the mission according to plan? If not, why did you change? What is necessary to change if the plan would be executed again?

After the internal staff debriefing, the opposing teams meet and they are given time to provide their different views of the operation. This part of the debriefing is more unstructured, and the staffs may discuss the operation at any level of detail. The debriefing is concluded by the instructors who give their view of the performance of the staffs. After debriefing, the staffs returns to their rooms and another game session begins. In this session the roles are switched - the staff that was blue last game now played red and vice versa. The game and following debriefing sessions are otherwise conducted as described above.

After each staff has played one round as blue and one round as red they are given one day for replanning. During replanning they get the opportunity to make any adjustments to the plan, based on the results of the initial games. The following day, the staffs executes their plans once again in the same way as they did the first, including debriefing sessions. The only difference is that they do not play against the same staff as the first day. The week is concluded with one day of debriefings where the staffs and instructors are given time to discuss issues that were experienced during the games.

D. Evaluation weeks

During the evaluation weeks, the students wrote essays in which they related the theoretical concepts of operational art, international law, and leadership to the practical experiences received when playing the game. In operational art the students selects two principles of warfare, e.g. element of surprise or concentration of force, and describe how these principles applied to execution of their plan. In a similar way, issues regarding international law that were encountered during play, and issues regarding leadership and ethics are discussed in separate essays. The evaluation weeks finish with several written exams.

IV. RESULTS

The use of SSM has been evaluated on several occasions and from several perspectives. One obligatory evaluation is conducted at the end of each course, and is based on the students subjective experience of the course. At the end of each course the students fill in evaluation reports in which they give their opinions on the instructors' performance, how clear the course objectives were, if the exam focus on understanding instead of facts, the workload, and how well they developed general skills. They are also requested to give free-text descriptions of what they experienced as the best part of the course, and what they think has to be changed in the future. Another obligatory evaluation is conducted by the instructors. The instructors give their opinion on the outline of the course, the course objectives, the literature, and the exam. The students further write several exams which are graded by the teachers. The exams consist of both classroom tests, as well as essays.

The SSM have also been evaluated in other contexts. In one course at junior level, Lif et al. (2011) administered several questionnaires to the participating cadets and the results of the study was presented at ICCRTS 16. Waldenström (2010) used the SSM as a microworld and had highly experienced naval officers (Lieutenant Commanders to One-Star Admirals) plan and execute a naval escort mission. As part of the study the participant gave their opinion of how well the microworld recreated the decision problem the participants had faced at sea. The results was reported at ICCRTS 15. During a senior course, pre-exercise – post-exercise interviews were conducted with both participants and instructors to investigate what the participants believe they learned from playing a two-sided naval wargame (Waldenström, 2012).

The following part will focus on the SSM, and consequently, evaluations regarding the literature, the performance of the instructors, and such will not be discussed, unless it is relevant in regard to the use of the wargame. Beginning with the senior course, twenty-one navy lieutenants, graduating as lieutenant commanders, with approximately 10-15 years experience from active duty answered the obligatory evaluation and the results suggested that the students believed that trying out the theoretical and abstract concepts of operational art of war in a planning and execution exercise was good (Egnell, 2010). When asked to express what they thought was the best part of the eight-week course, sixteen out of twenty-one explicitly stated the wargaming week. In the same evaluation, the instructors stressed the importance of using the game as a tool to allow the students to get practical experiences of the complexities inherent in a naval operation. The game served as a "simulated simplified reality where the students got a chance to try out their thoughts and knowledge" (Egnell, 2010, p.3, translated from Swedish). As a result, they started to reflect upon what they have learned and how that knowledge could be applied to their future work. Further, the instructors also believed that the quality of the students' essays had increased since the wargame was introduced as part of the course.

In the study by Lif et al. (2011) twenty-seven cadets rated items on a seven step Likert-scale regarding five concepts; learning experience, feedback, influence on real situation, and immersion. The results suggested that the cadets experienced the learning and the feedback in the wargame as high (five and above on the seven step scale), experience of playing the game was above six, realism was rated medium (between four and five) and engagement in the game above six. Lif et al. (2011) concluded that both students and instructors believed SSM to be a useful tool for teaching marine tactics to cadets, the game succeeded in being a good representation of naval warfare at the same time as it was engaging.

In a decision-making study of experienced naval commanders, Waldenström (2010) had six participants rate how well the SSM replicated the decision problems the participants faced during their active duty at sea. The participants responded on a six-step Likert-scale (1='Not at all', 6='To a very high degree'), with a mean result between four and five.

Waldenström (2012) conducted pre-exercise – post-exercise interviews with the participants at the senior course discussed above. The instructors were also interviewed, but only once. The purpose of the study was to identify what the students and the instructors believed that the the students learned from playing a two-sided, low-fidelity naval wargame. Preliminary results suggest five areas in which they believe learning occurs: the *duel*, *dynamic decision making*, *command and control*, *naval tactics*, and *staff work*. The duel refers to the challenges of facing a thinking opponent, i.e. how Clauzewitz describes it. Dynamic decision making refers to the problems related to handling the inertia and the delays inherent in a naval warfare, a well known problem from that field of research. Command and control refers to the task of executing a plan, laying out new objectives as the situation requires, and deciding out what tasks to execute, and when and who should do it. Finally, staff work relates to insights of how to best organize a staff to solve a certain problem.

To summarize, SSM seems to provide a good environment for learning naval tactics. The lack of fidelity does not seem to obstruct the students from acquiring the knowledge the course aims at teaching, which suggests that the system seems to have captured the central decision problems of the naval warfare domain. An important observation, however, is that it appears that SSM alone does not provide learning. It is instead when the gaming system is treated as a tool that provides practical experiences to the students, and is integrated into a larger learning context, that learning can take place in relation to the course's learning objectives.

V. Discussion

This paper presented a naval wargame that had been used to support courses in naval tactics in a classroom setting. The game had purposely been designed to be a low-fidelity representation of naval warfare. The rationale behind that was that low-fidelity would reduce development costs, time to train the users before using the system, and less time required by the instructors to setup a scenario. The wargame has been used in several courses and the evaluations of the system suggest that it has have provided a good environment where the students are allowed to experience some of the decision making problems facing a naval warfare commander. It was further suggested that learning was not a direct consequence of playing the game, but rather occurred when the decision dilemmas and the results experienced in the game was related to the theoretical concepts taught in the classroom.

Despite that current development within the simulator industry pushes towards ever increasing fidelity the results of this paper suggest that it is not only the fidelity of the simulator that influences the learning of skills and knowledge - a low-fidelity simulator can also be an effective tool. This suggestion adds further evidence to claims that fidelity is not the key issue, but rather how well the simulator is integrated into a larger learning context (Salas et al., 1998; P. Alexander et al., 1994; Ricci et al., 2002). To be effective other activities of learning must be included, such as feedback, performance measurement, and deliberate practice, to mention a few.

Kirkpatrick (1959), Cannon-Bowers et al. (1989), and Stout et al. (1997) have suggested that simulation based training programs should be evaluated on several levels - reaction, learning, behavior, and results. The evaluation of SSM have, so far, predominantly focused on evaluating what the students experience when playing the wargame. Such evaluations are important, because subjective aspects, such as engagement and immersion, also influence learning (see for example Garris, Ahlers, & Driskell, 2002). The way students experience the simulation has, however, showed no correlation to subsequent performance in the trained task. Thus, those evaluations rather becomes an evaluation of the simulator and not of the student.

The student's progress towards the training objectives, learning in Kirkpatrick (1959)'s taxonomy, has been measured using the normal tools used in classroom education, i.e. essays and written exams. Nevertheless, it is hard to draw any definite conclusions regarding the effectiveness of the wargame since the evaluations, so far, has not been experimental. No comparison between a condition with teaching with the wargame, compared to a condition without it has yet been conducted. Anecdotal evidence obtained from the interviews with the instructors suggest that the quality of the written essays have increased as a result of introducing the wargame in the courses but such evidence is vague. Nevertheless, this observation gives some reason to initiate future studies to investigate this issue.

To conclude, this paper suggests that low-fidelity simulators can be effective training instruments, if they are treated as tools to support a larger training setting - alone the simulator does not provide learning. Instead, traditional training activities such as feedback, guided practice, and deliberate training, are vehicles for learning where the experiences gained while playing the wargame are transformed into knowledge. This knowledge can then be used when solving other problems within the target domain. Nevertheless, before anything more conclusive is said about the effectiveness of the wargame it must be subjected to an experimental evaluation.

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