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A Study on the Effects of ARPA/Radar Simulation Training

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Abstract : *In this study, a survey was conducted among students who received ARPA/radar simulation training in order to verify the effect of training. An effective training method based on the analysis results was also proposed. Furthermore, this study analyzed full mission simulation conducted over one semester, and found that training effect increased as time passed. The survey showed improvement in skills related to radar/ARPA utilization, ARPA decoding, ship handling, and overall skill. Students responded practical skills improved more than theoretical knowledge, and also analysis showed that ship handling skills had a larger effect than radar decoding skills on improving overall skill, therefore proposed that theoretical education regarding the functions of radar and ARPA should be reinforced in ARPA/radar simulation training.*

Key Words : *ARPA/radar simulation, Training effect, Training method, FMSS, Marine transportation*

1. Introduction

Automatic radar plotting aids (ARPA) and radar simulation training is part of a legal compulsory education that officers must receive in order to work on-board ships. This training aims to familiarize trainees with radar operation and functions. Maritime education institutions are required to be equipped with radar simulation and ARPA set equipment as described in Attachment 18.1 (Facility Requirements for ARPA Training Curriculum), in accordance with Attachment 17.1 (Facility Requirements for Radar Simulation Training Curricula) and the International Convention Code A-1/12 (Simulation Performance Criteria). Maritime education institutions in South Korea have installed the relevant facilities in order to satisfy these requirements and, recently, are using a full mission simulator system (FMSS), which includes a radar simulator and ARPA set, for ARPA/radar simulation training.

According to the guidelines for VTS simulation training, VTS operators in South Korea currently participate in simulation based training programs (Jung and Song, 2010). For leadership and management skills education, in accordance with International Maritime Organization (IMO) model course 1.39, simulation training is included as part of a mandatory course. Also, more than half of all ship handling simulation (SHS) training for captains and chief officers is conducted using FMSS.

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The concept of a simulation training system refers to state-of-the-art ICT convergence technology that enables safer and less expensive education and training than on-site training by simulating an environment that is similar to an actual manufacturing, national defense, medical, or disaster scene (MOTIE, 2014). In 2018, the overseas market for simulation was estimated to be worth 88.4billion USD and the South Korean market gained a 1,908.5billion KRW investment. Simulation training systems are expected to grow as a high added-value industry in the near future. However, due to the characteristics of marine transportation, maritime simulation training systems need to recreate vessel movement on the water and are more difficult to develop than land simulation systems. As a result, they receive less investment for research and development from the government compared to other fields such as manufacturing, national defense, and disasters. They are also less researched than medical simulation systems.

So far, the only study on maritime training using FMSS was Park`s “Study on the Standardization of Education Modules for Radar Simulation” (2016), which made curriculum suggestions but did not fully investigate the effects of these training and evaluation methods.

Therefore, this study verified the effects of ARPA/radar simulation training by conducting a survey among students who received the training and proposed an effective training method based on analysis results. Also, the effects of field training based on simulation training provided over one semester were analyzed in order to generate basic data for the development of more practical simulation curricula in the future. Based on these findings, we aim to develop a systematic simulation training method and evaluation module for the purpose of providing students with learning results that can be applied in the field.

2. Analysis of Curriculum

This paper analyzed and explained the background and procedure of ARPA/radar simulation training. The simulation scenario used in this study for the verification of training effects is also described.

2.1 Necessity of Training

The curriculum for ARPA/radar simulation training is defined by the relevant domestic and international guidelines, and the subjects of training overseas are selected based on the STCW Convention and IMO model course (IMO, 2010; Maritime Training Centre Equator, 2017).

In South Korea, the curriculum is decided by a designated educational institution according to the Ministry of Oceans and Fisheries Notice (MOF, 2017), and the content is the same as for the STCW Convention.

Maritime education institutions in South Korea provide 8-day (64 hour) training according to the Enforcement Rule of Ship Officers Act (Korea Ministry of Government Legislation, 2017) and relevant domestic and overseas guidelines (SOA, 2017), but there is no specific standard related to training subjects. However, the Park`s “Study on the Standardization of Education Modules for Radar Simulation” (2016) researched specifications for the training subjects and curriculum.

2.2 Training Procedure

In this study, training was conducted among students at K University for one semester (8 weeks) with four hours per session or 64 hours in total. In Week 1, the students were familiarized with the radar, ECDIS, and simulation operation methods of the new simulation model. During Weeks 2 to 4, ARPA plotting was taught using videos and plotting sheets. Subsequently, for practical ARPA/radar simulation training, simulation was conducted according to a designated scenario.

This simulation training was based on role playing and, students familiarized themselves with exercises through a preliminary briefing and developed route planning. Once training was complete, a simulation was conducted and evaluated the simulation by debriefing.

2.3 Training Scenario

To foster efficient navigational competence, a scenario was created based on actual sea circumstances with large port traffic in Korea and elsewhere. Table 1 shows the details of such a scenario (Park, 2016).

Table 1. Scenarios for ARPA/Radar Simulation

No.	Waterway Name	Ship
1	Singapore Strait	Container Ship
2	Busan - Gadeokdo	Container Ship
3	Busan New Port	PCC
4	Port of Incheon	VLCC
5	Dover Strait	Chemical Tanker
6	Port of Hong Kong	Bulk Carrier
7	Kanmon Kaikyo	Container Ship
8	Shanghai	PCC
9	Bisan Seto	Chemical Tanker
10	Port of Sydney	Bulk Carrier

3. Survey for Verification of Training Effects

A survey was conducted among students who completed the ARPA/radar simulation training at K University, in order to investigate competence improvement on an individual level. The survey items consisted of individual competence assessments for radar ARPA utilization, radar decoding skills, ship handling and overall skills before and after training and most and least improved skills after training. Then, survey results were analyzed based on 303 copies of the questionnaire collected from senior students who attended the simulation training course between 2014 and 2016. For data analysis, SPSS and Origin were used, along with frequency analysis, a t-test, One-way ANOVA, and regression analysis.

3.1 Frequency Analysis

Fig. 1 shows subjects’ estimation of their own skills related to ARPA/radar simulation prior th the training, divided into seven levels from worst to best. The results showed that the largest percentage of students, 27.37 %, answered that they had a “common” skill level, but there were more students who answered that they were “not familiar with ARPA/radar knowledge” (44.77 %), than those who said that they were “familiar with the knowledge” (27.87 %).

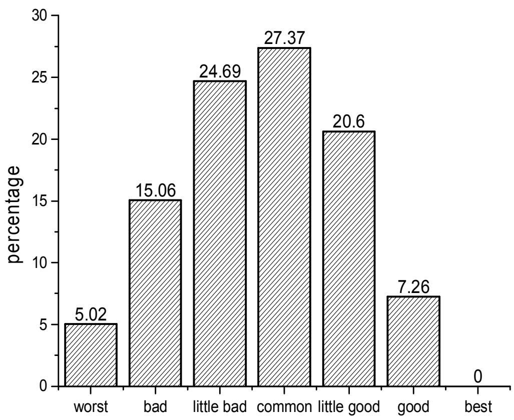

Fig. 1. Self-evaluation before ARPA/Radar Simulation Training.

Fig. 2 shows subjects’ estimation of their own skills related to ARPA/radar simulation after completion of training, divided into seven levels from the worst to best. The results showed that the largest percentage of the students, 44.46 %, answered that their ARPA/radar knowledge was “good”. Moreover, a significantly higher percentage of students (90.5 %) answered that they were familiar with ARPA/radar knowledge than those who answered that they were not (2.9 %).

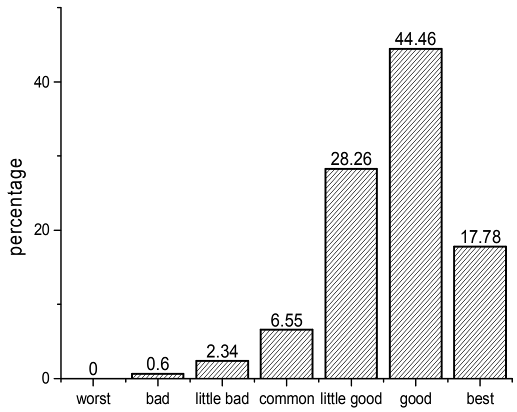

Fig. 2. Self-evaluation after ARPA/Radar Simulation Training.

T-tests for self-evaluation conducted before and after training showed that, as in Table 2, the p-value (p) was smaller than 0.001 and, therefore, the result were statistically significant.

Table 2. T-tests for self-evaluation, before and after

Classification		Mean	SD
Self evaluation	before	3.66	1.291
	after	5.66	.955
	t-value(p)	-29.230***(.000)	

***<0.001

Considering student responses that their ARPA/radar utilization skills had significantly improved after training, analysis of Figs. 1 and 2 suggests that ARPA/radar simulation training using FMSS had sufficient effects on students.

Fig. 3 shows student’ responses to the question regarding the level of improvement of their overall skills, divided into eight levels from 0.5 times to 4 times. Analysis showed that the largest percentage of students, 38.7 %, answered that their overall skills improved twofold, and only 4.58 % responded that their overall skills had not improved.

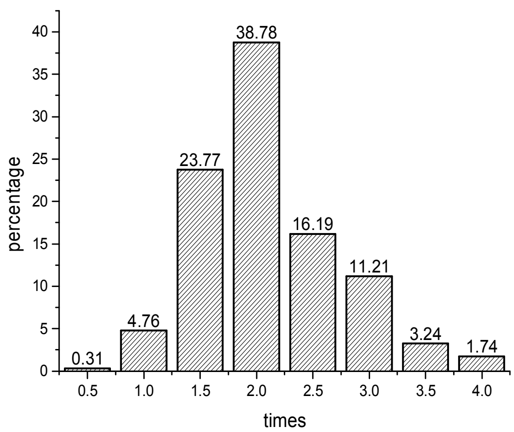

Fig. 3. Capacity improvement of ARPA/Radar/Ship handling skills due to training.

Figs. 4 and 5 show levels of improvement for radar decoding and ship handling skills, respectively. Analysis showed that, in both categories, about 40 % of students answered that their relevant skills improved twofold and only about 5 % responded that their skills were had not improved. In weekly practical training, students performed ship handling and radar operations, which seemed to have positive effects in terms of improving overall competence.

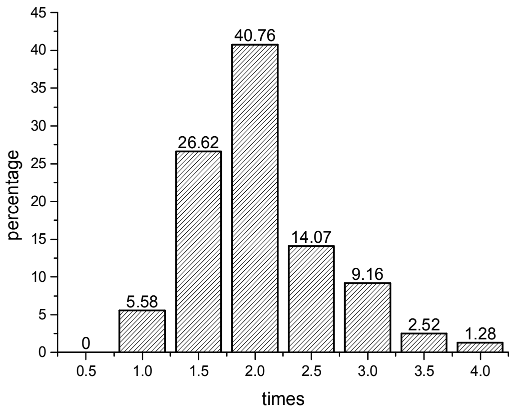

Fig. 4. Capacity improvement of radar decoding skills due to training.

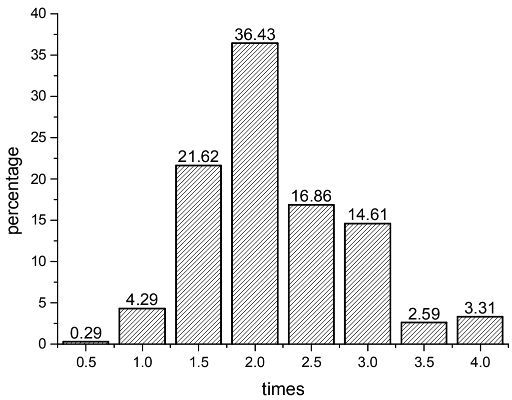

Fig. 5. Capacity improvement of ship handling skills due to training.

Table 3 shows student response percentages regarding most improved skills after ARPA/radar training. Analysis showed that students answered that their skills for collision prevention in congested waters, radar data interpretation, and radar basics and plotting, improved most, in that order.

Table 3. Skills most improved after ARPA/Radar Training

Skill Type	Percentage (%)
Radar navigation	11.87
Basic knowledge related to radar mechanisms	5.27
Radar operation skills	10.66
Radar data interpretation skills	18.88
Ship characteristics and simulator control units	8.60
Radar basics and plotting	14.43
COLREG application skills	6.46
Collision prevention in congested waters	23.83

Table 4 shows the percentages of responses by students regarding least improved skills after ARPA/radar training. Analysis showed that students answered that their skills regarding basic knowledge related to radar mechanisms, ship characteristics and simulator control units, and COLREG application skills improved least, in that order.

Skills that were used during practical training sessions seemed to have improved more, as training focused mostly on ARPA/radar simulation and less on theoretical aspects.

Table 4. Skills least improved after ARPA/Radar Training

Skill Type	Percentage (%)
Radar navigation	0.83
Basic knowledge related to radar mechanism	22.92
Radar operation skills	9.20
Radar data interpretation skill	7.56
Ship characteristics and simulator control units	21.94
Radar basics and plotting	7.72
COLREG application skills	15.11
Collision prevention in congested waters	14.71

3.2 One-Way ANOVA and Regression Analysis

Although ARPA/radar simulation training is based on a fixed curriculum, training methods can differ each year according to the instructor and educational environment. In order to analyze the effects of different training methods, data from 2014 to 2016 were compared and analyzed.

Table 5 compares levels of improvement for ship handling, radar decoding, and overall skill by year, based on one-way ANOVA. In the results, the p-value (p) was greater than 0.05, and, therefore, the null hypothesis that there was a difference between years was rejected. In other words, statistically, there was no difference in training effects between different years.

Table 5. One-way ANOVA analysis by year

Classification		Overall skill	Radar decoding skills	Ship handling skills
		M	M	M
Year	2014	4.27	4.01	4.46
	2015	4.24	3.97	4.23
	2016	4.12	4.39	4.39
	F-value(p)	0.421(.657)	1.603(.203)	0.747(.475)

In ARPA/radar simulation training, students experience not only ARPA decoding and radar operations but also general navigation skills like ship handling. In order to identify which skills students most improved during virtual navigation training based on various practical exercises, as shown in Fig. 6, we created a graph of the correlation between ship handling and radar decoding skills with overall skill. Analysis showed that ship handling skills (0.79588) had a more effect than radar decoding skills (0.67598) on improving overall skill. We believe this result was mainly due to the fact that, during training, ARPA decoding and radar operation were used as supplementary tools while students performed ship handling.

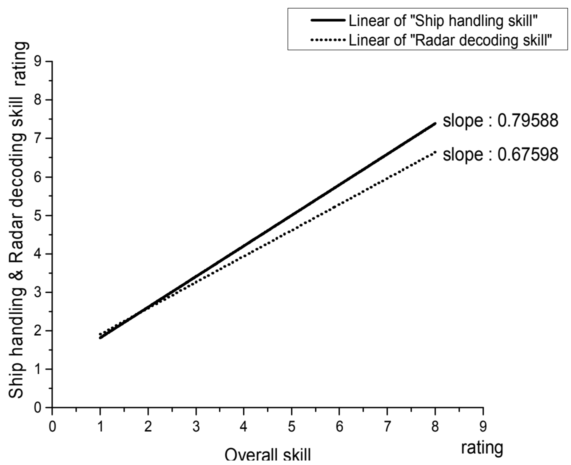

Fig. 6. Regression analysis on ship handling skills and radar decoding skill.

4. Analysis on the Effects of Simulation Training

At K University, students were divided into teams of four to five for simulation training in each class of 30 students. However, only one instructor was in charge of supervising and managing the entire class. Therefore, it is difficult to expect objective evaluation of training. In this study, we quantified and analyzed students' simulation tracks and raw data for the purpose of objectively verifying the effects of ARPA/radar simulation training. Analysis was conducted during the semester that began in March 2016 and ended in June 2016, based on a total of eight scenarios. Singapore Strait was simulated and analyzed 14 times, Busan Gadeokdo 20 times, Busan New Port 12 times, Incheon 17 times, Dover Strait 17 times, Port of Hong Kong 24 times, Kanmon Kaikyo 24 times, and Shanghai 25 times. However, the number of simulation sessions differed and the established training scenarios were not completely implemented, apparently due to the intermittent absence of students and cancellation of class due to school events.

4.1 Analysis Method

(1) Control Analysis

Control was used for quantitative evaluation of the level of difficulty with of ship handling by calculating the rudder angle used by the relevant vessel and the average engine usage and margin controlled variable.

In this study, we measured the length of time during which the limit rudder angle of 30 degrees or larger was used after facing an emergency situation due to failure to detect a risky ship with sufficient time. However, average engine usage and the margin controlled variable were not evaluated because ship navigation scenarios were performed instead of approaching handling and, therefore, vessel speed was rarely controlled.

(2) Proximity Analysis

Proximity was used for evaluating risk based on collision probability and separation distance, which were calculated based on the distance from the target point or line of estimated danger (the closest point of approach, CPA) using sample standard deviation.

In this study, we set a buoy on the course or land target where danger was expected during navigation as a reference point and measured the CPA between the main vessel and the target point in order to obtain the probability in collision of each scenario.

4.2 Weight Setting

The eight simulation scenarios used in this study involved different fairway breadths, distances from surrounding ships, numbers of course changes and crossing situations. Also, survey results showed that students perceived different levels of difficulty in different scenarios, and, therefore, it was difficult to evaluate the effects of training based on the same set of standards. In consequence, we investigated the fairway breadth, distance between ships, number of course changes, and number of crossing situations, for each scenario and classified difficulty according to five levels from 1 (easy) to 5 (difficult). The levels of subject difficulty perceived by students were likewise quantified as 1 (low), 2 (medium), or 3 (high), and the relevant weights were set as shown in Table 6.

Table 6. Weights set for evaluation

No.	Fairway breadth	Distance between ships	Crossing situation	Course change	Subjective difficulty
1-1	3	1	2	1	2.5
1-2	2	4	2	1	
2-1	1	2	1	1	1.8
2-2	1	5	1	2	
3-1	3	4	3	1	1.9
3-2	4	5	1	1	
4-1	1	3	1	2	2.0
4-2	2	3	1	2	
5-1	1	5	4	1	2.2
5-2	1	4	1	1	
6-1	4	3	4	4	2.2
6-2	4	1	5	5	
7-1	5	5	4	2	2.7
7-2	5	5	3	3	
8-1	5	3	3	1	2.1
8-2	4	4	2	2	

Table 7 shows the standard for each factor established for calculating the weights in Table 6.

Table 7. Standards for weight selection

Weight	Fairway breadth(m)	Distance between ships(m)	Crossing situation (times)	Course change (times)
1	0~450	0~650	1	1
2	450~900	650~1300	2	2,3
3	900~1350	1300~1950	3	4,5
4	1350~1800	1950~2600	4	6,7
5	over 1800	over 2600	5	8,9

4.3 Control Level Analysis

After calculating the rubber angles used by students in the eight scenarios, from Week 1 in Singapore Strait to Week 8 in Shanghai, we applied the average weight and presented the results in chronological order in Fig. 7. Analysis showed that, from Weeks 1 to 2, students used a rudder angle of 30 degrees or larger for 60 seconds or longer, and, from Weeks 3 to 7, they used the rudder at 30 degrees or wider for about 30 seconds. In the final week, Week 8, students rarely used the rudder at 30 degrees or wider.

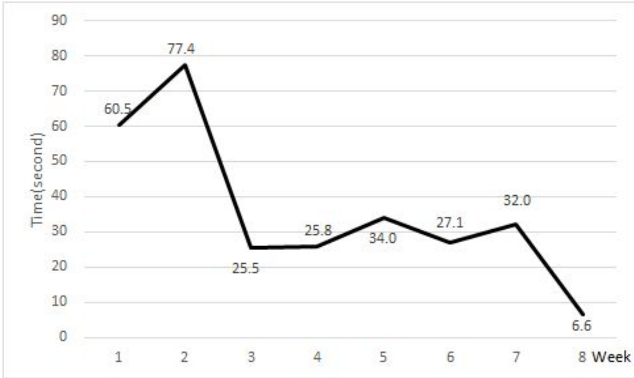

Fig. 7. Control level analysis from weeks 1 to 8.

4.4 Proximity Analysis

After calculating the probability of collision based on the distance between the main vessel and target point during navigation, we applied the average weight and presented the result of each scenario in a chronological order in Fig. 8. Analysis showed relatively high probabilities of collision from Week 1 to 3, and lower probabilities from Week 4 until final Week 8.

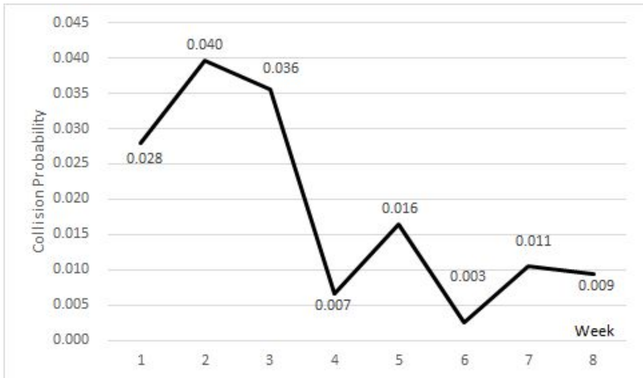

Fig. 8. Proximity analysis from weeks 1 to 8.

According to simulation analysis, despite poor results during the early part of the semester, students reduced the control level and proximity from the middle of the semester. We believe collision probability was high during the early weeks of the semester because the students faced risky situations and used rudders frequently during simulation, often leaving the course. Also, after the first half of the semester, students seemed to become familiar with the navigation simulation and, therefore, were able to avoid dangerous situations through ARPA decoding, radar operation, ship handling, and active communication with the student who acting as the controller.

5. Conclusion

ARPA and radar simulation training aims to familiarize trainees with functions and skills related to radar operation. Currently, maritime education institutions have installed a full mission simulator system (FMSS) that includes radar simulator and ARPA sets for equipment training. These institutions provide training for both radar operation and comprehensive navigation practice using this equipment. However, due to the slow developmental process, maritime simulation training systems have been researched less actively than land-based simulation systems. Further research of the effects and procedure for maritime simulation training needs to be conducted for both familiarization with the relevant equipment and improvement of overall maritime navigation skills.

Therefore, this study analyzed the effects of ARPA/radar simulation training based on a survey over the span of three years. An effective training method was also proposed based on the results. Furthermore, the effects of training were objectively analyzed, based on navigation simulations conducted over one semester.

The findings of this study are as follows:

(1) The survey on the effects of training showed improvement in skills related to radar/ARPA utilization, ARPA decoding, ship handling, and overall skill.

(2) Student` responses suggested that after training practical skills such as collision prevention, radar interpretation, and radar plotting improved more than theoretical knowledge including basic radar mechanisms, ship simulation characteristics, and COLREG applications. Also, analysis showed that ship handling skills had a larger effect than radar decoding skills on improving overall skill. Therefore, it has been proposed that theoretical education regarding the functions of radar and ARPA should be reinforced in ARPA/radar simulation training.

(3) According to simulation analysis, during the early weeks of the semester, students showed frequent misjudgment of dangerous situations and poor scores in for proximity and control levels due to route deviations. However, during the latter half of the semester, proximity and control levels were reduced by more than half, demonstrating the positive effects of ARPA/radar simulation training.

Although this study verified the effects of ARPA/radar simulation training, there were limitations for simulation analysis due to inconsistencies in the scenarios used for evaluating students. Also, a systematic evaluation analysis module is needed to calculate the weights of different scenarios. Based on these suggestions, further research should be conducted in order to develop a training evaluation system that can provide instant feedback to students after completion of simulation.

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