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The Effects of Sea Experience and Computer Confidence on Ecdis Training

K. Øvergård[1,*] and P. Smit[2]

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ABSTRACT

The potential for catastrophic events as consequences of human navigational errors underlines the importance of proper training in the use of new ECDIS. Outcomes of ECDIS training courses using a self-assessment questionnaire are presented in the paper. Possible influences of experience at sea, confidence attitudes in the use of computer and previous involvement with ECS/ ECDIS where evaluated. Participants (N=64) were maritime navigators and students. Linear regression analyses and paired samples t-tests indicated positive self-reported learning effects of the training courses. Neither experience at sea nor confidence in use of computers had a significant effect on the learning outcome of the training courses. Those with experience in similar systems had both higher initial and end scores thus indicating relative less perceived learning outcomes.

1. Introduction

Navigational errors can lead to catastrophic events as involving loss of lives, environmental pollution and loss of values. Position monitoring, route keeping, situational awareness and proper decision making is vital to avoid collisions and groundings with subsequent damage on health, property and environment. Navigation has been altered by the introduction of new technologies (Hutchins, 1995). The amount and complexity of electronic equipment is still increasing on navigational bridges (Lützhöft & Lundh, 2009). Electronic Chart, Display and Information System (ECDIS) have been given increased focus in the manila revision of STWC 2010 (STCW, 2011). ECDIS replaces traditional paper charts as means for navigation and seems to require new kind of competence. The possibilities with the new system are multiple and varied. The system can be a burden and a hindrance to safe navigation if the navigator does note have sufficient knowledge of the use(s) of the system (O'Dwyer, 2012). It is essential for navigators to learn to use ECDIS thoroughly and be familiar with the system in order to navigate safely (Mate, 2012; MAIB 2008, 2012; NTSB, 2009).

The requirements for proper familiarization of the on-board equipment are clearly stated in the International Ship Management Code (ISM Code). This includes ECDIS implicitly. Port State Controls also have focus on the generic training as well as familiarisation of ECDIS. International Maritime Organization (IMO) has recently come up with new requirements regarding ECDIS competence and proficiency (STCW, 2011). ECDIS will become the primary means for navigation on most commercial vessels in the future (SOLAS V, 2012). Thus there is a massive need for training to update the navigator's competence and prepare them for the new technology thereby safeguarding against navigational errors due incompetent and erroneous handling of ECDIS.

Proficiency requirements in STCW seems to be founded partly on Blooms taxonomy (Carson-Jackson, 2010) with emphasis on knowledge, understanding and demonstrated skills (proficiency), together with criteria for evaluation (STCW, 2011). The proficiency in ECDIS is mainly operational, and the Model Course suggests the use of various methods *"The outcome of this course may be achieved through various methods, including simulation based classroom and laboratory training, or in-*

[1]Professor of Maritime Human Factors and Chair of Cognitive Systems Engineering and Human Factors at the Global Maritime Knowledge Hub. He is also Head of Maritime Research at the Faculty of Technology and Maritime Sciences. Buskerud and Vestfold University College. Department of Maritime Technology and Innovation. Postboks 4, 3199 Borre. Norway. E-mail Address: koe@hbv.no.

[2]Assistant Professor at the Department of Maritime Studies where he is responsible for simulator training courses and bridge resource management training. Buskerud and Vestfold University College. Department of Maritime Studies. Postboks 4, 3199 Borre. Norway. E-mail Address: paul.n.smit@hbv.no

[*]Corresponding Author. E-mail Address: koe@hbv.no

service training, or combinations of these methods, such that each trainee is provided access to an ECDIS with ENC data for all required hours of practice and assessment in a controlled visual underway navigational environment" (IMO Model Course, 2012, p. 4). There is apparently no explicit learning theory behind the training requirements. It is thereby up to the training centers to offer proper training in order to meet the STCW requirements, which can be done by using the IMO Model Courses (2012).

1.1. Electronic Chart Display And Information System (ECDIS)

Together with the introduction of marine RADARs (Radio Detection (Direction) And Ranging) around the 1940's (Kjerstad, 2002)and GNSS (Global Navigation Satellite System) starting from the 1960's, ECDIS can be regarded as an important innovation in the area of maritime navigation. During one century, the equipment for navigation has changed dramatically. Computers were used on vessels from the late seventies (Hydro, 2010). ECDIS is currently the final computerised tool for aiding navigation.

ECDIS is a computer-based system where hydrographical and information databases together with relevant external information are made visible on a screen as a chart to help the navigator to plan a route and monitor the ships position along the route. In addition to this it is a system for information management. The information could come from external sensors, from the operators and from the databases itself. Information from AIS (Automated Identification System) and RADAR will also give an excellent overview over the surrounding vessels and environment. The essential elements of ECDIS are a central processing unit, data storages, a display with keyboard and track ball and interfaces both for data communication with other computers, navigational devices and sensors. In short it is a computer with databases, a human-technology interface and data communication facilities.

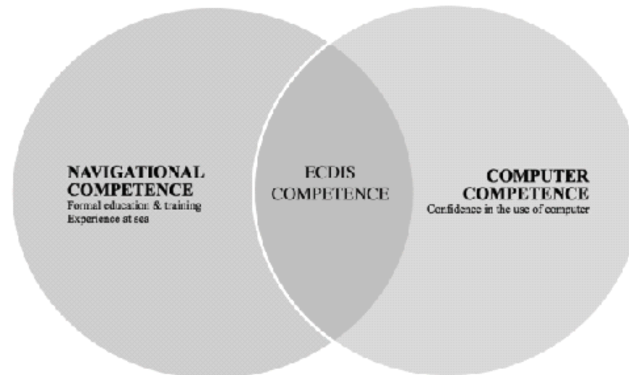
The difference between ECS and ECDIS is that the hydrographical information used in ECDIS has to be officially approved, and the system has to fulfil specific standards, with IMO, IHO (International Hydrographical Organization) and IEC (International Electrotechnical Commission) as the main premise providers. There are also certain requirements for backup, power, sensor inputs (position, speed and heading) and training which have to be fulfilled if the ECDIS are to replace paper charts.

Effective use of ECDIS as the central part of the electronic equipment on the bridge is essential for the safety and efficiency of navigation. New competency requirements in the use of ECDIS (STCW, 2011) make training courses highly relevant. The outcome of training courses need to be evaluated so the courses can be adapted and altered to better suit training needs.

1.2. Knowledge Domains

Coxon (2012) defined domain knowledge as *"knowing lots of information about the relevant area"* (p. 29), which also denotes a narrowing towards expertise knowledge. Expertise knowledge is regarded as domain specific (Ericsson 2006), and

Figure 1: Domains of ECDIS competence in the intercept between the of navigational competence and computer competence.



Source: Authors

the acquisition of everyday skill and expertise seems to follow the same rules. The incipient learning of a specific skill will thus have the same characteristics as found in the research on expertise. Domain specificity is defined as *"...the idea that all concepts are not equal, and that the structure of knowledge is different in important ways across the content areas"* (Hirschfeld & Gelman, 1994, p. xiii).

The use of ECDIS is based on the use of a specialized computer system to support navigation. Navigation and computer-use can be seen as typical general knowledge domains placed between peripheral general expertise and core domain-specific expertise (Weisberg, 2006). However, use of ECDIS differs both from the use of computer and traditional navigational operations. Hirschfeld and Gelman argue that *"much of human cognition is domain-specific"* and that *"many cognitive abilities are specialized to handle specific types of information"* (1994, p. 3). Thus, it might be that the use of ECDIS for navigation as can be sufficiently specialized to be a specific knowledge domain. The domain specificity of ECDIS use in the intersection between navigation and computer-use is shown in Figure 1.

1.3. Hypotheses

The primary hypothesis is that there will be a positive effect of the training course. This effect is observed if we find a higher post-test score than pre-test score. The secondary hypotheses where related to individual factors that influences ECDIS learning. Hypothesis 2a expected that those with experience with similar systems (ECS/ECDIS) would report better learning outcomes. Hypothesis 2b was related to the question whether experience and confidence with the use of computers would have some effects on the learning outcomes. Higher experience and more confidence would both be expected to increase the learning outcome of the training sessions.

Hypothesis 2c was related to the question whether experience at sea would have some effects on the learning outcomes. Experience at sea would be assumed to have an effect but the direction of the effect was not possible to identify prior to this study.

2. Methods

2.1. Participants

A total of 64 persons aged between 20 and 61 participated in the courses. The mean age was 36.14 (σ = 12.14). Experience at sea ranged between 0 and 360 months. Mean seagoing experience as navigators was 99.85 months and varied greatly between participants (σ = 113.62). However, all participants had either undertaken nautical studies, or were studying nautical science at the time the courses were given. Thus, all participants had the same minimum level of competence in navigation on operational level needed for their certification.

2.2. Research Design

There were three different ECDIS courses with the same technical content. The first was a technical familiarization course over two days. The next was a generic course based on the IMO model course 1.27 (IMO 2012). The third was a generic course for the students, spread over several weeks, also based on the IMO model course. The difference between the familiarization course and the other was the theoretical content of the generic courses. The courses were given at two different laboratories. Each of them was equipped with desktop simulators with ECDIS, radar and conning. All groups were treated as one sample group due to few participants in the courses and a limited number of courses. The purpose of the courses was to instruct the participants about the technical use of ECDIS and to let them explore and train on the system without any operational pressure.

2.3. Questionnaire

The research was based on questionnaires at the start and the end of the ECDIS course. At the start the participants got an introduction to the research project and explanation of the questionnaire. They also wrote under a consent form. They answered the questions in an excel sheet on a computer. All questions were answered before and after the training courses, entailing a pre-test post-test experimental design. The instructor was always present to answer questions from the participants.

The questions in the questionnaire was based on "A revised draft model course on the operational use of ECDIS" (STW 43/3/1 2009), which prepared for the 2010 revision of IMO Model Course (IMO2012). The questions were divided in three parts.

The first part was about demographic information such as age, nationality, country of birth, country of education, country of living, type and length of maritime education, experience as navigator, current position.

The second part was about experience with and confidence in the use of computer and electronic chart systems (ECS/ECDIS). This part consisted of three types of questions. The first type was skill orientated, presented as "rate your ability to...?" followed by a verb. The next type of questions was about knowledge, presented as "how much do you know about...?" The last type of questions was about understanding, and presented as "rate your understanding of...?".

The third and main part was derived directly from a checklist of proficiency in the draft model course and consisted of questions about specific areas within ECDIS. The questions in the second and the third part had to be answered with the same scale. The participants had to range their answers from "no..." or "not..." to "very..." or "very high..." in five steps, resulting in six different possibilities (0-5).

The ECDIS specific questions were grouped in nine subdomains covering the whole system. The groups were Alarms, Sensors, Route, Chart, Position Awareness and Monitoring, Documentation and Replay, Information and Presentation, Chart handling and Theory. All of the domains had six questions each. The aggregated means of the questions in each domain was regarded as an indicator of skill and knowledge for that particular domain. All 54 questions for the nine domains were computed to a global average.

2.4. Statistics and Data Analysis

All statistical tests where performed using the software package IBM-SPSS 20. A paired samples t-test where used to evaluate the main hypothesis. Linear regression analysis was used to evaluate hypotheses 2a-c. The rejection level for the null-hypothesis was set to .05.

3. Results

A paired sample t-test revealed a statistic significant and positive difference between pre- and post-test scores ($t_{(63)}$= -14.015, Mdiff [95%CI] = -1.512 [-1.728, -1.297], Cohen's d = -1.752). The results indicated an overall perceived positive learning outcome of the course with a very large effect size (Cohen, 1992). This is in accordance with Hypothesis 1 and the null-hypothesis is therefore rejected.

A linear regression analysis was used to evaluate the effects of experience with ECS/ECDIS (hypothesis 2a), experience in computer use (hypothesis 2b) and experience at sea (hypothesis 2c). The initial results are presented in table 1. The z-transformed scores of 'confidence of computer use', 'ECDIS competence' and 'Experience at Sea' were used as independent variables in the linear regression analysis.

Table 1: Effects of three competence scores on post-test score on self-assessment of competence in use of ECDIS

Variables	B	Beta	t	Sig.	[95% CI for B]
1 (Constant)	3.499		41.199	.000	[3.329, 3.669]
z_Experience at Sea (months)	0.061	.086	0.691	.492	[-.115, .237]
z_Confidence in use of Computer	0.098	.138	1.099	.276	[-.080, .275]
z_Experience with ECDIS/ECS	0.251	.358	2.921	.005	[.079, .423]

Source: Authors

The results in Table 1 indicated that previous experience with ECS / ECDIS affected the learning outcomes of the course. However, the outcome had to be controlled for the initial level of the student's competence, because the learning outcome would be influenced by the initial competence in ECS / ECDIS. The results of the regression analysis where the initial competence are controlled for are presented in Table 2. The z-transformed scores of 'confidence of computer use', 'Experience with ECDIS / ECS' and 'Experience at Sea' were used as independent variables in the linear regression analysis.

Table 2: Effects of experience at sea, confidence in computer use and experience with ECDIS/ECS when controlled for the student's initial competence

Variables	B	Beta	t	Sig.	[95% CI for B]
2 (Constant)	2.780		13.932	.000	[2.380, 3.180]
z_Experience at Sea (months)	0.022	.031	0.273	.786	[-.137, .181]
z_Confidence in use of Computer	0.113	.161	1.425	.160	[-.046, .272]
z_Experience with ECDIS/ECS	0.013	.018	0.132	.896	[-.184, .210]
Pre_mean	*0.367*	*.544*	*3.898*	*.000*	*[.178, .555]*

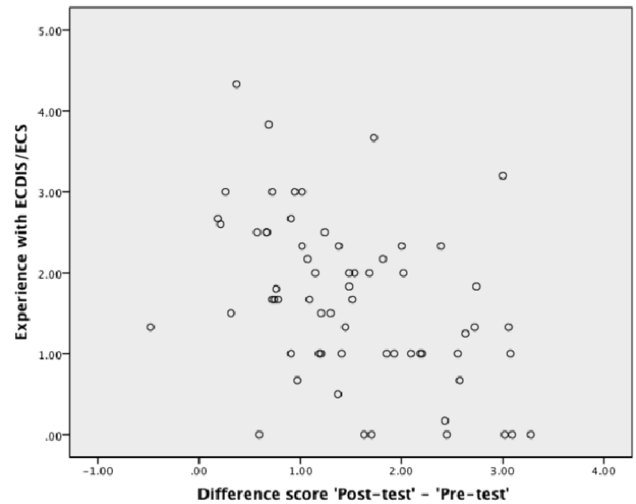
Source: Authors

As with in the first regression model, there is no statistical significant effect of experience at sea and no effect of confidence in the use of computer, neither in Table 1 nor in Table 2. Hypothesis 2a and 2b are thereby rejected. Also, when controlling for the initial level of competence in the use of ECS/ECDIS (pre-test score) the effect of Experience with ECS/ECDIS was reduced (reduction in Beta from .358 to .018) so that it no longer had a statistically or practically significant effect on the learning outcome thereby also rejecting hypothesis 2c.

A scatterplot comparing the self-assessed learning outcomes (measured as post-test - pre-test) and the initial levels of self-assessed competency revealed that all but one individual had some learning effect (person with no learning effect scores under 0 on horizontal axis). See Figure 2 for a graphical depiction of the pre-test score on competence in use of ECS/ECDIS and the learning outcomes.

The scatterplot shows a large negative correlation between the initial level of ECDIS competence and learning outcomes (Pearson's r = -.445, p ¡ .001). This indicate that participants with higher levels of initial competence had a lower self-reported learning outcome than persons with no or low initial experience and confidence in the use of ECS/ECDIS. This could possibly be explained by the fact that these courses where familiarization courses not aimed at creating expert users.

Figure 2: Initial levels of ECDIS/ECS competence measured against self-assessed learning outcomes (Post-test score - Pre-test score)



Source: Authors

4. Discussion

The purpose of this research was to investigate the learning effects of an ECDIS training course. We expected that computer confidence; experience and confidence in ECS/ECDIS; and experience at sea would have significant effects on the learning outcomes. However, we did not find any effects of confidence in use of computer and experience at sea had any effect on the learning outcome of the training courses.

The results revealed clearly that there were positive differences between the questionnaires in the total scores. The assumption that self-assessments would increase from pre-test to post-test, indicating learning outcome was corroborated. The main effect of the course was positive difference as regards learning outcome. The general reason for this might be the instructions by professional instructors and the possibility for the participants to train on and explore the system on desktop simulators with more or less instructor guidance according to their needs (ability, willingness to learn, curiosity, understanding of the importance etc.).

4.1. Computer Confidence

The total absence of influence by confidence in the use of computers was not expected. Competence in the use of computers was expected to transfer to the use of ECDIS because the operations and interface of ECDIS is in many respect similar to that of ordinary computers. A possible reason is that learning was not associated with the operational use of computers, but with the tasks that was to be done with the system, the use of ECDIS. The computer components of the ECDIS operations were seemingly not perceived as such, and thus the former computer competence was not utilized.

The assumption that playing computer games can "help prepare for science and technology" (Ballantine, Larres & Oyelere, 2007, p. 987) seemed to support the hypothesized statement that confidence in the use of computer should have a positive impact on the learning of ECDIS. In their conclusion however, Ballantine et al. stated that despite the fact that "recreational use of computers among students is fairly wide-spread, the academic side of computing for most students is rather dull and lacks stimulation" (Ballantine et al., 2007, p. 987). This could support the finding in this study, but even more exaggerated. Hence, computer competences in domestic environment might not necessarily support competencies in more structured and specific settings as learning to use ECDIS. Other research can support this assumption. For example, Cretchley (2007) did a study evaluating the relationship between computer confidence, learning with computers and learning mathematics using computers. Measuring confidence in both computer and mathematics with different self-reporting instruments, together with performance testing. There were measurements at the beginning, in the middle and the end with additional tests even later. He did not find any indications that computer confidence influenced many of the tasks in the course, "not even those that specifically required the use of technology" (Cretchley, 2007, p. 35). Our findings are in this regard similar to Cretchley's findings. Computer competence as rooted in a more general domain did seemingly not transfer to the other and more specific knowledge domains, even though some of the competencies were apparently similar.

Another study supporting the findings concludes that the student's computer skills are not necessarily transferable into more specific and "advanced IT applications". They found a clear distinction between "using IT for personal versus academic purposes" (Messineo & DeOllos, 2005, p. 54). That could indicate that although reporting high computer confidence, the students do not transfer this to new and more specific settings. ECDIS can be regarded as an "advanced IT applications", and also as "academic purpose" in this setting. The confidence and implicit also the competence in computer use could be regarded as a general competence versus the specialisation into the ECDIS area as domain-specific competence. This could mean that the competence in one domain might be distinctly different from that of another domain, which is supported by Vygotsky's ideas in his argumentation about the "specific capabilities": *"...the mind is not a complex network of general capabilities such as observation, attention, memory, judgment, and so forth, but a set of specific capabilities, each of which is, to some extent, independent of others and is developed independently. Learning is more than the acquisition of the ability to think; it is the acquisition of many specialized abilities for thinking about a variety of things. Learning does not alter our overall ability to focus attention but rather develops various abilities to focus attention on a variety of things."* (cited in Hirschfeld & Gelman, 1994, p. 3)

Blume et al. (2010) notified the training transfer to be more relevant for open skills than for closed skills. Both advanced computer skills and ECDIS skills satisfied the characterizations for closed skills and then the findings also got support here. The results showed that the only influence on the perceived learning outcome were from the course itself and not from previous experience and confidence in the use of similar systems. This could indicate that the use of ECDIS is to be regarded as a specific domain, or type-specific competence. As a specific domain, competence has been built to be specific in way that competences in other domains seemed to have little transfer effect on it.

Our study gives reason to reconsider the quite common assumption in the maritime industry that the young deck officers have grown up with computer and should therefore be better on ECDIS because of their presumed computer literacy (Norris, 2012).

4.2. Navigational Experience

We did not find any relationships between navigational experience and training outcome in the use of ECDIS. It could however be argued that experience at sea not necessary means experience with navigational tasks. This depends on the types of vessels, the trade and manning of the bridge. Normally the second officers are responsible for the navigation, although the Master has the overall responsibility. The second officers and chief mates execute the navigation. Long experience at sea normally means long service as captains with possibly less daily activity as navigators and then not necessary that long experience as active navigator. Nevertheless they should have long experience and good proficiency in the "old" way of navigating. A competence that also is necessary in the use of ECS/ECDIS.

It could also be discussed whether the ECDIS domain is a subgroup under the navigation domain and hence influenced by experience in navigation, regarding navigation as a "superordinate" skills, more complex than ECDIS skills. The use of ECDIS as a specific domain with more complexity seemed to be more plausible. Presumably the use of ECDIS will consolidate as a specific domain different from both the traditional navigation domain and the more general computer skills, and be regarded as kind of intercept between the two other domains. When considering the relationship between experience and performance, it is worth to note that Durso and Dattel (2006) found in their literature review that the relationship between experience and performance was not straightforward and there were no evidence for claiming that the quality or even the length of experience necessarily would influence performance positively. Especially when experience in a domain was challenged by a more unusual task, the experienced would not always use his expertise in a profitable way. Similarly when the participants in the ECDIS course used the new tool, ECDIS, they apparently did not make use of former experience in traditional navigation to enhance learning in the use of ECDIS.

As the ECDIS is used for navigation, and the courses use navigational simulators with active navigation, the results from this research support the idea of navigation with ECDIS as the specific domain. Whether it is a subdomain under navigation can be discussed. Maritime navigation can clearly be regarded as a domain. It was expected that experience at sea could mean long experience with navigation tasks. Experience with navigational tasks was predicted to have influence on navigation with ECDIS. The results did not support this.

4.3. Experience with Similar Systems

The experience with ECS/ECDIS did not positively influence the self-reported learning outcome as assumed. However, the persons with higher experience from ECDIS tended to have a higher competence after the training scenarios (Post-test). However, the training effect was smaller than those with little or no experience with ECDIS. This can be explained by the fact that the purpose of the courses was to familiarize navigators with the ECDIS system and to teach them how to navigate with ECDIS according to a required level of standard. The intention was to get all those inexperienced with ECDIS up to the required level of competence while also affirming the competence of those navigators with previous ECDIS experience. This could clearly explain the observed negative correlation between experience with ECDIS and learning outcome.

4.4. Limitations of this Thesis

Using self-assessment requires concise definitions of the concepts involved. In this study, the introduction and clarifying of such concepts as confidence and experience have potential for improvement. Especially the concept of confidence could be confusing in this setting. Although the participants could have clear definitions of the concepts, their particular definition was not conveyed or communicated through the answering of the questionnaire, nor was the intended meaning of the concept for the questionnaire explained in advance. It appears likely that additional and more detailed and specific questions would have enhanced the reliability and also the validity of the answers.

The reliability of self-assessment is a possible challenge to the reliability of this study. However, self-assessments have been found to have a high reliability when it comes to evaluation of competence. For example Chang, Tseng and Lou (2012) did an empirical study of different types of assessments (self-, peer- and teacher-assessments) of a web-based portfolio management environment. They found that self-assessments had a high consistency with teacher-assessments, while peer-assessments had a low consistency with both self- and teacher-assessments. Encountering the challenge of self-assessment could help the students comprehend their way of learning and prepare them for enhancing their knowledge (National Research Council, 2001).

Even with a clear definition of confidence the participants *"may have different criteria for deciding if they are confident or not"* Coxon (2012, p. 122), which could mean that personal factors had an influence on the answering. However, our experimental design with a pre-test post-test repeated measures design controls for this type of individual differences as long as there are no ceiling effects.

The relationship between 'confidence in use of computer' and 'competence in use of computer' is also one challenge in our study. We can expect that the answers given by the participants on "confidence" included the familiarity with using computers, which is possible based mostly upon domestic use, but it could be difficult to determine the exact relationship to the participant's competence. We expected that confidence and competence in computer use is linked, although this can create some challenges since they are not "synonymous linked" as discussed by Carlisle (2000). The lack of complete correspondence between these two concepts open up for the extreme case of high confidence with low level of actual performance, the "unconsciously incompetent practitioner". However, this challenge was not expected to have any complications for the results in this study as the experimental design would control for individual differences.

The classroom context of answering the questionnaire can lead to challenges with making conclusions about the use of ECDIS in a real dynamic context, as well as the use of ECDIS as a tool for safe navigation on a vessels bridge and as an integrated part of the bridge equipment. To this challenge we can only say that we agree. Assessments of operational and professional skills should be based on practical tests rather than paper-and-pencil (see e.g. Nilsen, 2013).

5. Conclusion

Learning outcomes from ECDIS training courses seemingly are not affected by navigational experience or by the trainee's confidence in the use of computers. Previous experience ECDIS or similar systems lead to a higher initial competence level and thereby a lower learning potential - especially for familiarization courses in ECDIS systems. This effect is realised by a lower learning outcome for those with much experience of ECDIS. Also, those with a high self-reported confidence in use of computers do not do better than those with a low confidence in computers. We should perhaps reconsider the quite common assumption in the maritime industry that young deck officers who have grown up with computers should be better on ECDIS because of their presumed computer literacy (Norris, 2012).

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