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From Parametric to Contextual Assessment in Maritime Simulators: The Evolution from TEAS to e-Tutor

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Abstract. Maritime simulators play a key role in training and assessing cadets' operational competencies, especially within the framework of the STCW Convention. Traditionally, evaluation has relied on instructor-based assessment, which, although comprehensive, introduces a degree of subjectivity and variability. The integration of automatic assessment systems, such as the Transas Evaluation and Assessment System (TEAS), used by older versions of Navi-Trainer Pro (NTPro) simulator software, has improved objectivity by applying rule-based evaluation using measurable navigation parameters. Previous studies have shown that TEAS reduces variability and increases consistency compared to instructor assessment. However, its predominantly parametric approach limits the ability to capture complex decision-making processes and dynamic behaviours. In this context, the e-Tutor module, implemented in the latest versions of NTPro, represents a natural evolution, maintaining the Boolean logic foundation of TEAS while significantly increasing the complexity and flexibility of rule-based evaluation. This paper analyses the transition from TEAS to e-Tutor, highlighting the shift from parameter-based rules to more complex structures that integrate multiple variables, temporal conditions, and system responses. As a result, assessment moves towards a contextual and behaviour-oriented approach. The findings indicate not only a technological advancement but also a methodological shift towards more realistic and standardised evaluation, aligned with STCW requirements.

Keywords: maritime simulators, automatic evaluation and assessment, rule-based evaluation, behavioural assessment.

1. Introduction

The use of maritime simulators has become an essential component in the process of training and assessing the practical skills of future navigation officers. Studies in this field highlight their role in developing the skills necessary to perform the duties of a watch officer under controlled and safe conditions [1], [2]. Maritime simulators are used in maritime education and training (MET) to develop the technical and non-technical skills needed by seafarers to manage complex operational situations [7].

The International Maritime Organization (IMO), through the STCW Convention, regulates the process of training and assessment of seafarers' skills [4]. Maritime simulators are useful tools for training and assessment of skills, as they allow the development of technical and non-technical skills in safe,

controlled and reproducible conditions, through the use of simulated operational scenarios [7], [11]. The efficiency and effectiveness of training based on the use of maritime simulators depends on the realism of the scenarios, the training and competence of the instructors and the integration of feedback into the learning process [11]. Furthermore, simulators allow for the practice of situations that cannot be replicated in real-world conditions for safety, economic, or ethical reasons [9].

The instructor plays a key role in this process, providing guidance and evaluating student performance. The importance of the instructor in achieving learning objectives in simulator-based training has been highlighted in the literature [3].

However, performance evaluation in simulators is traditionally carried out by instructors, which can introduce a certain degree of subjectivity. The need to increase objectivity has led to the development of evaluation methods based on measurable parameters and real-time performance monitoring, in accordance with the technical standards applicable to maritime simulators [8]. Studies in this field have demonstrated that the use of automated assessment systems contributes to increasing the consistency and objectivity of the assessment process [1].

In the context of technological advancements and the digitization of maritime training, modern simulation systems are increasingly focused on integrating advanced technologies and assessment methods based on automated performance analysis [12], [13]. At the same time, recent studies highlight the importance of transferring skills acquired in simulators to the real operational environment as an essential element for enhancing maritime safety [10]. Elsayed and Ibrahim examine the educational and operational safety implications of full-mission simulation, identifying both its practical training benefits and implementation challenges, including costs and the risk of overwhelming trainees [15].

A first step in this direction was the integration of automated assessment systems into maritime simulators, such as the Transas Evaluation and Assessment System (TEAS). Studies conducted at the "Mircea cel Bătrân" Naval Academy have demonstrated that the use of TEAS contributes to reducing the dispersion of results and increasing the consistency of evaluation by applying rules based on measurable parameters and logical expressions defined by the instructor [1]. At the same time, these studies also highlighted certain limitations of the system, stemming from the predominantly parametric nature of the assessment, which does not always allow for capturing the complexity of the cadet's behavior in dynamic scenarios.

From a technical standpoint, automated evaluation systems such as TEAS are based on the definition of evaluation rules in the form of logical expressions, built on the principles of Boolean algebra, which correlate navigation parameters with predefined thresholds and generate penalties in the event of deviations [3]. This approach has allowed for the partial standardization of the evaluation process and the reduction of human influence, but it remains limited in terms of integrating the operational context and the interdependence of actions.

In this context, the development of advanced automated evaluation systems, such as the e-Tutor module, represents a natural step in the evolution of simulator-assisted training. Although, similar to TEAS, e-Tutor uses rules defined by Boolean logic, it introduces a higher level of complexity by integrating multiple parameters, temporal conditions, and the system's dynamic reactions based on the user's actions [17]. Thus, evaluation is no longer limited to verifying compliance with predefined thresholds but can reflect the interaction between variables and the operational context in which they occur.

This evolution highlights the transition from assessment based on isolated parameters to integrated assessment within complex scenarios, in which the operator's performance is analyzed in relation to the operational context and the interaction between multiple variables.

This paper aims to analyse the evolution of automated evaluation systems used in maritime simulators, from TEAS to e-Tutor, with a focus on the increasing complexity of evaluation rules and its impact on the objectivity and relevance of the training process. To this end, the article uses the results of previous studies as a starting point and expands upon them through a comparative conceptual analysis of the two systems, highlighting the transition from a predominantly parametric assessment to a contextual one, oriented toward behaviour and operational decision-making.

2. The TEAS System – A First Step Toward Automated Assessment

The integration of automated assessment systems into maritime simulators marked a significant milestone in the standardization of training and the evaluation of operational competencies. In this context, the Transas Evaluation and Assessment System (TEAS), integrated into the Navi-Trainer Professional 5000 simulator, is one of the first solutions used for the objective assessment of cadet performance during navigation exercises [3], [5].

An analysis of the TEAS system is essential for understanding the initial stages of assessment automation in maritime simulators and for identifying the limitations that led to the development of more advanced solutions. In this regard, simulation-based assessment systems generally use deterministic models and logical rules to quantify performance in relation to measurable parameters [11], [12].

TEAS allows for the definition of assessment scenarios based on a set of rules, each rule being described by a logical expression built on the principles of Boolean algebra. These rules correlate specific navigation parameters—such as ship speed, closest point of approach (CPA), deviation from course, or compliance with the captain's orders—with predefined limit values. If these limits are exceeded, the system generates penalties proportional to the degree of deviation and the importance of the evaluated criterion [1], [3].

The structure of a rule within TEAS typically includes a description of the evaluated criterion, the monitored parameter, the associated logical expression, and a penalty system based on points and weights.

The evaluation using the TEAS module is thus performed in real time by continuously monitoring relevant parameters and comparing their values with threshold limits predefined by the instructors. The system provides an objective and measurable assessment of the cadet's performance during the exercise [1], [3], [11]. Individual parameters limit the interpretation of behavior in complex operational contexts, where actions are interdependent and are continuously influenced by the evolution of environmental and traffic conditions [12], [13].

This limitation becomes relevant in dynamic scenarios where the trainee has to make successive and interconnected decisions. The evaluation carried out by the TEAS system alone does not always provide a complete picture of the student's performance. The system only monitors whether certain values exceed the limits set by the instructors, but cannot interpret the cause of the deviation. The system cannot identify whether a penalty is the result of a serious error, a deviation due to the dynamic conditions of the exercise, or a justified change in the execution stage of the flight plan. For this reason, the evaluation carried out by the TEAS system does not always reflect the way in which the student analyzed the situation and made decisions [13].

The TEAS system allowed the transition from the evaluation carried out by the instructor alone to a mixed evaluation. The final grade was established by combining the instructor's assessment with the result automatically generated by the TEAS system. Statistical analysis showed differences between the two methods. The automatically generated grades were closer to each other, while the grades given by the instructors varied more.

The system contributed to reducing the differences in grades and to a more uniform evaluation [1]. This difference can be explained by the fact that the instructor's assessment also includes a subjective component, based on the instructor's experience and interpretation of the situation [1], [12].

The TEAS system represented an important step in the automation and standardization of assessment in maritime simulators. The system provided an objective basis for the assessment of practical skills. Its limitations show the need for more advanced systems that also take into account the operational context. The identified limitations demonstrate the need to develop more advanced evaluation systems, capable of analyzing not only the values of individual parameters, but also the sequence of actions, the relationships between decisions, and the response of trainees to changes in the operational environment. However, the increasing complexity of training scenarios and current requirements for assessing

operational competencies necessitate the development of systems capable of integrating the operational context and user behaviour in a more realistic manner [12].

This limitation highlights the need to develop more flexible and sophisticated evaluation systems capable of moving beyond a strictly parametric approach and incorporating the contextual dimension of the decision-making process—aspects that will be addressed in the following section through an analysis of the e-Tutor module.

3. e-Tutor – The Evolution of Automated Assessment Systems

Modern training and assessment systems, integrated into advanced simulators, utilize complex operational scenarios in which the navigation environment, maritime traffic, and the behavior of the vessels involved are modelled simultaneously. This evolution reflects current trends in the field of Maritime Education and Training (MET), focused on integrating digital technologies and advanced performance assessment methods [12], [13].

In this context, the e-Tutor module represents a significant evolution of automated assessment systems, expanding upon the principles previously implemented through TEAS. It is designed as an integrated system for training control and automated competency assessment, used to create, monitor, and evaluate training scenarios within maritime simulators [6], [16], [17].

Similar to the TEAS system, e-Tutor uses rules defined on the basis of Boolean logic to evaluate cadet performance. However, the fundamental difference lies in how these rules are structured and applied. While in TEAS the rules are predominantly formulated as linear logical expressions associated with individual parameters, in e-Tutor they are organized as complex logic diagrams, which allow for the simultaneous correlation of multiple parameters, conditions, and events [17].

This approach reflects the shift from simple deterministic models to more flexible systems capable of integrating the interdependence between variables and the dynamics of the decision-making process—aspects considered essential for performance evaluation in complex simulated environments [12].

The modular architecture of e-Tutor facilitates the definition and management of training scenarios through specialized components, such as the scenario editor, the rule editor, and the message, action, and question modules, as well as the performance monitoring module. This structure allows the instructor to create dynamic scenarios in which the system's behavior adapts in real time based on the cadet's actions [16], [17].

An important feature of e-Tutor is the integration of temporal and sequential conditions into the evaluation rules. The e-Tutor system checks whether certain values exceed the established limits and how they change over time, taking into account the order of actions and the reaction of the learner to different events. The evaluation thus takes into account both the learner's actions and the sequence of events in which they occurred [12], [13].

The e-Tutor system can automatically generate different actions when certain conditions are met. The system can display information or warning messages, introduce simulated failures and modify the training scenario. Thus, the e-Tutor system is used for both evaluation and training, thanks to the real-time feedback facility [11], [17]. The feedback function meets the current requirements of simulator training, as part of adapting the scenario to the learner's actions [10], [11].

Another advantage of the e-Tutor module is the possibility of following several learners at the same time and of automatically generating evaluation reports. The reports contain the monitored values, the events produced and the system reactions. This information allows for a clearer analysis of the results and supports the instructor in applying uniform evaluation criteria [17].

In this context, evaluation is no longer carried out exclusively by checking individual parameters, but by analysing critical events (collision risks, manoeuvre execution or operator reaction times). This approach allows for a more accurate representation of behaviour in real-world navigation situations and contributes to increasing the relevance of the training process [12].

Therefore, e-Tutor can be considered an evolutionary extension of logic-based assessment systems, in which the focus shifts from parametric assessment to contextual and behavioral assessment. This

transition reflects not only a technological development but also a paradigm shift in how the training and assessment process is conceived in maritime simulators [13].

4. A Comparative Analysis of the TEAS and e-Tutor System

The fundamental difference between traditional and modern assessment systems in maritime simulators lies in the shift from validating individual parameters to behavioral assessment within complex operational scenarios. This evolution reflects current trends in simulator-based training, which are oriented toward integrating the operational context and the decision-making process into performance assessment [12], [13].

The conceptual differences between TEAS and e-Tutor are illustrated in Figure 1, highlighting the transition from threshold-based evaluation to integrated, context-aware performance analysis.

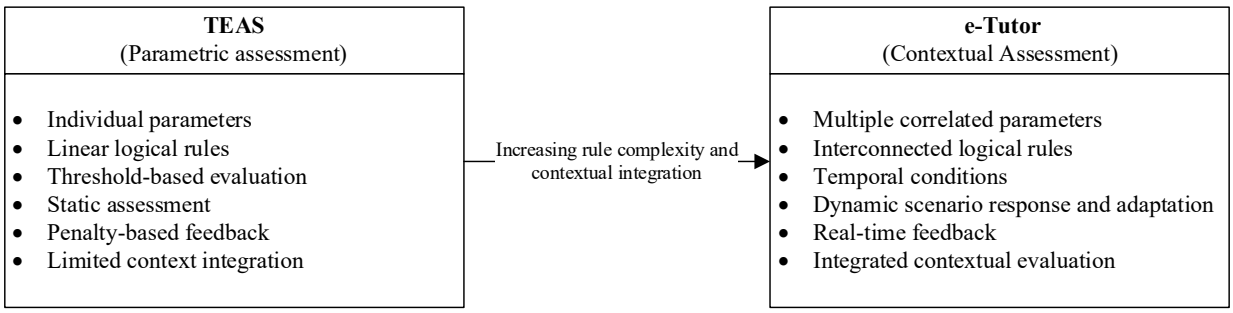


Figure 1. Conceptual evolution from parametric to contextual assessment in maritime simulators

Both the TEAS system and the e-Tutor module are based on the same conceptual foundation, namely the use of rules defined by logical expressions built on the principles of Boolean algebra. This approach allows for the formalization of evaluation criteria and their integration into an automated process for analysing cadet performance [1], [3], [17]. However, the differences between the two systems do not lie in the logical nature of the rules, but in their level of complexity, flexibility, and integration within training scenarios.

Within the TEAS system, rules are predominantly defined as linear logical expressions that correlate a limited number of parameters with threshold values. Evaluation is performed by verifying compliance with these thresholds and applying proportional penalties in case of deviations. This approach is effective for quantifying performance against well-defined criteria but remains limited in terms of modelling the interdependence between actions and their evolution over time [1], [3], [12].

In contrast, the e-Tutor module significantly extends this approach by introducing rule structures organized in the form of logic diagrams, which allow the simultaneous integration of several parameters, conditions and temporal relationships. Thus, rules are no longer treated as independent entities, but as interconnected elements in a complex evaluation system, capable of reflecting the dynamics of the cadet's decision-making and behavioural process [12], [17].

An essential aspect of this evolution is the introduction of the temporal dimension in the evaluation. While TEAS mainly evaluates the state of a parameter at a given time or the deviation from a threshold, e-Tutor allows the evaluation of sequences of actions and reaction time, which leads to a more faithful representation of the cadet's behaviour in real navigation situations [13], [17].

The differences between the two systems can be summarized in terms of the level of complexity of the rules and the type of evaluation they allow, as presented in Table 1.

Table 1. Comparison of TEAS and e-Tutor systems from the perspective of complexity of rules and type of assessment.

Feature	TEAS	e-Tutor
Logical Foundation	Boolean Algebra	Boolean Algebra
Rule Structure	Linear Logic Expressions	Complex Logic Diagrams
Number of Correlated Parameters	Limited	Multiple
Integration of Temporal Conditions	Reduced	Advanced
Reaction Type	Penalty	Penalty, Messages, Actions, Scenario Changes
Assessment Type	Parametric	Contextual and Behavioural
Monitoring	Individual Parameters	Parameters + Events + Sequences
Number of Correlated Parameters	Limited	Multiple
Role in Training	Assessment	Assessment + Feedback + Autonomous Training

This comparison highlights the fact that the evolution from TEAS to e-Tutor does not consist in a change of the basic principles, but in an extension of the capacity to model the evaluation rules. If in the case of TEAS the evaluation is focused on the analysis of individual parameters and deviations from pre-established limits, in the case of e-Tutor the emphasis shifts to the analysis of the interactions between parameters, the sequence of actions and the operational context.

In this sense, a clear transition can be identified from a parametric evaluation, specific to the TEAS system, to a contextual and behavioural evaluation, specific to the e-Tutor module. This transition reflects the need to adapt the evaluation methods to the increasing complexity of the simulated scenarios and to the requirements imposed by international standards regarding the operational skills of navigation officers [4].

Thus, the evaluation becomes dependent not only on the result of an action, but also on the way in which it is influenced by the operational context, including environmental conditions and the dynamics of maritime traffic.

Therefore, the fundamental difference between the two systems is not determined by the use of Boolean logic, common to both solutions, but by the level of complexity of the implemented logical structures and their ability to model real behaviours. This evolution marks the transition from assessment based on isolated parameters to assessment based on behaviour and context, constituting an important step towards the standardization and objectification of the training process in maritime simulators.

This transition marks a paradigm shift in the assessment of maritime skills, from a rigid, compliance-based approach to a flexible one, oriented towards behavioural analysis and decision-making.

5. Discussion

The results of the comparative analysis highlight that the evolution from the TEAS system to the e-Tutor module is not just a technological improvement but reflects a paradigm shift in the way the assessment process is conceived in maritime simulators. While TEAS has significantly contributed to increasing the objectivity of the assessment by reducing human subjectivity, e-Tutor extends this approach by integrating the assessment into a more complex framework, oriented towards the cadet's behaviour and the dynamics of the decision-making process.

This transition is in line with current trends in the field of simulator-assisted training, which highlight the need to integrate the operational context and real-time feedback into the performance assessment

process [11], [12]. Thus, modern assessment is no longer limited to verifying compliance with certain parameters but rather follows the way in which the operator manages complex situations and makes decisions under dynamic conditions. The study on seafarers' self-awareness and emergency decisions through bridge simulator training [14] addresses a related dimension of this discussion: the trainee's awareness of their own responses and decisions in emergency scenarios.

The introduction of automated assessment through TEAS has led to a reduction in the variability of results and an increase in the consistency of the assessment, compared to the assessment carried out exclusively by instructors [1].

By using more complex rules, e-Tutor allows for a more realistic assessment. Performance is no longer assessed solely against cut-off values, but also based on the learner's behaviour [13], [17].

This development has direct effects on the learning process. Assessment becomes more objective, as the same criteria are applied to all learners, and the influence of the instructor's subjective assessment is reduced. Second, it allows for a more detailed assessment of skills, including not only the final outcome of actions, but also the decision-making process and behaviour of the cadet. Third, it facilitates the development of forms of autonomous training, in which the cadet benefits from real-time feedback and can adapt action strategies depending on the evolution of the scenario [10], [11].

The degree of complexity of the evaluation systems also generates some difficulties. The responsibility for defining the rules within the e-Tutor system lies with the instructors. They must take into account the logic of the scenarios when defining the evaluation rules. If the rules are too complicated, the results may be difficult to interpret, and the scenarios may become too rigid. However, the efficiency of the e-Tutor system depends on how the rules are defined and the scenarios designed.

IMO, through STCW, specifies the competencies that deck officers must acquire. On the other hand, the evaluation methods and systems on maritime simulators are not specified [4]. From this point of view, systems such as e-Tutor can contribute to the application of more uniform evaluation methods, both at institutional and international level.

In the future, automatic evaluation systems can be developed by integrating artificial intelligence. These systems could better track the operator's behaviour and adapt the training process according to his actions.

The transition from TEAS to e-Tutor can be considered an intermediate step towards the development of intelligent assessment systems that take into account performance, context, and decisions made during the exercise. In the future, these systems could learn from user behaviour and automatically modify assessment criteria.

6. Conclusions

The analysis highlights the evolution of the assessment systems used in maritime simulators, from approaches based on subjective instructor assessment, to automated systems such as TEAS and, subsequently, to advanced solutions such as e-Tutor.

The integration of the TEAS system represented an essential step towards increasing the objectivity of the assessment, through the use of logical rules and measurable parameters. The variability of the results was reduced, and the standardization of the assessment process was achieved [1].

The predominantly parametric nature of the assessment carried out through TEAS limited the ability to capture the complexity of the decision-making process and the behavior of the cadet in dynamic scenarios. This assessment based exclusively on preset thresholds does not allow the integration of the operational context and the interdependence between actions, which can lead to an incomplete assessment of performance [12], [13].

The e-Tutor system has improved automatic assessment by using more complex rules. It can track the evolution of the learner's actions over time, generate automatic reactions, and analyze multiple parameters and events simultaneously.

This approach allowed the transition from a parametric evaluation to a contextual and behavioral one, closer to the operational reality of the activities carried out on board ships [17].

The results highlight the fact that the evolution from TEAS to e-Tutor represents not only a technological development, but also a paradigm shift in the assessment of maritime skills. The emphasis shifts from verifying compliance with limit values to analysing behaviour, decision-making and reaction in dynamic situations, which contributes to increasing the relevance and realism of the training process.

From an applicability perspective, advanced automated assessment systems can contribute to increasing the objectivity and comparability of results, facilitating the standardization of the assessment process in accordance with STCW requirements [4]. At the same time, they support the development of modern training models, based on real-time feedback and autonomous learning [10], [11].

In the future, the integration of emerging technologies, such as artificial intelligence and advanced data analytics, may lead to the development of assessment systems capable of more accurately modeling operator behaviour and dynamically adapting the training process. Thus, the transition from TEAS to e-Tutor can be considered an intermediate stage in the development of intelligent assessment systems, oriented towards performance, context and operational decision in complex maritime environments.

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