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3D MODELING FOR COMPETENCES DEVELOPMENT OF NEW DEGREES WITHIN THE FIELD OF MARITIME

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Abstract

This paper describes a pilot study involving a 3D modeling workshop as an educational innovation tool intended for development of spatial vision which is a competence that should be acquired according to curriculum of European space for higher education in the new bachelor's degrees within the field of Maritime, Nautical and Marine Engineering. The study has been performed with students in Marine Engineering, Nautical Engineering and Maritime Transport and Engineering Radio-electronics degrees at the University of La Laguna (Spain) during the 2010-2011 academic year. Software chosen for this workshop was the free version of Google Sketchup 8. For measuring its influence on student's spatial vision, MRT and DAT5-SR tests are used. After completing the workshop students fill a satisfaction survey. Format and structure of this workshop allow its implementation on virtual learning environments (virtual classroom).

Key words: 3D modeling, educational innovation, new technologies, spatial vision, competence, European space for higher education.

INTRODUCTION

In the framework of European Space for Higher Education, main aim of teaching-learning process is not only acquisition of knowledge by students but also develop-

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ment of several competences (skills and abilities) according to academic and professional profiles. Competences are understood as those knowledge related to professional duties as a result of learning.

One competence contemplated in the field of Maritime, Nautical and Marine engineering is spatial vision ability. This competence is also considered by several authors as fundamental for performing engineering duties (Adánez y Velasco, 2002;) (Ferguson, 1992).

However in courses of study for these new degrees there are no explicit activities focused on spatial vision improvement. It's understood than taking subjects related to drawings, diagrams and part's models that skill is developed although its effects are not measured.

Having this in mind, we propose a 3D modeling workshop focused on improvement of spatial vision measuring effects on that skill. Workshop's contents have been developed through a virtual classroom on Moodle teaching platform. So, it allows its easy implementation in any faculty or school which uses any similar platform in their virtual campus.

In this paper we will describe the experience of training for improvement of spatial skills. First, we will define spatial ability concept as well as tests used for measuring it. Workshop contents details are below together with results obtained through statistical analysis. Finally, conclusions obtained from this experience as well as future works proposal which staring from this workshop's model may develop competences related with design and interpretation of *drawings*, *sketches,* sections and *views from ship components*.

BACKGROUND

On January 21st 2009 the seven Technical Colleges and Nautical Faculties of the Spanish Universities and the official school of the Merchant Marine seeking an agreement on academic competences that may be acquired taking the decision of including spatial vision ability alongside representation, standardization, computer assisted design and industrial design fundamentals techniques as basic formation competences for the new degrees.

Science and Innovation Ministry published in the official State Bulletin (BOE 18th, 19th and 20th February 2009) a Ministerial order for each bachelor's degree with their acquirable competences for qualifying students in the exercise of their professions. One competence that should be acquired is 'Spatial vision ability and graphic representation techniques knowledge through traditional descriptive and metric geometry methods as well as computer assisted design applications'.

So, spatial vision ability is present as an acquirable competence in the curriculum for new bachelor's degrees of Marine Engineering degree, Naval Radio Electronic Engineering degree, Nautical Engineering & Maritime Transport degree, Naval architecture degree, Marine Engineering degree, Naval Systems and Technology Engineering degree and Marine propulsion and services Engineering degree.

It's remarkable that some curriculums refer to it as spatial conception, meanwhile others designate it as spatial vision. Both terms refer to ability for mental manipulation of objects and their parts in 2D and 3D environments. (Martín, 2009).

Indeed, in this curriculums knowledge of objects' dimensions in space as well as possible interaction between them through geometric projection use, CAD introduction and abilities acquisition for assembly drawings and mechanics dismantling appear as learning results.

That's why in university education, spatial ability reveals as a necessary skill for successful addressing of educational contents by students. Several authors relate high level of these skills with success in technical careers: spatial thinking is essential for scientific thought and it's used for information representation and handling while learning as well as for problems resolution. (Smith, 1964; McGee, 1979; Clements y Battista (1992).

In the maritime field this spatial vision ability intervenes in installations plan representation during visualization of its different components in both 2D and 3D as well as during parts setup and mechanizing on 3D environments for naming but a few.

In formation of future seamen, STCW code establishes simulator use as obligatory (Gorgoulis, 2010) where spatial vision does also intervene. When handling propulsion and auxiliary ship system simulators, available 2D information needs 3D visualization easing maintenance and operation tasks providing several improvements in ergonomic parameters. Many authors use simulators in the design of ship parts (Lamas, Rodríguez, Rodríguez & González, 2010) and for educational applications (Eguía, Trueba & Milad, 2008)

Many studies show that spatial skills may be developed through training if appropriate materials are provided (Cohen, Hegarty, Keehner, & Montello, 2003), (Kinsey, 2003), (Newcomer, Raudebaugh, McKel, & Kelley, 1999), (Potter & Van der Merwe, 2003) and there is common agreement that spatial ability can be improved through training (Sorby, Wyssocky, & Baartmans, 2003).

In this paper we will describe experience from training to improve spatial skills through a 3D modeling workshop.

SPATIAL SKILLS AND ITS MEASUREMENT

Spatial capacity is accepted by various authors throughout history as a component of intelligence. Some people have greater degrees of innate aptitude, but the vast majority can train this skill through practice (Sorby, Wyssocky, Baartmans, 2003). In this work we use the term spatial ability referring to the part of the spatial capacities that we can practice through training.

While studying components of spatial ability we found different approaches for establishing its classification and at the same time, several tools for finding out quantitative results through testing.

In recent years, a large number of authors classify the components of spatial ability using two categories: (Linn Petersen, 1985 ;) (Olkun, 2003):

— Spatial Relations (or Mental Rotation): ability for rotating 2D or 3D figures quickly and accurately in our imagination.
— Spatial Visualization: ability for recognizing 3D parts through folding and unfolding of their faces.

Some researchers (Maier, 2004, Mafalda, 2010) include spatial orientation as one of the components, defined as the ability for orienting themselves relating to the environment and location self-awareness. In the case of three-dimensional objects modeling we opted for the two categories classification: Spatial Relations and Spatial Visualization.

Around this classification there is a lot of testing in order to measure each of the components. In our research we use two of them which have been validated by fieldwork and use in other studies similar to ours (Devon, Engle, Foster, Sathianathan, & Turner, 1994; Sorby & Baartmans, 2000, Gerson, Sorby, Wisocki & Baartmans, 2001, Martin-Dorta, Saorin and Contreras, 2008):

— Mental Rotation Test (MRT) for measuring spatial relations (Albaret and Aubert, 1996; Vanderberg & Kuse, 1978).Highest score possible in this test is 40 points.
— Differential Aptitude Test 5- Spatial Relations Subset (DAT5-SR) for spatial visualization. (Bennett, Seashore y Wesman, 2002). Highest score possible in this test is 50 points.

PILOT TEST: 3D MODELING WORKSHOP

Description

This workshop proposes a strategy for improvement of spatial skills with a 3D modeling workshop combining handling of real parts and three-dimensional computer images.

This strategy has been validated separately by other researchers: some have worked with real pieces (Alias, Black & Gray, 2002, Ben-Chaim, Lappan & Hougang, 1998; Duesbury & O'Neil, 1996) and others conclude than manipulating the image of an object by computer is enough for improving spatial skills (Wiley 1990, Sorby, 1999).

Participants

Participants in our 3D modeling workshop includes undergraduate students in Marine Engineering, Nautical Engineering and Maritime Transport and Radio Electronics engineering of the University of La Laguna during the academic year 2010-2011. From a total of 72 students, 26 volunteers (20 men and 6 women) with an average age of 21 years.

Hardware and software

Pentium IV computers with 512 Mb RAM and the Windows XP operating system were used.

There are different commercial programs like Pro/Engineer, AutoCAD Inventor, Solid Works and others which are able to generate 3D models. Software chosen for our study is the Google SketchUp8, a multimedia application with free access and download that, although cannot compare in features and possibilities to commercial programs, it still offers the possibility for introducing us in 3D modeling with few technical knowledge and in a very short time. It has a friendly interface with few but intuitive commands which combined with easy use encourage quick learning. The fact that it's free eases its implementation at any centre, avoiding the problem of the software licenses acquisition cost.

Measurements

For measuring spatial ability: each participant performed both tests (MRT and DAT5-SR) prior to the experiment and after its completion for evaluating results.

For measuring user satisfaction (likability) each participant fills a survey upon workshop completion. Questions were asked according Likert's scale where numeric values are assigned to each question showing level of agreement or disagreement in a 5 points scale.

Survey has 56 questions organized according to three variables: the first refers to structure, presentation, design and materials of the workshop, meanwhile second refers to the contents and, finally, the last one to user satisfaction and motivation.

Instruction

Workshop consists of two phases: introduction and improvement. There are also three difficulty levels obtained from incorporation of inclined and curved faces. At the same time, figures are drawn in a three-dimensional grid which complexity increases with each level, containing 24 figures, where participants are asked to solve at least a minimum of six (Table 1).

The design of this workshop has been validated by Dehaes research group (Skill Development Space: http://www.degarin.com/dehaes/) at the University of La Laguna for the 2010-2011 academic year, verifying quantitatively the adequate distribution of learning stages and difficulty levels. Average times for solving exercises have been 3 minutes for the introduction phase and 8 minutes for development phase.

Table 1: Workshop structure.

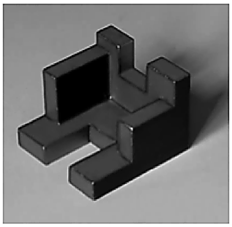
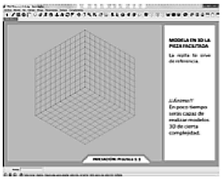
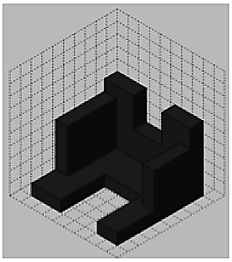
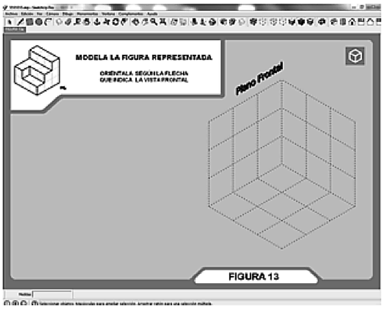
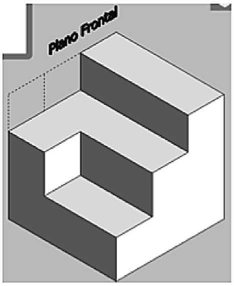
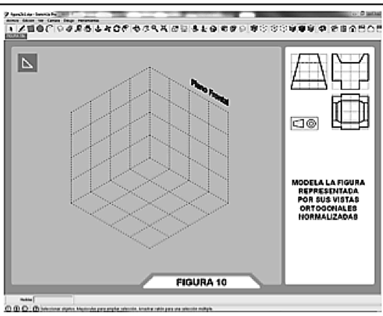
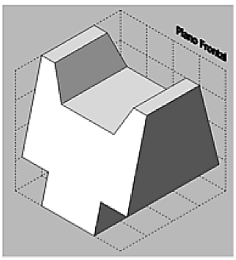
PHASE	PRACTICES/LEVEL		LOGO	DESCRIPTION
INTRODUCTION PHASE	PRACTICE 1.1			Creation of 3D models from real aluminum pieces
	PRACTICE 1.2 Creation of 3D models from isometric perspectives figures	LEVEL A		24 figures entered in a 3x3x3 grid with their faces parallel to coordinate planes
		LEVEL B		24 figures entered in a 4x4x4 grid including inclined faces
		LEVEL C		24 figures entered in a 5x5x5 grid including curved faces
IMPROVEMENT PHASE	PRACTICE 2.1 Creation of 3D models from standard view figures	LEVEL A		24 figures entered in a 3x3x3 grid with parallel faces to coordinate planes
		LEVEL B		24 figures entered in a 4x4x4 grid including inclined faces
		LEVEL C		24 figures entered in a 5x5x5 grid including curved faces

At introduction phase, following instructions included in the video tutorial, student takes basic training in use of SketchUp software. Students learnt most important functions of the program, such as line and polygon drawing in 3D space as well as making extrusions model as a basic operation.

Once they get used to the program they perform practice 1.1 creating 3D models from real pieces of aluminum. For this phase have been used five sets of case M14 (lote14A) Maditeg Company (Maditeg, 1997) consisting of 30 aluminum machined parts. Afterwards student proceeds to practice 1.2 creating 3D models from isometric perspectives figures in three difficulty levels.

At the improvement phase students carried out practice 2.1 creating 3D models from standard orthogonal figures views. In this phase students receive theoretical indications about representation basics and fundamentals, focusing on the European System of Standardized views for being able to perform this level. Like in practice 1.2, this phase is also structured into three levels A, B and C in increasing difficulty levels. (Table 2)

Table 2: Workshop description.

ACTIVITY AND MATERIALS	FORMAT STATEMENT	WORKSPACE	RESULT FORMAT
1.1 Creation of 3D models from real aluminium pieces. **Statement:** Aluminium pieces **Support:** SketchUp file in custom template.	 Statement	 Custom Template	
1.2 Creating 3D models from a isometric perspective. (Level A, B y C) **Statement and Support:** SketchUp file in custom template.	 Statement and workspace		
2.1 Creating 3D models from standard orthogonal figures views (Level A, B y C) **Statement and Support:** SketchUp file in custom template.	 Statement and workspace		

Meanwhile, workshop time distribution is found on table 3:

Table 3: Time distribution.

		Duration (minutes)	Number of pieces to be taken
Introduction Phase	Basic Training	30	—
	Real Parts	30	1
	Level A	30	6
	Level B	30	6
	Level C	45	6
Improvement Phase	Level A	45	6
	Level B	60	6
	Level C	60	6

Workshop contents are implemented within a virtual classroom as this format allows immediate incorporation in any center. Besides, work performed by students in digital format can be received, stored and properly evaluated in a virtual classroom structure.

Thanks to the modulation of the workshop it can be implemented in formal teaching by adapting the number of exercises to be developed depending on student's level and number of hours available for that subject, proposing more or less figures to work with at each level.

Work hypothesis

Work hypothesis set is the following:

— A 3D modeling workshop is a valid tool for the aim of spatial abilities improvement.

— Use of new technological tools for learning improves student motivation.

For validating hypothesis 1 a null hypothesis (H0) is set so assumption will be validated or not through statistical inference methods. For hypothesis 2 all data from satisfaction surveys completed by participants at the end of the workshop are added.

DATA ANALYSIS

Spatial skills

The workshop took place during the first weeks of the semester, for avoiding possible influence from contents covered by other subjects, such as Graphic Drawing thus preventing other factors which may interfere with the test measuring spatial skills.

Table 4 shows the scores mean obtained by students prior to (pre) workshop and after it (post) as well as average gains for MRT and DAT5-SR tests.

Table 4: Mean pre and post test scores and overall score gains.

		MRT			DAT5-SR		
Course 2010-11	Total N=26	Pre (s.d.)	Post (s.d.)	Gain (s.d.)	Pre (s.d.)	Post (s.d.)	Gain (s.d.)
		16.60 (7.64)	22.80 (7.23)	6.30 (5.03)	24.90 (6.95)	35.60 (7.88)	11.20 (5.91)

s.d. standard deviation

For statistical analysis we use the t-student variable (Student`s *t*-test), starting from null hypothesis (H0): mean values of spatial abilities have not changed after training. *t*-Student test is applied for paired series getting the *p*-values representing probability that this hypothesis is true (Table 5).

Table 5: Significance level for Google SketchUp course.

	MRT	DAT5-SR
Course 2010-11	P=0.0000030808 < 0.001	P=0.0000000020 < 0.001

It is shown that significance level never reaches 1‰ , so null hypothesis is rejected in all cases and we can state, with a significance level above 99.9% that average variation of studied group has increased. So, workshop has a clear effect on the average value of the spatial abilities measured from those who underwent training through the 3D modeling workshop.

From statistical analysis we may conclude that spatial skills experience a significant average increase of 6 points for the MRT test and 11 points in the case of DAT5-SR.

Satisfaction survey

Satisfaction survey provides some relevant data about studied variables:

Variable 1 (workshop structure, presentation, design and materials): A 95.6% of students consider that workshop structure, phases and levels are appropriate or very appropriate. 87% preferred this format based on digital and virtual classroom materials rather than the traditional paper format.

Variable 2 (contents): 87% agree or strongly agree on the workshop contents clarity. Thus, 82.6 per cent considered that these contents have allowed them better understanding of standard views.

Variable 3 (user's satisfaction and motivation): 91% of participants believe that workshop improved their attention and motivation for studying matters related to analysis, design and interpretation of forms. 100% of the students who took the survey answered affirmatively when asked if they would be interested in 3D modeling courses which work with the design and interpretation of drawings, sketches, views and sections of ship components.

CONCLUSIONS AND FUTURE WORK

From this experience with implementation of the 3D modeling workshop we may conclude about hypothesis raised:

— Hypothesis 1: The skills can be developed through training. 3D Modeling Workshop using Google SketchUp has proved to be a good choice for this purpose: it has significantly increased the space capacity of the participants with an average gain of 6.30 points (5.03 s.d.) and 11.20 points (5.91 s.d.) in the MRT and DAT test SR-5 respectively.

— Hypothesis 2: use of new technological tools for learning improves the motivation of the student: 91% of the students agree with this.

About future works:

— It would be interesting adapting contents of this workshop to the new portable media devices such as digital tablets of recent appearance for example.

— According to survey results, we propose developing digital material that combines two and three dimensions for performing exercises from auxiliary vessel elements, incorporating Augmented Reality technology.

The implementation of these workshops in a virtual classroom provides the possibility for immediate incorporation to any other Center as well integration into formal teaching. So, we could exchange experiences between different Nautical technical colleges establishing benchmarks.

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MODELADO TRIDIMENSIONAL EN EL DESARROLLO DE COMPETENCIAS DE LOS NUEVOS GRADOS EN EL ÁMBITO DE LAS INGENIERÍAS MARÍTIMA, NÁUTICA Y MARINA

Resumen

En este artículo se describe un estudio piloto consistente en el diseño de un Taller de Modelado 3D como Herramienta de Innovación Educativa que desarrolla la capacidad de visión espacial. Dicha capacidad es una de las competencias a adquirir en los planes de estudio del Espacio Europeo de Educación Superior para las nuevas titulaciones de Grado en el ámbito de las Ingenierías Marítima, Náutica y Marina. El estudio ha sido realizado con estudiantes de Grado en Ingeniería Marina, Ingeniería Náutica y Transporte Marítimo e Ingeniería Radioelctrónica de la Universidad de La Laguna durante el curso académico 2010-2011. El software elegido para el Taller ha sido Google Sketchup 8, en su versión gratuita. Para medir la la influencia que ha tenido la realización del mismo sobre la visión espacial de los alumnos se emplean los test MRT y DAT5-SR. A la finalización del Taller los alumnos cumplimentan una encuesta de satisfacción. El formato y estructura del Taller permite su implantación en entornos virtuales de aprendizaje (aula virtual).

INTRODUCCIÓN

En el marco del Espacio Europeo de Educación Superior, el objetivo principal del proceso de enseñanza-aprendizaje consiste no solo en la adquisición de conocimientos por parte del alumno, sino en el desarrollo de una serie de competencias en función de los perfiles académicos y profesionales. Se entienden por competencias a aquellos conocimientos relativos a la actividad profesional que son resultado del aprendizaje. Una de las competencias contempladas en los planes de estudio de las titulaciones de Grado en el ámbito de las Ingenierías Marítima, Náutica y Marina es la capacidad de visión espacial. En este sentido, proponemos un Taller de Modelado 3D dirigido a la mejora de la visión espacial, midiendo el efecto sobre dicha capacidad.

Los componentes de esta capacidad se clasifican en dos categorías (Linn & Petersen, 1985; Olkun, 2003).

— Relaciones Espaciales o Rotación Mental: habilidad de rotar en nuestra imaginación, rápida y acertadamente figuras de dos o tres dimensiones.
— Visión Espacial: habilidad de reconocer piezas tridimensionales mediante plegado y desplegado de sus caras.

Para medir la mejora de la visión espacial cada participante realiza dos test antes y después de llevar a cabo el experimento: Mental Rotation Test (MRT) para medir la componente de Relaciones espaciales (Albaret and Aubert, 1996; Vanderberg & Kuse, 1978) y Differencial Aptitude Test 5– Spatial Relations Subset (DAT5-SR), para medir la componente de visión espacial (Bennett, Seashore y Wesman, 2002).

En el Taller de Modelado 3D han participado estudiantes de Grado en Ingeniería Marina, Ingeniería Náutica y Transporte marítimo e Ingeniería Radioelectrónica de la Universidad de La Laguna durante el curso académico 2010-2011. De un total de 72 alumnos, han participado 26 voluntarios. El software elegido para nuestro estudio es el Google SketchUp8, una aplicación multimedia de libre acceso y descarga gratuita.

El Taller consta de dos fases: Iniciación y Perfeccionamiento. Existen a su vez tres niveles de dificultad que se consiguen con la incorporación de caras inclinadas y caras curvas. A su vez, las figuras están dibujadas en una rejilla tridimensional que aumenta su complejidad con el nivel. Cada nivel contiene 24 figuras, de las cuales se les solicitó a los participantes que resolvieran un mínimo de seis de ellas. El diseño de este Taller ha sido validado por el Grupo de Investigación DEHAES (Desarrollo de Habilidades Espaciales: http://www.degarin.com/dehaes/) de la Universidad de La Laguna durante el curso 2010-2011, comprobando cuantitativamente la adecuada distribución en fases de aprendizaje y niveles de dificultad: se han obtenido unos tiempos medios de resolución de ejercicios por fases y niveles de 3 minutos para la fase de iniciación y de 8 minutos para la fase de perfeccionamiento.

En la fase de Iniciación, el alumno realiza un entrenamiento básico del manejo del software SketchUp. Una vez familiarizados con el programa realizan la práctica 1.1, consistente en crear modelos 3D a partir de piezas reales de aluminio. Posteriormente, el alumno accede a la práctica 1.2, en la que ha de crear modelos 3D a partir de perspectivas isométricas de figuras, con tres grados de dificultad creciente. En la fase de perfeccionamiento el alumno realiza la práctica 2.1, consistente en crear modelos 3D a partir de vistas ortogonales normalizadas de figuras. Como en la práctica 1.2, esta fase está también estructurada en tres niveles A,B y C en grado creciente de dificultad.

Los contenidos de este Taller se han desarrollado dentro de un aula virtual en la plataforma educativa Moodle. Gracias a la modularidad del Taller se puede implementar en la docencia reglada adaptando el número de ejercicios a desarrollar en función del nivel del alumno y del número de horas de que disponga la asignatura, proponiendo trabajar, en cada nivel, con más o menos figuras.

Hipótesis de Trabajo

Las hipótesis de trabajo de las que partimos son las siguientes:

1. Un Taller de Modelado 3D es una herramienta válida para el objetivo de mejorar las habilidades espaciales.
2. El empleo de nuevas herramientas tecnológicas de aprendizaje mejora la motivación del alumno.

Para poder validar la hipótesis 1 se fijará una hipótesis nula (H0) y se validará o no la suposición a través de métodos de inferencia estadística, a partir de los resultados obtenidos en los test. Para la hipótesis 2 se aportan datos de encuestas de satisfacción cumplimentadas por los participantes al finalizar el Taller. Las preguntas de la encuesta están formuladas en una escala tipo Likert y consta de 56 preguntas organizadas de acuerdo a 3 variables: estructura, presentación, diseño y materiales del Taller; contenidos y, finalmente, satisfacción y motivación del usuario.

CONCLUSIONES Y FUTUROS TRABAJOS

De la experiencia obtenida en la realización del Taller de Modelado 3D podemos concluir, respecto de las hipótesis planteadas:

— Hipótesis 1: Las habilidades se pueden desarrollar mediante entrenamiento. El Taller de Modelado 3D utilizando Google SketchUp se ha mostrado como una buena opción para este propósito: ha aumentado significativamente la capacidad espacial de los participantes con una ganancia media de 6,30 puntos (5.03 s.d.) y 11,20 puntos (5,91 s.d.) en los test MRT y DAT SR-5 respectivamente.

— Hipótesis 2: El empleo de nuevas herramientas tecnológicas de aprendizaje mejora la motivación del alumno: un 91% de los alumnos así lo consideran.

En la línea de futuros trabajos sería interesante adaptar los contenidos de este Taller a los nuevos soportes móviles como por ejemplo las Tabletas Digitales de reciente aparición, combinando 2D y 3D para la realización de ejercicios de elementos auxiliares del buque en un entorno de Realidad Aumentada.

La implementación de estos Talleres dentro de un aula virtual ofrece la posibilidad de incorporarlos de manera inmediata en cualquier otro Centro e integrarlos en la docencia reglada. De este modo, se podrían intercambiar experiencias entre las distintas Escuelas Técnicas Superiores de Náutica, estableciendo parámetros comparativos.