This is the accepted version of a manuscript published in IEEE Geoscience and Remote Sensing Magazine.
ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

A World Wide Web-Based Practice That Disseminates Photogrammetry

Inspiring secondary students to pursue geomatics careers

Gil-Docampo, M. Ortiz-Sanz, J., Rego-Sanmartín, T. Arza-García*, M.

***Abstract*— The D3MOBILE Metrology World League was established in 2013 with the aim of encouraging curiosity and interest in science, and particularly geoscience, in the secondary students of grades ISCED 1 and 2. Presented as an international championship, D3MOBILE introduces students to the discipline of photogrammetry through the e-learning methodology concept. The use of well-known technologies by the pupils, such as their own mobile devices (smartphones or tablets), allows us to develop educational procedures that are attractive and challenging for them. All the work that we propose for the participants is presented in a scientific, technical, and professional language but in a more interactive format than traditional textbooks or theoretical classes. The proposed challenges provide students with the opportunity to establish their own learning objectives, work as a team and take responsibility for their work. This paper addresses the experience, from an educational perspective, carried out by our research group CIGEO (Civil Engineering and Geomatics) during the organization of the first five editions of this international "concept submission competition". During this period, we tried to create and improve a project-based learning (PBL) methodology that can be adapted to e-learning and daily classwork at the high school level, which can be easily implemented regardless of the number of participants and can be implemented anywhere in the world. The obtained results demonstrate the potential of alternative teaching methods combined with new technologies to engage students in science learning and improve the perception of the geosciences as a job opportunity.**

***Index Terms*—Educational activities, Engineering education, Geoscience, Metrology**

I. Introduction

THERE IS growing concern all over the world that society is not preparing a sufficient number of students, teachers, and practitioners in the areas of science, technology, engineering, and mathematics (STEM). Many secondary students have failed to achieve proficiency in math and science, and many are taught by teachers lacking adequate knowledge of the subject matter [1]. This has also been reflected in the reduced number of students, mainly women [2], who have enrolled in science degrees at the university level for a number of years now [3], [4].

In particular, academics and institutions involved in the fields of photogrammetry, remote sensing and spatial information sciences have been aware of a general worldwide decline in the number of undergraduates embarking on degree programmes in geomatics [5]. The current difficulty in attracting students is making departments and programmes less viable, and there is a serious risk that a number of these smaller departments or programmes will be threatened with closure.

Paradoxically, graduates in the spatial sciences have never

Manuscript submitted July 24, 2018. This work was supported in part by FECYT—Ministerio de Economía y Competitividad (FCT 12-3495; FCT 13-5961; FCT 14-8038; FCT 15-9481); and Xunta de Galicia (ED431B22016/030; ED341DR2016/023).

M. Gil-Docampo (ml.gil@usc.es), J. Ortiz-Sanz (juan.ortiz@usc.es), and M. Arza-Garcia* (m.arza@usc.es) are currently with the CIGEO – Civil and Geomatics research group of the University of Santiago de Compostela, 27002 Lugo (CampusTerra), Spain.

T. Rego-Sanmartin (teresaregosanmartin@edu.xunta.es) is currently with the Regional Government (Xunta de Galicia). Culture, Education and University Department.

*Corresponding author.

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

been in such high demand by the professional market, as the role of spatial information in society has been well documented. The application of this knowledge is varied and has been extensively implemented in the fields of urban and regional planning, industrial manufacturing, cultural heritage, environmental monitoring, and 3D design, among others [6]. Geomatics education is a transversal discipline that acts as a bridge between these sci-tech advancements and practical applications.

II. Key Issues

A. *STEM projects to encourage scientific vocations*

To address this situation, many interesting ideas and projects have been proposed at the secondary school level, such as implementing interdisciplinary projects or research programmes within scheduled courses or outside of them, in the form of after-school classes. These new approaches to project-based learning (PBL) are needed to develop the skills suited to the twenty-first century (i.e., inquiry, problem solving, innovation, entrepreneurship, technological communication, experimental design, and investigativeness) in these students [7]–[9]. However, current trends in educational programmes are changing the STEM approach to STEAM by incorporating the Arts as a vital interdisciplinary link [10], [11]. The STEAM paradigm, in addition to emphasizing the importance of classical STEM education, argues that the arts have the ability to open up new ways of seeing, thinking, and learning.

Integrating new technologies into school projects, which are attractive to students, seems to be an effective way to engage them. Robotics [12], [13] and video games [14], [15] are some of the technologies that have been widely and successfully implemented in this type of activity. When we think of high-impact STEM initiatives, the first ones we think of are frequently global projects, such as the First Lego League, NASA Engineering Design Challenges, Google Science Fair, Big Bang UK Fair, Imagine Cup, MIT Think Competition, The Odysseus II Project, and Zero Robotics, etc. The reason for this is not only because these initiatives have very strong partners but also because they represent worldwide competitions.

Projects based on competitions have the positive effects of engaging and motivating students [16]–[18]. At the high school education level, it has been shown that competitions and scientific challenges contribute positively to post-secondary matriculation [19]. The variations in STEM competitions can be very broad (e.g., Science Olympiads, tournaments, and presentations), but what the ICS (Institute of Competition Sciences) calls "Concept Submission Competitions" are becoming particularly popular due to the flexibility in participation they offer. Within this category of projects, students are often tasked with creating a product in response to a topic statement. These are then reviewed by a committee and are typically implemented online.

B. *Mobile devices and 3D technologies as learning tools*

Among the most appropriate technologies integrated into educational programmes, due to their level of accessibility, are mobile devices, such as tablets or smartphones [20]. Mobile learning has emerged in recent years as a branch of ICT education due to the use of mobile technology, either alone or in combination with other kinds of information and communication technology, to enable learning anytime and anywhere. In this sense, international organizations such as UNESCO have made efforts to examine how mobile devices, embedded in broader educational ecosystems, can support literacy and increase the capacity of teachers.

In addition to their communicative functions, mobile devices can be used in the development of activities based on the use of their own integrated sensors (i.e., light sensors, motion sensors, photo and video cameras or positioning systems). Successful examples of the integration of mobile sensors and components in classes can be found in many projects [21], [22].

The compatibility of these low-cost mobile technologies with 3D modelling and visualization tools has provided new opportunities to explore different ways to support teaching and learning, thus strengthening a variety of educational domains and professional fields [23], [24]. Moreover, 3D modelling is compatible with the new changes in perspective from STEM to STEAM, as these initiatives can be directed at both a scientific and an artistic level due to the transverse nature of this technique.

However, these initiatives must also be enriched with transversal disciplines, such as metrology, which are fundamental in modern society, as they establish a common and standardized language and procedures that ensure the reliability of measurement results. Governments and institutions have made great efforts to help children understand concepts such as measurement standards or error analysis. Some examples of these initiatives are the US Measurement League (https://www.nist.gov/kids/meet-measurement-league), http://www.metrologycareers.com/, and the BIPM-OIML Resource Center, which is jointly operated by the Bureau International des Poids et Mesures (BIPM) and the International Organization of Legal Metrology (OIML, http://www.metrologyinfo.org/).

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

Fortunately, the versatility of mobile devices has made it possible to easily integrate them with methodologies based on 3D techniques from a variety of different perspectives, such as modelling, the arts and metrology, thus making this an attractive topic for the development of educational proposals.

C. *Promoting geomatics to young people*

The field of geomatics and geoinformation represents an area where a noticeable effort has been made to promote it from an early age. The main international organizations in this field: the International Society for Photogrammetry and Remote Sensing (ISPRS), the American Society of Photogrammetry and Remote Sensing (ASPRS) and the Geoscience and Remote Sensing Society (GRSS) have identified geomatics education and training as an essential activity [6]. Many initiatives have been carried out within this framework to develop tools and resources for geospatial training and education at the university level [25]–[28], even in the form of massive online open courses (MOOCs) [29]. However, for a number of years, the increasing need to attract more students to geomatics and related disciplines has called for marketing efforts to be directed at high schools [30]. For that reason, some projects related to implementing the use of geospatial technology at the high school level have arisen in recent years [31]–[33]. The increase in the demand for geotechnologists is related to major changes at the professional level due to technological developments, as 3D spatial skills are now essential for many traditional jobs, such as medicine, mining, design, and construction.

Photogrammetry, as a 3D scanning technique, is one of the disciplines in the geosciences that best integrates the ability to acquire 3D skills. In this sense, photogrammetry constitutes a powerful tool that can be incorporated into educational projects. Some of these initiatives, although relatively few, are also aimed at the pre-university level and involve both aerial photogrammetry [34] and terrestrial photogrammetry [35].

D. *Open photogrammetric resources*

A quick review of the recent history of photogrammetry indicates that the entry into the current internet age has contributed much to the diffusion and degree of use that it currently enjoys. During the last years of the past century, some people, such as [36], wondered why photogrammetric software programs based on simple equipment and simple currently existing methods have not been more widely used. The problem remains how to promote the need for the use of photogrammetry and how to teach others about the use of this technique. The more widespread use of photogrammetric software would undoubtedly reduce its cost.

A very significant advance in this sense came from the new possibilities afforded by the cloud, which led to the appearance of ARPENTUR (Architectural Photogrammetry Network Tool for Education and Research) [37]. This application was the first digital photogrammetric workstation on the web, and it paved the way to current photogrammetry tools, many of which are also available online or have been openly distributed: Arc3d (www.arc3d.be), VisualSFM (ccwu.me/vsfm/), COLMAP (https://colmap.github.io/index.html), MESHRECON (http://zhuoliang.me/meshrecon.html), REGARD3D (http://www.regard3d.org/index.php), 3DF Zephyr Free (https://www.3dflow.net/3df-zephyr-free/), and GRAPHOS (https://github.com/itos3d/GRAPHOS).

With the emergence of smartphones, another great advance in the diffusion of photogrammetry has emerged to the point that many apps for 3D reconstruction are currently available for any platform, including QLONE (https://www.qlone.pro/), SCANN3D (http://scann3d.smartmobilevision.com/), TRNIO (http://www.trnio.com/), and XYZPhoto3D (https://www2.xyzprinting.com/en-GB/software?appCategory=mobile). Even Google has presented, under the name Tango-project, a mobile phone with both hardware and software that is fully designed to track its own motion and capture 3D scenarios in real time [38].

In parallel to the accessibility of the photogrammetric technologies that have emerged in recent years, online communities promoting free 3D model sharing (such as Sketchfab or Thinkiverse) have been also boosted by the democratization of related technologies, such as 3D printers or low-cost UAVs. All of these elements play a critical role in the dissemination of the 3D ecosystem and have increased interest in photogrammetry, thus bringing it even closer to amateur users.

With the advent of photogrammetry, the demand for skilled manpower is increasing, as is the need for training, education, research and dissemination at all levels [39]. Many e-learning initiatives have emerged, thus facilitating learning and improving performances by creating, using and managing appropriate resources through digital and network-enabled technology [40]–[44]. These resources provide more flexible access to content and instruction at any time and from any place.

E. *The “D3MOBILE Metrology World League” project*

With the STEAM framework in mind and with the objective of addressing the widespread lack of interest in science, and particularly geoscience, we started a project entitled the D3MOBILE Metrology World League five years ago. This

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

project is aligned with the overall objectives of UNESCO and the international organizations involved in the knowledge of geosciences through the combined use of mobile devices in education and 3D technologies. Presented as an international championship, D3MOBILE brings students closer to the disciplines of photogrammetry and metrology through the e-learning methodology concept. All the work that we propose to the participants is presented to them in a scientific, technical, and professional language but in a more interactive format than that provided by traditional textbooks and theoretical classes. Teachers are encouraged to include alternative interactive experiences and class discussions to stimulate learning. This methodology allows students to gain 3D skills, learn the basics of photogrammetric techniques, gain experience in the modelling of simple objects and practice a range of techniques related to the science of measurement. For this purpose, we tried to design a PBL methodology that can be adapted to m-learning and the daily classwork of secondary schools, which can be easily implemented regardless of the number of participants and whose format corresponds to a concept submission competition that can be implemented anywhere in the world. Moreover, we have designed complementary tools for the effective dissemination of work and supporting tools for participants, avenues to recognize student work (e.g., an annual award ceremony) and satisfaction enquiries to monitor the opinions of participants.

III. Materials and Methods

A. *D3MOBILE as a World Wide Web-based project*

The “D3MOBILE Metrology World League” project was carried out over a 5-year period (2013–2017), and we are currently seeking sponsors to support the next edition. The target audience was secondary students (12-16 years old, ISCED 1 to 2 students), and the e-learning nature of the project was designed to reach as many pupils as possible. All of the necessary reference material (e.g., methodology, quizzes and championship guidelines) is available online for the participants.

The D3MOBILE championship website (http://www.d3mobile.es/index.php?idioma=en) constitutes the main source of communication with students and teachers. We use the web to upload publications and videos from schools and to feature satisfaction enquiries, information about the championship and relevant or remarkable scientific information.

The impact of the project is assessed through quantitative criteria based on the number of registered teams (stimulation to research), the number of registered foreign teams (internationalization) and visits to the website (social impact).

B. *The design of the trials*

Before the start of each school year, we open a registration period during which a teacher, who will lead one or several groups of 3 or 4 students each, should register. After registration, each teacher will have access to our content and methodological guides so that they can implement this process in their classes.

The content of the quizzes into which the competition is divided has varied slightly from year to year to implement improvements and to allow different groups of students to participate in several editions. Nevertheless, the general outline of the championship has remained invariant during these first five editions, with a structure comprising three tests. The structure of these independent trials makes it possible for teachers to decide how far to proceed with their students based on the teaching plan for each subject and each high school.

First quiz

The first exercise has a formative and self-evaluative nature. At the content level, this exercise introduces the concept of photogrammetry and allows students to become familiar with 3D modelling techniques with the use of their own smartphone/tablet. The modelling of a common object is proposed for all teams.

In the corresponding guide to the quiz, each group is provided with different basic techniques to improve the quality and stabilization of its images. Using this guide and help from their teachers, the participants set the configuration of the device parameters and take photographs of the object. Then, using these images and free software (e.g., Trnio, Scann3D or Arc3D), students can generate their own 3D model.

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

Fig. 1. Scanning real objects with mobile devices and photogrammetry: (a) taking photographs with a mobile device camera and (b) 3D object reconstruction.

Second quiz

The objective of the second quiz is to use the knowledge acquired in the first introductory test and apply it to a real case. For this purpose, the 3D modelling of an object of their own choice is proposed for each team. In addition to reinforcing theoretical concepts, this exercise allows students to develop their creativity.

Furthermore, in the second part of this quiz, participants are introduced to the world of 3D editing, and they use specific computer tools designed for this purpose (e.g., Meshlab) to edit their own model. Participants also learn to geo-reference their models based on the GPS measurements obtained with their own mobile devices. Finally, students carry out the publication of their model in an online repository for 3D models (e.g., Sketchfab.com), which allows them to disseminate their model to the general public and to their personal social circle through social networks.

Fig. 2. Free object 3D scanning: fundamentals of photogrammetric 3D reconstruction with images obtained from different angles (a); and GPS data acquisition for model georeferencing (b).

Third quiz

The last test is focused on the metric assessment of 3D models. In the first part of the quiz, some basic concepts associated with metrology, such as accuracy, precision, and error or measurement uncertainty, are reviewed with practical examples.

The second part of the test involves the scaling, from a well-known reference distance, of a photogrammetric model created by the staff of the championship. Using the scaled model, the participants must measure the distances between different points on the model so that the competition judges can verify that this process has been carried out correctly.

Fig. 3. Scaling a 3D model: (a) a stone slab with target points and reference distances from the caliper used in the last D3MOBILE edition; and (b) the process of marking points in the Meshlab software to scale the model.

The trial design requires enormous effort to obtain well-articulated results, and the online format of the "concept submission competition" requires the presentation of procedures in which cheating is impossible. The possibility of cheating is very difficult for any participant and is sufficient reason for immediate disqualification.

Additionally, the need to adapt to a large number of

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

participants affected the design of the evaluation process of the trials. In this way, the evaluation of the most subjective aspects, such as the visual quality of the 3D models, was resolved using an automated voting system among the participants.

C. *Integration in student curricula and skill development*

The D3MOBILE project has been designed to adapt to e-learning methodology in a way that is compatible with the daily work at the high school level and can thus be directly incorporated into students' curriculum.

However, in addition to the provided tests, we also make available a set of tools (e.g., guides, discussion forums or video tutorials) and activities to students and teachers that facilitate their teaching work. The teaching materials are organized in a way that allows a single teacher to supervise up to six teams of four students each. In this way, the project can be integrated into classwork, either as voluntary or mandatory work, within a given lesson plan.

The design of the project is based on highlighting the skills that a STEM professional should possess. In this sense, the championship is designed as a team competition to reinforce the brainstorming capacity and teamwork of the pupils. These pupils are intended to develop their analytical capacity by solving problems. Although we provide them with the detailed documentation of the trials that should allow for autonomous work, they have to solve the problem together. We also try to design the championship tools to allow them to improve their communication skills.

On the other hand, the ability to visualize in three dimensions is a cognitive skill that has been shown to be important in engineering and other technological fields. The use of 3D scanning mobile applications and working with photogrammetric models have been shown to reinforce students' 3D spatial skills. Particularly, the contents of the three trials are designed to cover the following topics:

- Photogrammetry principles
- Common problems of photogrammetry (e.g., reflective objects, blurring)
- Point clouds and TIN surface representation
- Model texturing
- Object transformations, including translation, scaling, rotation, and reflection
- 3D coordinate systems
- The concepts of accuracy/precision, uncertainty and error

D. *Promoting interest in science and geosciences*

Promoting science is critical because important and broadly used advances are often beyond society's understanding. The D3MOBILE project has been carefully designed to enhance interest in the sciences and particularly the geosciences by highlighting the professional possibilities offered by photogrammetry and the use of 3D techniques in many fields.

To achieve this goal, it is essential to present theoretical and practical content related to these fields in an attractive way. However, this system is also designed to encourage students to disseminate their own work to get votes, which can attract the attention of their entire social network. This project is also expected to allow students to reinforce their vocational choice by influencing their environment.

At the end of each edition, feedback was also requested from teachers and students using opinion surveys. After each championship, these surveys were analysed to determine what aspects were working properly and what aspects should be improved. Teachers from some schools also visited our university to personally discuss with the staff ideas, proposals, and theories about students and to solve any problems that arose.

IV. Results and Discussion

A. *D3MOBILE as a World Wide Web-based project*

The "D3MOBILE Metrology World League" project achieved considerable dissemination from the very beginning. In the year 2013, a total of 1126 students, exclusively from Spanish high schools, participated in the first edition of the championship. Due to the good reception of the project, we proposed extending the programme worldwide in its second year. Since then, the number of participants has increased over the years, resulting in the last edition featuring 1476 students from 44 countries.

TABLE I
Summary of the number of schools and students involved in each edition of the D3mobile championship

D3MOBILE edition	# of Schools	# of Countries	# of Students
2013	126	1	1126
2014	142	24	632
2015	130	33	1070
2016	223	37	1348

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

2017	268	44	1476

To achieve a greater impact and make the project more interesting to students, we have strengthened our presence in social networks (mainly Facebook: https://www.facebook.com/d3mobile-120484484779686; YouTube: https://www.youtube.com/user/d3mobileague; Twitter: https://twitter.com/d3mobile; and Sketchfab: https://sketchfab.com/d3mobile-m_world_league).

Considering the best annual results of previous years in terms of the social media impact (1,476 students registered from 44 countries, 2,200 visits / month to the website, 3D models visualized 15,000 times, voting performed by 2,100 voters, 200 "likes" on Facebook and 1,260 followers on Twitter), we can say that the first five editions of this project have had a good impact.

At the end of each championship edition, teams submitted their georeferenced models and we made a map depicting all of the participants, which provided us with an idea of the level of internationalization that was achieved.

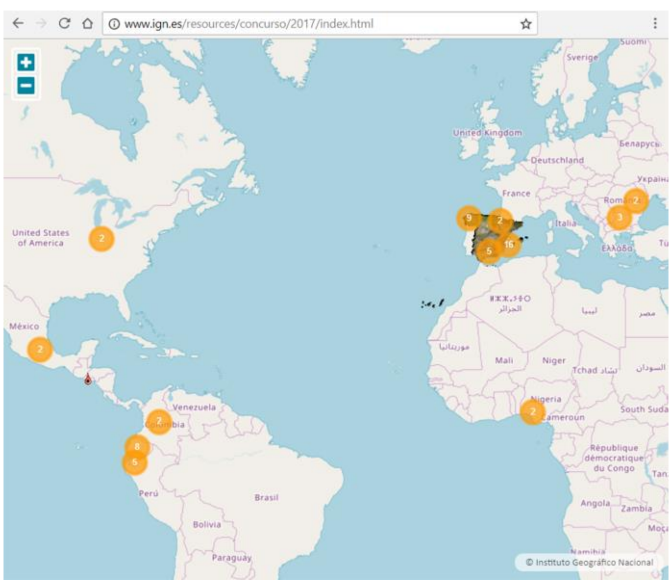

Fig. 4. Map of participating students. http://www.ign.es/resources/concurso/2017/index.html.

Moreover, at the end of each annual contest, we organized an official event in our city (Fig. 4) involving our sponsors and collaborators, who donated prizes to the winners of each category. We suggested that teachers who were unable to attend the awards ceremony prepare parallel events in their own high schools. The event was broadcast live; in it, we also played videos of appreciation for the winners (e.g., https://youtu.be/AOJUKb_Eg4w), thus allowing all of them, either in person or virtually, to receive recognition.

Fig. 5. D3MOBILE annual awards ceremony in Lugo, Spain (a and b); parallel event in a Colombian high school; and (c) some of the prizes awarded in the last edition.

The e-learning format of this project allows our team to offer this championship to any local, national or international entity that is interested in promoting photogrammetry and related sciences to the students in its environment. These entities can participate simply by offering a prize within the structure of D3MOBILE (e.g., prizes Frontera Reyes of Bogotá) or by organizing their own championship integrated with the methodology of D3MOBILE, such as the Latin American Society of Science and Technology (SOLACYT).

However, this idea can even be implemented to achieve another specific objective or to address a completely different topic. This occurred in the case of the project CompostelaEnVerde (http://compostelamedraenverde.blogspot.com.es/), which was designed to promote environmental preservation among Galician students. However, instead of implementing this project through a typical narrative, photo or video championship, this project involved the use of 3D models. The winners can be observed at https://sketchfab.com/uscan3d/collections/compos3d-2016.

As a result of five years of hard work, our research group CIGEO (GI-2084, USC) was invited to present this project in workshops and scientific events such as SCIENTIX, Ciencia y Redes (http://cienciaenredes.com/) and SPIN2016 (http://www.spin2016.org/). D3MOBILE has also been selected as a "Good Practice" by the European Commission by

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

its initiative for innovative education "Open Education Europe" (https://www.openeducationeuropa.eu/).

B. The design of the trials

Due to the difficulties involved in managing a large number of schools in an international context, we tried to implement several improvements after the first year to facilitate participation. The guides and tutorials for each quiz are available in different languages, and the deadlines of the activities were extended to make the contest compatible with the heterogeneous schedules of different learning centres. During these years, more award categories were also added to increase the flexibility of the student access profiles and to allow D3MOBILE to provide an integrative education from a STEAM perspective.

Several participants (mainly in the first editions) reported having compatibility problems with the proposed software due to the operating systems of their devices. Thus, we also tried to integrate diverse procedures in the contest guides for the use of different types of software. With this improvement, we managed to avoid the model of the device (i.e., Android, Windows or iOS) becoming a limiting factor for the participants.

As expected, students reacted positively to the use of mobile photogrammetric apps, and some practice with the technique was sufficient for them to obtain satisfactory results. In several of the surveys completed by the participants at the end of the championship, many were surprised by the level of detail and metric quality that could be achieved by their models, which were made with standard camera smartphones.

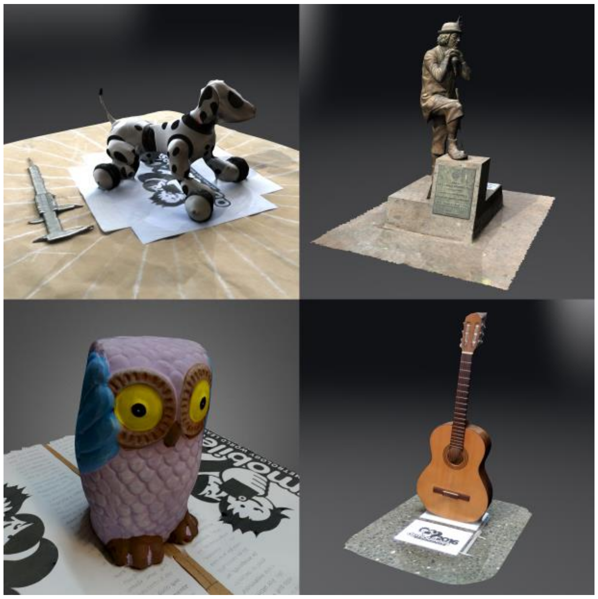

Fig. 6. Some of the 3D models created by students. All models are available at: www.sketchfab.com.

In general, the scoring system is appropriate for the participants because it reduces subjectivity. The designed tests have proven their effectiveness, and no complaints have been received about them. Very few deliberate attempts at fraud were detected, namely, one case in which the results of the first repetition were identical to those of the second repetition, which is impossible in practice; and another case where the 3D model was created with a reflex camera, which allows the user to substantially improve the quality of their photos and measurement results.

C. Integration in student curricula and skill development

In addition to developing their 3D skills, the proposed activities require students to engage in teamwork and promote their interest and curiosity in the search for solutions. Both teachers and the project staff have agreed to emphasize the involvement of teams and originality when developing ideas to improve their results. Some examples of this can be seen in the following figure, where the participants managed to improve their photograph-taking process using their available resources.

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

Fig. 7. Geniuses at work: stabilizing smartphones (a) with a cord or (b) with an improvised tripod; and managing the illumination of the scene (c and d).

Since the first edition, we have promoted the dissemination and publicity of the championship involving the participants in this challenge. With this objective, we have also created a specific award for the 3D model with the most votes, which has been an excellent way to improve the students' communication skills. This award encourages participants to promote their own model among their social circle using the aforementioned social networks and many other media, thus indirectly enhancing the visibility of the championship itself. On our website (http://www.d3mobile.es/vota_promo.php), we have compiled some of the most interesting proposals that students have used to request votes for their teams (e.g., https://youtu.be/5UpTMGAqcRE).

Teachers are also encouraged to disseminate the successes of their students in their centres and in the local press (e.g., http://d3mobile.es/hallfame.php) to recognize student efforts and also enhance the visibility of the championship. In many cases, not only teachers but also the government entities of these countries are engaged in the process of student recognition (e.g., the Ministry of Education of Ecuador, https://educacion.gob.ec/unidad-educativa-fiscomisonal-calasanz-de-loja-alcanzo-el-subcampeonato-en-mundial-de-diseno-3d/).

D. Promoting interest in science and geosciences

The "D3MOBILE Metrology World League" demonstrates that although students may be interested in science, some concepts and techniques, such as some of those included in our project, can be difficult to teach. Student surveys (Fig. 7a) reveal that the synergy between science and new technologies can remarkably improve the perceptions of both fields by the students.

From the teachers' standpoint, the results were also definitively positive (Fig. 7b). Teachers observed a general increase in interest in science and a better understanding of concepts compared to those of students in previous school years, who were taught only using standard lecture instruction. In their opinion, the overall student involvement was remarkable, and it was particularly notable for students who had been observed to have had poor interactions within groups in other circumstances.

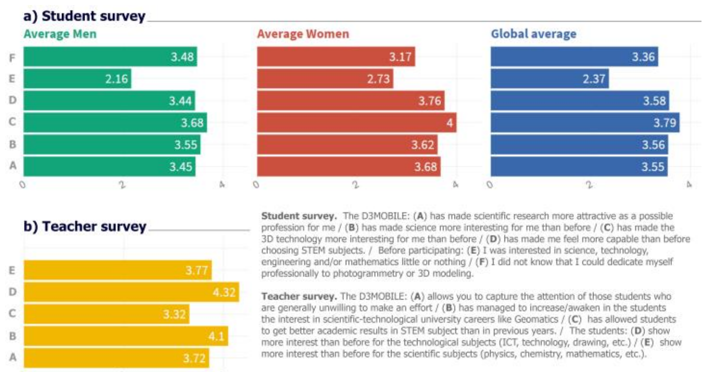

Fig. 8. Results of interest in science and technology before and after participating in D3MOBILE. The results obtained from the surveys received (2017): a) by the students and b) by the teachers. Rating: 1- completely disagree, 5- agree entirely.

The project tried to allow students to approach science from a more practical and less theoretical perspective by means of the integration of different challenges using the mobile devices with which they are familiar. Based on the surveys obtained here, we believe that the project has met its initial expectations.

More specifically, the programme has served to encourage future students to pursue vocations in the field of geomatics by showing them the wide possibilities of this specialty in areas such as 3D modelling, which has enormous prospects for job growth. Since the years of economic crisis, a reduction in the demand for careers related to building and civil construction has been perceived, particularly in the hardest-hit countries, such as Spain. The case of degrees in geomatics has been particularly serious since the low number of new enrolments has forced many universities to stop offering these degrees. Therefore, we believe that it is vitally important to convey the possibility of working in this field using related technologies such as 3D digital modelling and to demystify the classic and exclusive association of geomatics with construction.

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

V. Conclusions

The levels of participation and internationalization achieved by this project allow us to be optimistic about future editions of D3MOBILE. Several factors, such as the e-learning format and the structure of a concept submission competition, have contributed to the dissemination of this championship and the engagement of students. Thus, we will continue to use this experience as a reference for future projects.

Throughout the 5 years of the championship, constant communication was maintained between teachers and organizers. School feedback regarding necessary improvements and students' responses to every activity were extremely valuable for subsequent editions. The greatest difficulties for both the organization of the championship and the participants themselves was mostly the time required for the completion of the quizzes. Due to the differences in academic calendars depending on the courses and countries of the participants, it was not easy to establish a common schedule that could contain all of the teaching activities. However, in recent editions, these deadlines were made more flexible so that participants could adapt to the calendar without affecting their daily lessons.

Participating in a championship allows students to remain motivated in a competition environment and encourages them to use teamwork to achieve their objectives. Furthermore, the use of digital technology with which they are familiar (i.e., computers and, particularly, their own mobile devices) increased their engagement. In addition, alternative teaching methods were able to better involve certain students who do not benefit from traditional classroom methods. The combination of computer-based learning and a suitable learning approach thus represents an excellent tool that can be integrated into education programmes.

Overall, the responses of students and teachers to the project were very positive. Competing with other students from around the world was one of the characteristics of the contest that was most valued by the students. Other positive points for students included getting a chance to win different prizes and obtaining recognition of their environment (i.e., appearing in the local press and social networks or participating in the award ceremony). Teachers also expressed the importance of this type of project for applying the knowledge acquired in theoretical classes. Encouraging students to develop ideas and experiments and to discuss among themselves can foster much more positive attitudes towards learning. Overall, providing scientific information and teaching science from various standpoints using different methodologies seem to have motivated and inspired the participants, thus yielding the desired outcome. Indeed, this project has emerged as the perfect tool for interacting with students.

Furthermore, the D3MOBILE project allowed us to improve the awareness and visibility of some scientific fields, including photogrammetry and metrology, thus changing students' perceptions of them. The development of 3D products was indicated by most participating students to be an attractive professional field for them in the future.

Acknowledgment

We thankfully acknowledge the financial support from FECYT—Ministerio de Economía y Competitividad (FCT 12-3495; FCT 13-5961; FCT 14-8038; FCT 15-9481); and Xunta de Galicia (ED431B22016/030; ED341DR2016/023). We would also like to thank our large number of sponsors and collaborators: Universia, BQ, Autodesk, National Geographic Institute (IGN), City Council of Lugo, Provincial Council of Lugo, Spanish Center of Metrology (CEM), Fundación Vodafone, CEAPA, City Council of La Coruña, Fundación Barrié, ANPE, CSI-F, Fundación Comforp, PCE, Univ. Tecnológica Nacional (Argentina), Fundacion Mujeres, EDUCACION 3.0. and likely even more entities. Finally, we would like to thank the schoolteachers and students whose work and dedication allowed this project to achieve its objectives.

References

[1] European Commission, "Science Education for Responisble Citizenship," Rep. to Eur. Comm. Expert Gr. Sci. Educ., 2015.

[2] A. D. Aragón, M. J. Rura, and R. Morton, "Geospatial Science Learning: In STEM and advocacy for Girls and Women," Photogramm. Eng. Remote Sens., vol. 83, no. 2, pp. 73–76, 2017.

[3] F. Becker, "Why don't young people want to become engineers? Rational reasons for disappointing decisions," Eur. J. Eng. Educ., vol. 35, no. 4, pp. 349–366, 2010.

[4] B. Convert, "Europe and the Crisis in Scientific Vocations," Eur. J. Educ., vol. 40, no. 4, 2005.

[5] J. P. Mills, D. Parker, and S. J. Edwards, "Geomatics. org. uk: A UK response to a global awareness problem," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 35, no. B6, pp. 1–6, 2004.

[6] J. Gong et al., "Geoinformatics education and outreach: looking forward," Geo-Spatial Inf. Sci., vol. 20, no. 2, pp. 209–217, 2017.

[7] M. Corlu and E. Aydin, "Evaluation of Learning Gains Through Integrated STEM Projects," Int. J. Educ. Math. Sci. Technol., vol. 4, no. 1, p. 20, 2016.

[8] K. Lesseig, J. Firestone, J. Morrison, D. Slavit, and T. Holmlund, "An Analysis of Cultural Influences on STEM Schools: Similarities and Differences Across K-12 Contexts," Int. J. Sci. Math. Educ., pp. 1–18, 2018.

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

[9]J. Edmunds, N. Arshavsky, E. Glennie, K. Charles, and O. Rice, "The Relationship Between Project-Based Learning and Rigor in STEM-Focused High Schools," Interdiscip. J. Probl. Learn., vol. 11, no. 1, pp. 1–6, 2017.

[10] B. Sriraman and M. Roscoe, "Interdisciplinary perspectives to the development of high ability in the 21th century," Int. J. Talent Dev. Creat., vol. 3, no. 2, pp. 1–6, 2016.

[11] T. Barrett, A. Ruthmann, E. Anttila, and B. Haseman, "Learning Across Disciplines: A Collective Case Study Of Two University Programs That Integrate the Arts with STEM," Int. J. Educ. Arts, vol. 16, no. 7, 2015.

[12] D. Alimisis et al., "Introducing robotics to teachers and schools : experiences from the TERECoP project," in Constructionism, 2010, pp. 1–13.

[13] N. Fava, S. Monfalcon, M. Moro, E. Menegatti, J. Arlegui, and A. Pina, "Teacher Training in the Scientific Field Through Robotics Activities: Some Experiences From Italy and Spain," in Proceedings of the INTED2009 Conference, 2009, no. March, pp. 747–756.

[14] L. Annetta, J. Minogue, S. Holmes, and M. Cheng, "Computers & Education Investigating the impact of video games on high school students ' engagement and learning about genetics," Comput. Educ., vol. 53, no. 1, pp. 74–85, 2009.

[15] J. Guerra-Varela et al., "A Zebra in the Water: Inspiring Science in Spain," Zebrafish, vol. 13, no. 4, pp. 241–247, 2016.

[16] R. Christensen, G. Knezek, and T. Tyler-Wood, "Alignment of hands-on STEM engagement activities with positive STEM dispositions in secondary school students," J. Sci. Educ. Technol., vol. 24, no. 6, pp. 898–909, 2015.

[17] C. Belfield and H. Levin, "The Effects of Competition on Educational Outcomes : A Review of US Evidence," Natl. Cent. Study Priv. Educ., no. March, 2002.

[18] A. Gras-Velázquez, J. Price, M. Dżoga, and I. Pastuszyńska, "The European Science Fairs Evaluation Framework," Intel Educ., no. September, p. 60, 2014.

[19] A. Sahin, "STEM Clubs and Science Fair Competitions: Effects on Post-Secondary Matriculation," J. STEM Educ. Innov. Res., vol. 14, no. 1, pp. 2–3, 2013.

[20] S. Ekanayake and J. Wishart, "Mobile phone images and video in science teaching and learning," Learn. Media Technol., vol. 39, no. 2, pp. 229–249, 2014.

[21] S. Heggen, O. Omokaro, and J. Payton, "MAD Science: Increasing engagement in STEM education through participatory sensing," in UBICOMM - The Sixth International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies, 2012, no. October 2015, pp. 87–96.

[22] M. A. González and M. A. González, The use of smartphones in physics. Experiments inside and outside the laboratory, vol. 4. Department of Physics UVA, 2016.

[23] D. Spikol and J. Eliasson, "Lessons from Designing Geometry Learning Activities that Combine Mobile and 3D Tools," in Wireless, mobile and ubiquitous technologies in education (WMUTE), 6th IEEE international conference, 2010.

[24] J. Saorín, J. Torre-Cantero, C. Meier, D. Díaz-Melián, C. Ruiz-Castillo, and A. Bonnet-de León, "Creation, Visualization and 3D Printing of Online Collections of Three Timensional Educative Models with Low-Cost Technologies. Practical Case of Canarian Marine Fossil Heritage," Educ. Knowl. Soc., vol. 17, pp. 6–9, 2016.

[25] M. Ciolli et al., "FOSS Tools and Applications for Education in Geospatial Sciences," ISPRS Int. J. Geo-Information, vol. 6, no. 7, p. 225, 2017.

[26] M. de Lázaro, R. De Miguel, and F. Morales, "WebGIS and Geospatial Technologies for Landscape Education on Personalized Learning Contexts," ISPRS Int. J. Geo-Information, vol. 6, no. 11, p. 350, 2017.

[27] E. Lim, Z. Liu, M. Yin, D. Goh, Y. Theng, and W. Ng, "On organizing and accessing geospatial and georeferenced Web resources using the G-Portal system," Inf. Process. Manag., vol. 41, no. 5, pp. 1277–1297, 2005.

[28] H. Mills, "Use of mobile devices for e-learning in Geomatics," in The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Workshop of Commission VI 1-3. Advances in Web-based Education Services., 2015, vol. 40, no. 6W1, pp. 5–8.

[29] G. Koenig, "MOOCs - A force to be reckoned with or a temporary phenomenon," in International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Workshop of Commission VI 1-3, Advances in Web-Based Education Services, 2015, vol. 40, no. 6W1, pp. 23–29.

[30] J. Hohle, "Education and training in Photogrammetry and related Fields-remarks on the presence and the future," in International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, 2006, vol. XXXVI, pp. 4–11.

[31] C. Nielsen, A. Oberle, and R. Sugumaran, "Implementing a High School Level Geospatial Technologies and Spatial Thinking Course Implementing a High School Level Geospatial Technologies and Spatial Thinking Course," J. Geog., vol. 110, no. 2, pp. 60–69, 2011.

[32] P. Henry and H. Semple, "Integrating Online GIS into the K – 12 Curricula : Lessons from the Development of a Collaborative GIS in Michigan," J. Geog., vol. 111, no. November, pp. 37–41, 2014.

[33] M. Marsh, R. Golledge, and S. Battersby, "Geospatial concept understanding and recognition in G6-College students: A preliminary argument for minimal GIS," Ann. Assoc. Am. Geogr., vol. 97, no. 4, pp. 696–712, 2007.

[34] A. Tunley, "Photogrammetric Exercise for High School Students," J. Geol. Educ., vol. 34, 1986, no. 1, pp. 14–18, 2018.

[35] P. Ronnholm et al., "Activation, Motivation and Support of Learning Photogrammetry At the Bachelor'S Level," Cross-Border Educ. Glob. Geo-Information, vol. 38, no. 6, pp. 14–19, 2010.

[36] A. Almagro, "Photogrammetry for Everybody," in XVII CIPA Symposium, 1999.

[37] P. Drap and P. Grussenmeyer, "A digital photogrammetric workstation on the WEB," ISPRS J. Photogramm. Remote Sens., vol. 55, no. 1, pp. 48–58, 2000.

[38] T. Schops, T. Sattler, C. Hane, and M. Pollefeys, "3D Modeling on the Go: Interactive 3D Reconstruction of Large-Scale Scenes on Mobile Devices," in Proceedings - 2015 International Conference on 3D Vision, 3DV 2015, 2015, pp. 291–299.

[39] G. Koenig, P. Shih, and C. Katterfeld, "E-Learning – Best Practice in Photogrammetry , Remote Sensing and Gis – Status and Challenges," in International Archives of Photogrammetry and Remote Sensing and Spatial Information Sciences, XXII ISPRS Congress, 2012, vol. XXXIX, no. September, pp. 91–96.

[40] Z. Paszotta, J. Szulwic, and M. Szumiło, "Internet photogrammetry as a tool for e-learning," in 8th International Conference of Education, Research and Innovation, ICERI2015, 2015, pp. 4565–4573.

[41] T. Luhmann, "Learning photogrammetry with interactive software tool PhoX," in The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives. XXIII ISPRS Congress., 2016, vol. 41, no. September, pp. 39–44.

[42] M. Rodríguez-Martín and P. Rodríguez-Gonzalvez, "Learning based on 3D photogrammetry models to evaluate the competences in visual testing of welds," in IEEE Global Engineering Education Conference (EDUCON), 2018, pp. 1582–1587.

[43] E. Gulch, N. Al-Ghorani, B. Quedenfeldt, and J. Braun, "Evaluation and Development of E-Learning Tools and Methods in Digital Photogrammetry and Remote Sensing for Non Experts From Academia and Industry," in International Archives of the Phogrammetry, Remote Sensing and Spatial Informaiton Sciences. XXII ISPRS Congress, 2012, no. September, pp. 1–6.

[44] J. Hohle, "Designing of Course Material for E-Learning in Photogrammetry," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 35, no. Part B6, Comission VI, pp. 89–94, 2004.

All the links cited in the paper are accessed on July 23, 2018.

ISSN: 2168-6831 https://doi.org/10.1109/MGRS.2018.2876565

Please cite as: Gil-Docampo, M., Ortiz-Sanz, J., Rego-Sanmartin, T., & Arza-Garcia, M. (2019). A World Wide Web-Based Practice That Disseminates Photogrammetry: Inspiring Secondary Students to Pursue Geomatics Careers. IEEE Geoscience and Remote Sensing Magazine, 7(1), 86-97. doi: 10.1109/MGRS.2018.2876565

AUTHOR INFORMATION

Mariluz Gil-Docampo received the B.S. and M.S. degrees in agricultural engineering from the University of Santiago de Compostela, in 1992 and the Ph.D. degree in agricultural engineering from the same University in 2001.

From 1996 to 2003 she was an Assistant Professor and Researcher at the University of Santiago de Compostela, Spain. Since 2004, she is a Professor with the Agroforestry Engineering Department, University of Santiago de Compostela, Spain. At present she leads the CIGEO (Civil & Geomatics) research group at the same University. She is the author of five books and more than 25 articles. She also coordinates the M. S. degree in operation and engineering of UAVs. Her research interests include a wide range of applications of close-range photogrammetry and remote sensing disciplines. Since 2013, she has been involved with the organization of the D3MOBILE project.

Prof. Gil-Docampo was a recipient of the XIV 3M Foundation Award for innovation in 2012 as principal investigator.

Juan Ortiz-Sanz received the B.S. degree in agricultural engineering from the University of Valladolid, Spain, in 1989, the B.S. degree in agricultural engineering from the University of Santiago de Compostela, Spain, in 1993 and the Ph.D. degree in agricultural engineering from the University of Santiago de Compostela, Spain, in 2008.

Since 1995, is a Professor with the Agroforestry Engineering Department, University of Santiago de Compostela, Spain. He is the author of three books and more than 20 articles. His main research interests include the use of close-range photogrammetry in recording cultural heritage, structural analysis and rural building. He is a Researcher with the CIGEO (Civil & Geomatics) research group, and the principal investigator of D3MOBILE project.

Prof. Ortiz-Sanz was a recipient of the XIV 3M Foundation Award for innovation in 2012.

Teresa Rego-Sanmartín received the B.S. and M.S. degrees in agricultural engineering from the University of Santiago de Compostela, Spain, in 1994. She is currently pursuing the Ph.D. degree in agricultural engineering at the University of Santiago de Compostela, Spain.

Since 1997, she is a teacher with the Education Department, Xunta de Galicia, Spain. She is the author of two books and 8 articles. Her research interests include applications of close-range photogrammetry to cultural heritage. Since 2013, she has been involved with the organization of the D3MOBILE.

Marcos Arza-García received the B.S. in land surveying and geomatics, in 2011, and the M.S. degree in project management, in 2017, from the University of Santiago de Compostela, Spain. He is currently pursuing the Ph.D. degree in civil and rural engineering at the University of Santiago de Compostela, Spain.

Since 2017, he is a Researcher Assistant with the CIGEO (Civil & Geomatics) research group, University of Santiago de Compostela, Spain. His research interests include the use of spaceborne and UAVs data focused on civil applications. He has been involved with the organization of the latest editions of D3MOBILE.