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Developing and testing a new tool to foster wind energy sector industrial skills

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A R T I C L E I N F O

Article history:
Received 10 January 2020
Received in revised form 13 September 2020
Accepted 3 October 2020
Available online 6 October 2020
Handling editor: Yutao Wang

Keywords:
Industrial skill development
Wind energy education
Teaching learning material

A B S T R A C T

The wind energy sector has seen an increasing growth in the last decade and this is foreseen to continue in the next years. This has posed several challenges in terms of skilled and prepared professionals that have always to be up to date in an industry that is constantly changing. Thus, teaching tools have gained an increasing interest. The present research reviewed the state of the art in terms of digital interactive training tools pinpointing that the existing options do not feature the user involvement in the development of the training material. Hence, the main aim of this paper is to develop and test an innovative method based on gamification to increase wind energy sector industrial skills, providing a digital interactive environment in the form of a new user-friendly software that can allow its users to train and contribute to the teaching and learning contents. The first methodological step deals with the associated background studies that were required at strategy implementation and development stages, including market analysis and technology trade-offs, as well as the general structure and the implementation steps of the software design. Obtained results pinpointed that with minimal use of web-based database and network connectivity, a mobile phone application could work in the form of a time-scored quiz application that remotely located staff at wind energy farms could benefit from. The technological innovation brought by this research will substantially improve the service of training, allowing a more dynamic formative management contributing to an improvement in the competitiveness and a step towards excellence for the whole sector.

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1. Introduction

The importance of GreenHouse Gas (GHG) emission reduction has been widely assessed by researchers from all over the World (Li et al., 2018; Zeng et al., 2018a). Consequentially, several measures have been studied and applied to increase the energy efficiency (Sun et al., 2018; Zeng et al., 2018b) and the energy production from Renewable Energy Sources (RES) (Pfeifer et al., 2018). Thus, the energy industry has gained a key role in tackling Climate Change. In this framework, training professionals is essential to face today’s changes in the labour market and to support a competitive economy (Stanitsas et al., 2019), particularly in renewable energy (RE) sectors since the energy transition to decarbonized systems is speeding up the innovation processes of these technologies (Lin et al., 2017). Moreover, both in developed and developing countries there is a lack of studies that deal with stakeholders and professionals’ awareness level about RES (Kacan, 2015) and energy efficiency (Ciriminna et al., 2016).

As regard the wind industry, meeting the expectations of 2030 horizon is translated into an increase of 175% of the wind generation since 2015, reaching offshore installed capacity of nearly 70 GW (Aldieri et al., 2020). Europe is one of the world leader in wind technology development, with about 330,000 skilled workers in the wind energy sector (IRENA, 2019a). Approximately 25,000 people are employed in wind farms operation and maintenance
activities in European countries (around 70,000 worldwide), not considering force aimed at manufacturing and repairing components (IRENA, 2019b). Furthermore, it is also important to keep in mind the progressive ageing of maintenance workers who have difficulties to work in the harmful and narrow conditions of the old turbines. Consequently, a continuous turnover is needed and will offer potential opportunities for new professionals and green jobs. If we also consider the ageing of European wind farms and the tendency to increase their operating life, the European wind energy sector is clearly facing a challenge: the very limited availability of skilled operation and maintenance (O&M) staff and the future lack of it in the medium-term considering also the actual growth of the industry and the future projects needed to achieve the National Energy and Climate Plan (NECP) of each EU member state.

On one hand, the topic of safety is being dealt with globally by the Basic Safety Course of the Global Wind Organization (GWO), an international organization linked with the safety training, and is becoming a global standard. On the other hand, few initiatives have been carried out in the RE technology manufacturing industries to train technicians and mechanics working on both installation and O&M or RE devices (Kandpal and Broman, 2014). Consequently, new approaches for the training of technicians able to supervise installations and O&M interventions specifics for wind and for other renewable technologies are essential to foster the development of each RES (Kandpal and Garg, 1999; Tsoutsos et al., 2013). Several needs have been identified regarding the personnel’s specialization topic:

A. Current knowledge established for RE sector’s personnel in Europe (Court and Grimwade, 2014). As example, the Spanish organization National Institute of Qualifications (INICUAL) established reference exclusively for the operational training about wind farms installation and operation (ENAE 193.3 "Management Installation and Maintenance of Wind Parks").

Anyhow, in Europe there are no standard training programs yet. Whereas the actual recurrent mobility in the RE sector, a common training program at the European level would ease both the certification of professionals’ skills and, as consequence, the mobility of personnel between countries.

B. The RE sector training courses currently use conventional learning modes and techniques. Furthermore, those sectors present a frequent workplace relocation that makes it complicated to help organisations and training centres. By using original information and communication technology (ICT) training tools, learning from distance would be enormously eased (Gugerell et al., 2017).

C. The current job market demands an always-growing number and level of highly specialized personnel in renewable energy maintenance (Astiaso Garcia and Bruschi, 2016). That is true for both mature markets such as Germany, Spain and Italy and also for growing and emerging ones that experience a constant grow in scale of renewables and storage systems, as well as an increasing interest in energy efficiency issues (Castellani et al., 2017; De Santoli et al., 2017a, 2017b; Erdinc et al., 2015; Lo Basso et al., 2017). Moreover, the need for highly skilled staff will keep increasing due to the increasing refinement of system maintenance tasks that will require a raising qualification of workers (Sokka et al., 2016).

In this framework, ICT training tools are a worthwhile measure for the RE sectors including wind, wave, and tidal considering that these energy plants are very often based in remote locations and ICT training tools could ease staff’s specialization from any place (Ahmed et al., 2015; Garcia-Valcárcel et al., 2014). Furthermore, demands of today’s market will be improved by the enhancement of the integration of digital solutions in training programmes (Cocchi et al., 2018; Khalid et al., 2018; Stock et al., 2014).

Consequently, the use of interactive training tools, such as CITT (Cogtech Interactive Training Tools), Edoson, Incoterm 2020, Rallyware, will also improve industrial sectors’ competitiveness and the industrial staff’s qualification too, via promoting learning with Open Educational Resources (OER) and their introduction to the professional, as analysed by Xie et al. (2013) specifically for wind energy education.

Jointly with a high number of tools (Bonilla et al., 2018; Nardecchia et al., 2016), devices (Guglielmetti et al., 2015; Rodrigues et al., 2017), and smart systems (Chaudhary and Rizwan, 2018; Pagliaro et al., 2016), for energy saving and management, a number of digital interactive tools exist that allow engagement of the users in the process of learning in full digital format, such as Udemy (Udemy, 2016), Litmos (Litmos, 2016) and Docebo (Docebo, 2016) to mention a few of the recent and popular ones.

Udemy is one of the pioneers in supplying web-based environment for building new course in digital format with course material and course attendance facilities able to exchange most of the elements of an e-learning environment, developing an Android application to enable users to follow their courses directly from their mobile phones. The set of the stakeholders includes the instructor, the investors who invest on the marketing to attract students, and the ownership of Udemy hosting service.

Nevertheless, the use of ICT training tools alone does not ensure effective results. A major problem with fast-growing industries is the fact that training tools and education schemes must be always updated and engaging. In this context, ICT tools can be effectively associated to game-based learning (Gameffective, 2016; Harbinger Knowledge Products, 2016). Those basically increase the level of engagement and speed of access to the outcome of assessments by allowing users to act in a variety of game-style environments that are contextualized with learning contents of a domain topic.

Several existing digital interactive tools allow engagement of the users in the process of teaching and learning (Mindflash, 2016; Schoox, 2016). These tools have at least one or both of the following two features:

A. They are developed based on Experience API (xAPI), a popular application programming interface (API) that incorporates facilities to study the profile of the users by recording their activities on a continuous basis.

B. The right to authorship of the users is granted from a central originator of the created course. This intellect of central control to set who can or cannot collaborate could add a burden to both user account management and required security protocol.

In this context, Serious Games, and gamification in general, have been identified as a valuable option to raise individuals’ awareness about consumption, environmental impact and energy efficiency in general (Morganti et al., 2017) as well as for engaging customers to participate in energy efficiency programmes (Alskaif et al., 2018) (Ponce et al., 2020), solar technologies adoption (Rai and Beck, 2017), power plants performance evaluation (Mahmoudi et al., 2019) and also about broader concepts such as sustainability (Hallinger et al., 2020). The last-mentioned research could be considered as a key study since it precisely describes serious games potentials for learning analysing 376 research papers focused on simulations and serious games in educating for sustainability.

Furthermore, from the analysis of (Morganti et al., 2017) focused on experimental studies on the uses of serious games in the energy...
sector, emerges that while positive effects of playing games are now certain their potentialities are still understudied. 

Connolly et al. (2012) defined serious games as those that “have been developed for the broader purposes of training and behaviour change in business, industry, marketing, healthcare and government NGOs as well as in education’. Serious games have been demonstrated to be also an effective learning method to lessen the practical training needs of students and a useful tool in learning processes in general (Serrano-Laguna et al., 2017). This statement is also corroborated by the inherent educational features of the game, being a stimulating mechanism for users, having great flexibility in use, achieving important learning while being playful, and therefore promoting teamwork as a key element of society today (Hallinger et al., 2020).

In light of the above-mentioned current context, main research gaps include the standardization of the operational skills for the staff qualification and the development of an ad hoc serious game that considers and integrates the current approaches for professional trainings for installations and O&M activities in the wind energy sector.

Closing these research gaps is the main novelty of the present paper compared to the above mentioned state of the art. Indeed, the development of a serious game to qualify professionals in the skills of the wind energy sector has never been done before and it will improve substantially the service of training given at present, allowing a more dynamic formative management and a technological development inside a company, contributing an improvement in the competitiveness and a step towards excellence.

Therefore, answering the three essential questions (What? How? Why?) to be considered according to theory-development (Whetten, 1989), the main contribution of this research to theory is to standardise the operational skills needed for the qualification of employees of the wind energy companies (What) introducing a cutting-edge mode of training, developing and testing the first serious game on this industrial sector (How), in order to foster wind energy sector industrial skills enhancing the training in operation and maintenance to a higher level (Why).

Moreover, the learning tool proposed in this research is based on the application of ICT that allows the use of interactive information and quiz using a serious game environment thus supporting the development of efficient distance learning at any time. This feature is crucial since it aims to address one of the main issues affecting the wind energy sector trainings: the fact that personnel is often working in remote areas.

Hence, using ICT, this research proposes the development of an innovative training tool in the RE sector, particularly focused on wind energy sector.

Therefore, the main outcome of the research is the development of a mobile phone application with all the contents and elements required to improve the skills related to the ordinary activities of workers in the wind energy sector. Furthermore, a new specific approach has been used compared to the several ones recently introduced to RE education by means of the modern and flexible educational technologies (Jennings, 2009). In order to fulfill such goal, this research identifies, analyses and overcomes the different issues that affect the wind energy sector training courses as well as the technical issues for the development of an effective, accessible and always up to date serious game app.

Concluding, the rest of the paper has been structured as follow: the research methods for serious game development, building blocks design and pilot test organization have been described in section 2, while section 3 shows the main obtained results coming from the pilot tests with the related discussions. Lastly, concluding remarks highlights the main finds of the research, its possible applications and future possible researches.

2. Methods

In this section the research methods to overcome all the issues that have been faced in different stage of the fundamental design are explained in detail. In particular, the technology integration and development of the proposed solution has been described, covering the general structure, the building blocks of the proposed software system, and the implementation steps of the new software design.

The method section is structured as depicted in Fig. 1 and described as follows:

1. Identification of stakeholders and impact analysis;
2. Serious game development:
   - basic structure development;
   - building blocks design;
   - serious game questions and answers identification;
   - app implementation
3. Pilot tests and feedback analysis.

Each of the afore-mentioned topics has been described in a specific paragraph where the related issues have been presented and the strategies to overcome such issues explained in detail.

2.1. Stakeholders impact analysis

The developed system is not supposed to be directly profit making for any stakeholder. Realities such as industrial renewable associations, their member training centres, and the staff working for the renewable industry represent the main stakeholders of this research.

The first step is to preliminary identifying the stakeholder impact involving national and international associations and industries dealing with renewable energies. This step is crucial in order to understand and then fulfill stakeholders needs and expectations and to assess how the serious game will impact stakeholders (Bin Taher et al., 2015), as reported in Table 1.

In particular, a power/interest matrix (Olander and Landin, 2005) has been selected as the most appropriate for stakeholders mapping, since it is based on the following two main questions: 1) How interested is each stakeholder to impress its expectations on the serious game? 2) Does the stakeholder have the power to do so?

Then, the stakeholders have been grouped based on the power/interest matrix in Fig. 2, identifying the key players.

2.2. Serious game development

2.2.1. Basic structure development

The basic principles and the structure of the serious game are shown in Fig. 3; after initiating a category level, the user can advance to next levels only after having completed the previous ones.

Training has been taught differently depending on the different types of wind turbine generator (WTG); moreover, the maintenance of blades and high voltage (HV) equipment are differentiated from other trainings.

The game is based on twelve essential elements, namely:

1) Questions: the questions based on the specific RE sector, defined in collaboration with the main stakeholders to make them fit within the desired skill improvement and training program. Hundreds of questions have been designed considering the following topics: Basic concepts, Engineering, procurement, commissioning and operation, Predictive maintenance, Preventive maintenance, Corrective maintenance, Health and safety.
2) **Answers**: four possible responses have been predisposed and correlated to each question, but only one of these answers would be exact.

3) **Area**: questions are categorized in separate areas depending on the topic they refer to, e.g. Health & Safety, Engineering, Operation and Maintenance. This enables the users to select the area of interest in case they prefer to improve their knowledge on a specific topic.

4) **Levels**: the complexity of each question is stated by a numerical indicator, i.e. the level. Each question would be univocally correlated to a level so as to avoid the repetition of the same question on different levels. The number of questions to pass to the next level would depend on the level itself.

5) **Score**: at the end of each session, the software would output a set of scores for each of the levels. The score would be directly proportional to the number of correct answers.

6) **Reward**: a reward would be related to each score and it would be displayed as outcome of each run of the tool as the rewarding systems has been proved to be a valid educational and engaging method (Zhao and Guo, 2019).

7) **Timing element**: the score assigned to each correct answer would account for the time elapsed to respond. The score is

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Table 1

| Stakeholders types | Influence/Power | Interest/Positive impacts |
|--------------------|----------------|---------------------------|
| National associations dealing with Renewable Energy | Very High. Can have significant impact on its contents and dissemination. | Interested in improving renewable energy skills on their countries |
| Industries working on Renewable Energy | Very High. Can collaborate in developing game contents for ensuring high level of quality. | Interested in assessing the expertise of their workers of candidates. |
| Environmental NGOs | Moderate influence, mainly in local communities’ acceptance. Can contribute on serious game dissemination. | Interested mainly in social impacts but possibly skeptical about the serious game. |
| Unemployed | Little influence. | Interested in testing and certifying their skills on renewable energies |
| Renewable Energy experts and guru | High influence. Can collaborate in developing game contents | Interested in serious game progress. |
| Local and national authorities | High influence. Responsible for the supply of Renewable Energy | Can contribute to the success of the serious game releasing governmental support. |
| Universities | Moderate influence, mostly positive. | Can be negative if the serious game challenges their authorities |

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Fig. 1. Flowchart explaining methodology for the serious game app development.

Fig. 2. Example of power/interest matrix for stakeholder impact assessment.
inversely proportional to the time needed to answer correctly.

8) **Colour code**: in order to facilitate the perception and understanding of the questions’ level, a colour of the background display is univocally correlated to each level.

9) **Information**: the learning process is not exclusively represented by the quiz mode; in fact, a sequence of information and examples are provided to the player in order to empower the learning process of the user beyond the quiz itself. Hence, the informative material would be specifically developed with productive relationship to the questions’ topic differentiated by level.

10) **Issue**: The third route to work with is based on another type of questions that are not pre-designed with answers. They are so called issues. In other words, they are questions with open answers. To each issue many answers could be submitted.

11) **Comment**: Submitted answers to issues are comments. There could theoretically be unlimited number of comments submitted by the players per each submitted issue.

12) **Account**: a unique identifier associated to each user. This would allow basic requirement to the traceability of the user in charge of the submission of the information, issue, question, answer, or comment. Account information serves as the basic and standard overhead that setting responsibility for the nature of the submission would require.

A sample question together with the layout of the aforementioned items and characteristics are graphically explained in Figs. 4 and 5.

The scoring system foresees a score from 100 for Q1 to 500 for Q5, with an extra score of 50 if the question is answered by 20 s and an extra score of 25 if the question is answered by 40 s (the total available time is 1 min).

2.2.2. Building blocks design

Five building blocks have been designed in order to materialize and implement the above-mentioned essential elements (Fig. 6), namely:

1) **Database**: it stores and maintains two different datasets that interacts with players:
   a) a locked dataset including questions with relative answers, questions level, and the colour of the levels together with information, issues and comments. This set of data exists regardless of the player and they do not depend on player actions.
   b) the other dataset is the one produced by player actions. It comprehends answers and time elapsed to respond, each level score and final reward. This information is implemented during the game as the user proceeds with the serious game.

A synchronization software would be associated to the database component so that the player-generated data could be added to the fixed data as the game proceeds.

2) **Main program**: when executed, it deals with the interactions between building blocks and conducts the progression of operations.

The main program also includes handling of the database synchronization component. In particular, the concurrency and atomicity of the data exchange would be taken care of. Concurrency allows the players to see the same latest data if they submit a query, for example to see a question. Atomicity avoids submitting any changes before the submit action is confirmed by the player, for example when a button is pressed.

3) **Central database server**: in order to have the pool of questions, answers, issues, comments available to design and use by all

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**Fig. 3.** General structure of the serious game contents.

**Fig. 4.** General appearance of the screen displaying a question with four possible answers, score and time.

**Fig. 5.** The various areas in RE sector differentiated by colour, each one with five levels of difficulty. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)
users, a central database component is required to serve as the hub of data exchange.

Communication with this database server is handled by the program running on the player’s device from one end and the server software running on a web-hosted computer on the other end as better explained in section 2.2.4.

The concept of scalability and resilience are also important to be implemented in order to avoid overwhelmed computation of the database server (scalability) as well as connection failure. Proposing a solution for scalable and resilient web-based database service is considered out of scope of this research paper.

4) Graphic User Interface (GUI): it allows the player to interact with the game. Each element has a graphical icon and it is displayed in association with its specific task and with other items. The GUI’s appearance has been implemented to be as user-friendly and engaging as possible since it represents a major factor in the final uptake and effectiveness of the game (Bylinskii et al., 2017).

5) Account Management: the software component incorporated in the main program that allows registration of the new user and login process. It associates the unique identifier of each registered user to the username and password created by the user.

2.2.3. Serious game contents: questions on the wind energy sector

Thanks to the contributions of wind energy experts coming from industries from Italy and Spain, under the coordination of the Spanish and Italian Wind Energy Associations, respectively AEE and ANEV, a comparative analysis of the main European studies in the field of the wind energy industry has been developed and consequentially hundreds of questions and answers about wind energy sectors have been prepared considering the following key topics:

- Basic concepts
- Engineering, procurement, commissioning and operation
- Predictive maintenance
- Preventive maintenance
- Corrective maintenance
- Health and safety

In particular, for each question to be included in the serious game, four answers have been provided: one correct and three false. Among many other themes, the basic concept questions dealt with the power curve of a wind turbine, the wind intensity turbulence, the wind instruments of measuring, the indicators to evaluate the quality of a site, the rules and the functions of valves and hydraulic units, the role of the data logger, and generally each particular component of a wind turbine.

As regard engineering, procurement, commissioning and operation the questions dealt with, as examples, SCADA and switch characteristics, the implementation of a wind farm and the hosting system of wind turbines.

Finally, other examples of questions regarding predictive, preventive and corrective maintenance are: health and safety procedures, the main characteristics of maintenances, the six sigma improvement process.

2.2.4. Implementation for engagement

The variety of engagement with the tool was selected as the most relevant element. In fact, it is considered essential to enable the user with a diversity of training styles and preferences in order increase the possibility to effectively engage the users (Blau et al., 2020). This choice complies with the basic concept to develop the skills of the personnel involved in the wind energy sector.

Consequently, end users could choose to take advantage of the reading materials of the application that includes both tutorial information and user’s comments. End users may choose to take a quiz and answer some questions in order to assess their skill level, or, as an alternative type of learning engagement, they may add a question, so called “Issue”, and successively get the related answers, so called “Comments”.

The view of the application would appear as shown in diagrams from Figs. 7–9. The various colours used for blocks in the diagrams indicate a diverse degree of possible interaction with the running code.

The colour orange symbolizes actions that would necessitate an input from the user. For instance, the main subdivision criteria are i) to decide to play with the existing material, or ii) to play an admin role and add material. In addition, on the ‘player’ mode it should be decided to browse educational contents, i.e. tutorial, or to solve quizzes. In ‘Admin’ role, it should be decided to add to the comments for the issue of interest, to add issues, or to add to the knowledgebase tutorial information.

The colour blue instead symbolizes that the interaction with the directory or with the user occurs. In order to access to the directory, in the form of Structured Query Language, two subsequent actions would be needed:

1) provide starting data to enable the connection to the right register in the directory, e.g. by defining the characteristic area that contains the question;
2) receive from the directory the contents of the question, of its possible answers, and of the illustration related to the specific question.

As it is shown in Fig. 7, users have the option to design new training elements or to use the existing training elements. In designing new training material, users could create new question

![Scheme of the five serious game building blocks essential elements.](image-url)
with answers, or create new issue, or create new tutorial information. This feature has been considered essential since it enables the users to interact and also to constantly update the game materials and contents. Fig. 8 shows the serious game flow chart regarding the tutorial route (8a), the comment route (8b) and the issue one (8c). It is noteworthy the interaction between the
database and the user within the tutorial and the comment routes. In fact, the user’s actions are constantly processed and recorded by the database that, as response, provides useful information to the user to proceed with the tutorial (8a) or by just commenting back (8b). When submitting a new issue (8c), there is a one-way interaction since the database has not any knowledge about the issue yet.

Fig. 9a depicts the flow process for submitting new questions, while Fig. 9b shows the flow chart for recording new information into the database.

New training material, when submitted by the user, would be added to the pool of the training elements of similar type. This would guarantee the creation of a rich series of quiz questions and tutorials.

Three elements of variety have been contemplated and dealt with, namely:

1 Computing tool

The devices preferred by the specific sector industrial personnel for playing the developed application have been analysed. In most cases, phone devices are preferred to personal computers. Regarding the size of the app components and services, the mobile phone monitors size is sufficient for all the various game modalities.

2 Operating system

Android, iOS and Windows are the three predominant operating systems on mobile phones and on personal computers nowadays. For the application to be easily downloadable on mobile devices, it should be contained in the “app store”. Android operating system, for instance, offers an easier and more flexible solution since the setup file could be placed into the Android’s file directory and then installed.

However, there are platforms, e.g. Xamarin, that enables to use the exact same code into the three aforementioned main systems.

3 Network-enabled

An important feature of the application is if it should necessitate access internet or if it should just be a possibility. Numerous are the reasons and trade-offs on this element that are discussed here below.

a) Computational overhead: regarding the computational overhead, a thin-client application, when installed and run, uses the least number of executing codes on the player’s device. In fact, in order to reduce the computing overhead, it exploits servers on the app side through an internet connection. What has to be avoided is both to run and install on users’ devices burdensome executing codes and databases. Regarding data repositories, a central data storage, compared to a local one, facilitates the updating of data since it could be performed directly from the administration side of the server without the need for any update on the user’s device. Of course, all this flexibility and advantages come with a cost, in fact to work the application it would necessitate the connection to the internet network and the bandwidth availability. Regarding the wind energy sector, which presents an important amount of personnel working in remote areas, the necessity of a stable connection to the internet network at the user’s side would represent a serious deficiency. The intrinsic lightness of both the computation functions, not necessitating burdensome processing algorithms, and the data storage, just one set of some 10s of question records with about ten field per record, strengthen the choice to develop a standalone app. Thus, this application would not dissipate the processing and database powers of mobile devices. Rather it could be addressed as a standalone thin-client app with web-connectivity to access a central database service.

b) Backend as a service: in addition to the advantage of not requiring internet connection, there are other elements that a network enabled app can profit from. Fig. 10 shows the added benefits of a network-enabled application.

Having the possibility to utilize Backend As A Service (BAAS) could enable to exploit network based concepts that would largely enhance the app abilities and features. For instance, notifications would occasionally provide data and information without requiring any action to the user, the service just necessitates the user to agree and activate the service in order to start receiving occasional information. Furthermore, thanks to specific APIs, the user could customize the type of notification to be activated. For example, regarding the app presented in this paper, the BAAS might provide information about high scores and new records achieved by other users in the same RE sector. This could motivate other users to improve further their score and consequently their knowledge in order to remain competitive in the market (Kim, 2020).

On the contrary, the possibility to store the user’s account information in a central database allows the recovery of such data after a software restoration process due, for instance, to installing the software on a different device.

The compromise of BAAS is the reliance on the internet connection and the increased traffic and cost involved.

c) Using Web Application: another possibility that allows mobile devices to operate the application is its running as a web app. In this scenario, the user’s device will necessitate using an internet network browsing software that addresses the web application location.

A web-app works for each player and enables the interchange of questions and answers between the player and the web-app to run the serious game. Fig. 11 visually explains this concept. Additional information about the technologies and the logical actions that allows a web-app to work are shown in Fig. 12.

Amongst the benefits of combining web-app and BAAS is the acquisition and storage of the client information in a single location, it permits to easily access the processing server to deal with customized analysis. A valuable example of customized analysis usefulness is the possibility to identify the areas of knowledge that have the greatest effect on the overall professionalization process in
order for the user to focus the attention on these fields and thus improve the learning efficiency. These sensitivity analysis studies are explained more in detail in (Tavakoli et al., 2011).

Development platforms such Schoox would permit the execution of the code onto all the main operating systems (i.e. Android, iOS and Windows). An important feature is of course the economic one. Thus, the technology trade-offs have been also analysed. Tables 2 and 3 respectively summarise pros and cons, and show an estimate of the typical cost of the different configurations, i.e. Mobile-App and Web-App. In particular, as shown in Table 3, labour costs estimation has a significant variation, both for mobile app (between 6 and 20 thousand pounds) and for the web app (between 15 and 30 thousand pounds), depending on the estimated salary of the involved technicians and the related number of working days.

Considering the aforementioned estimations of pros and cons of the two platforms, a Mobile App and a minimal Web-based Database server is sought to implement this system.

2.3. Pilot tests of the prototype

In the framework of the research paper, 4 pilot tests of the serious game prototype have been realized, respectively in Spain, UK, Italy and Belgium. These pilots, whose duration was about half a day, have been coordinated by 1 trainer and at least 10 professionals coming from end users and stakeholders of each country. During these pilot tests, the trainers showed the contents and the potentialities of the app so as to test the app functions and

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**Table 2**

Comparison between the Mobile App and the Web App approaches, Pros for developer and users.

|                      | Mobile App (Xamarin) | Web App                     |
|----------------------|----------------------|-----------------------------|
| **Pros for developer** |                      |                             |
| One language (C#)    |                      | Can divide tasks between Front and back end developer |
| Can do one code for all platforms |                  | Instantaneous update for users |
| All smart devices have SQLite engine |                    |                             |
| Xamarin ready for App stores |                  |                             |
| does not need for maintenance of the web server |                  |                             |
| Can monopolise       |                      |                             |
| **Pros for users**    |                      |                             |
| No need for stable internet connection |                  | Run on every platform       |
| Runs natively         |                      | User data stored online     |
| Can see reviews on App store |                  | can use multiple devices    |

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Fig. 11. (a) Principal communication between Web-App and player is through request and response, and (b) BAAS, as further element beside of the main web application.

Fig. 12. Sample of technologies that support the Web-App development.
request feedbacks for improvements to the attendees, as summarized in the paragraph of results.

3. Results and discussion

Specifically, a learning tool, serious game for mobile and tablet, has been developed allowing players to get a set of predominantly practical knowledge and skills. It has been realized in English, Italian, French and Spanish in order to spread its use and eventual transnational initiatives.

The above described procedures attained the software tool required. Some screenshots of the current version in hand are shown in Figs. 13 and 14.

The final design of the serious game application includes three different game modes: novice, expert and master level. It is possible to play each topic separately (basic concepts; engineering, procurement, commissioning and operation; predictive, preventive and corrective maintenances) and consequently progress individually or play as a random trivial.

The serious game mobile application is an original tool that strengthens the sustainability of the RE sector by supporting the specialization and professionalization of the personnel involved in it. The target groups are diverse; indeed, it is addressed to private enterprises, associations, cooperatives, private centres of training and public Local/Regional/National/European and International Public Organisations of training in the RE sector.

The pilot tests provided a validation for the app and proved that all its functions are feasible and well-functioning. The feedbacks obtained from end users during the pilot tests of the prototype have been collected using a specific questionnaire, pinpointed positive reactions briefly summarized in Fig. 15.

Generally, the attendees were interested by the innovative approach of the serious game and very pleased by the development of the app. The fact that the app was considered user friendly and engaging represented an important feedback from the users since those were two of the main objectives. The difficulty level was considered fair, but it has to be noticed that one of the main feature of the app is represented by the fact that users can update it and add new issues; this particular feature can vary very much the perceived difficulty. An interesting improvement proposal was the possibility to introduce a sort of certificate for passing the different level of the game.

3.1. Implications for theory and practice

This research reaches not only current wind technicians as well as staff already working in the industry but also new professionals that are about to enter the market with a general training, offering a first approach to the real functioning of the wind turbine generator and fitting the trend in digitalization of wind farms and in the reinforcement of the manufacturing capacity consolidation through the Industry Plans 4.0. Also, it might serve as a constant and continuous learning tool for employees of the wind industry in order to be updated with the fast changes that the industry is continuously undergoing. Indeed, it perfectly suits the aim for the digital transformation of the industry providing an e-learning live tool enabled to be easily updated by users. This feature also supports transnational collaboration and exchange of knowledge. Therefore, this innovative tool would help on the challenge that the wind industry that is currently facing, which is the limited availability of skilled personnel, and the ones that will soon cope with considering the actual growth of the industry. The main implication for theory provided by this research is the standardization of the operational skills required for the qualification of employees working of the wind energy sector. In particular, a cutting-edge mode of training has been proposed, and a first serious game on this industrial sector has been developed and tested. Consequently, theoretical data and approaches in operation and maintenance training have been significantly implemented, providing a new tool for the wind energy sector industrial skills.

Moreover, this research represents an example of new technology applied to training available to the student and teacher interaction media, significantly improving the learning process. These innovative learning tool based on the use of ICTs allow the use of interactive contents through a serious game and it will provide a more engaging experience and more efficient quality training also enabling distance learning at any time and place. This

| Table 3 |
| Comparison between the Mobile App and the Web App approaches, Cons and approximate estimate on costs. |

| Mobile App | Web App |
|-----------|---------|
| Cons      | Need of maintenance |
|           | Does not assure complete security of users’ data |
|           | More complicated sequence of services to pay for |
| Estimated Expenses | |
| Included for free with MS Visual Studio (£500–600) | |
| iOS developer (£100) | |
| Labour: £16k ~ £20k | |
| £6k ~ £20k | |
| £30k | |
| £100 | |
| £500 | |
| £600 | |
| £100 | |
| £15k ~ £30k | |
| £60 | |
| £20 | |
| £30 | |
| £60 | |
| £100 | |
| £15k ~ £30k | |

Fig. 13. Sample snapshots of the Crowd Learning Serious Game Mobile Application software system proposed for wind farm.
Fig. 14. Sample snapshots of the Crowd Learning Serious Game questions and possible answers.

Fig. 15. Percentages of positive feedbacks obtained during the pilot tests of the prototype.
added value is even more important in the light of the Covid-19 emergency all over the world, that highlighted the need of virtual tools for training activities, especially for restricted areas like the wind turbine spaces, where the security distance could not be guaranteed.

Furthermore, the developed serious game enables communication and interaction between users that have the possibility to design new quiz, post new issues and comment to other users' issues.

Main targets and end users are private companies, professional Associations, Cooperatives of the wind energy sector, trainers, Public and Private centres of training and Local/Regional Public Organisms in training and wind energy sector scope including exploitation and maintenance of wind farms technicians, responsible for assembling wind farms, specialist installer of wind turbines.

The research fosters the standardization of the training as for professional qualification of the wind energy sector’s staff at European level, with the following implications for all the main stakeholders previously mentioned:

- improvement of the systems of learning and innovative materials of training;
- improvement of the access to the training, being able to be in classroom and also distantly;
- improvement of the knowledge for the use of the ICT;
- improvement the communication between personnel of the sector during the development of the project and networking;
- professionalization of the staff and sector;
- provision of an innovative materials and system of training;
- facilitated organization of the training and the development of recycling training;
- technological development and improvement of the competitiveness of the sector with the introduction of the ICT in the qualification training;
- promotion of practices, experience exchanges and future projects of transnational character.

In conclusion, the developed app represents a unique tool specifically designed for the wind energy sector with the support of the main stakeholders of the sector that have been engaged and consulted at various stage of the development. On the other hand, the main limitation is the need of a continuous update of the training contents according with new technologies and tools.

The technological innovation brought by this research with the development of a serious game to prepare professionals in the wind energy sector, that fully exploits the best ICT technologies of the market will cause a strategic development of the sector by improving substantially the service of training, allowing a more dynamic and formative management contributing to an improvement in the competitiveness and a step towards excellence.

In this framework, future researches will be focused on the implementation of a simulator for O&M training in the wind energy sector, starting from the contents of the serious game and obtained data from end users feedbacks. In this way, it will be possible to update and tailor the training contents to the new technologies.

4. Concluding remarks

The research described the development of a new tool to increase wind energy sector industrial skill by exploiting the ICT tools, fostering the training for the development of the installation and O&M activities in that sector using a serious game. One of the main research objectives and novelties was to propose a model to standardise at European level the operational and transverse knowledge required to prepare adequate personnel for the wind energy sector. In order to make the app a feasible European standard, it had to be able to renovate its contents to match the wind energy sector transition. Thus, the developed solution has been thought to be continuously updated thanks to users' feedback and inputs in order to be able to follow the market, technology and techniques changes that are happening faster than ever.

Particularly, the application enables actual employees and young people seeking for a working position within the RE sector, specifically in the wind one, to better quantify their skills and knowledge in the sector specific topics. Furthermore, organisations could use the game outcomes, i.e. the final score, and the detailed analysis of results obtained by the users to compare competences and skills of their actual personnel or of applicants to a job position for a wiser decision.

Moreover, the serious game use will facilitate and promote the standardization of trainings for the RE sector, will increase the competitiveness of the RE sector by introducing the use of ICT in professionalization trainings. Moreover, it will also favour the management of trainings, e.g. allowing training from remote areas, and the development of recyclable education. The obtained results have strong interrelationship with cleaner production in the wind energy sector since they suit perfectly the Industry Plan 4.0 aiming for the digital transformation of the industry, enhancing the e-learning tools available in the wind industry and providing with a live tool enabled to be updated by users. This innovative tool would help on the challenge that is currently present in the wind industry which is the limited availability of skilled personnel and the future lack of it in the medium-term considering the actual growth of the industry.

Concluding, the research highlighted that the use of computer program systems to realize training tools, that could help standardise competences of the staff involved in the RE sector, is possible with current technologies. Thus, this paper explained the development of an app and test its feasibility through specifically designed pilot tests as well as its incorporation into the currently adopted qualifying and professionalizing training set. Finally, considering possible next steps, the results obtained in the pilot tests could be implemented with specific tests about the validity of the tutorial information submitted by the end users.

Credit authorship contribution statement

Davide Astiaso Garcia: Conceptualization, Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing, Supervision. Daniele Groppi: Investigation, Methodology, Validation, Writing - original draft, Writing - review & editing. Siamak Tavakoli: Investigation, Methodology, Data curation, Software.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research has been carried out within the SkillWind project co-funded by Erasmus + Programme of the European Union (2015-1-ES01-KA202-015935).

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