Facets of Openness in a Serious Game: Opening up Format, Content, Software and Hardware

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Abstract. This paper advocates the claim that open licenses and open-source software are not enough to overcome the barriers to adoption of technologically innovative Open Educational Resources for educational institutions like schools. The paper analyses the case of the 4Ts game, a game designed to support the development of teachers' learning design skills. This case study exemplifies ways of dealing with four different facets of openness, namely format, content, software and hardware facets. The paper concludes that OERs for schools need to be flexible in terms of format and easy to amend in terms of content. Software should incorporate built-in features for personalization and localization that do not require coding skills. Hardware should be cheap and/or commonly found in schools.

Keywords: Open Educational Resources (OERs), Teacher Training, Game Based Learning, OER adoption, Serious Games, Board Games.

1 Introduction

Investigation of openness in educational research can be dated back to the beginning of the '90s, when the first database of so-called "Units of Learning Material" was conceived and designed in the context of the ESM-BASE European project [1]. At the time, the central idea was to build repositories that would make it easy for instructional designers and teachers to access and retrieve self-consistent chunks of reusable educational material so they could reuse and repurpose these for different contexts. The need addressed was making multimedia development easier, increase quality and, at the same time, widen the target audience.

However, it was only during the subsequent decade that the concept Open Educational Resources (OER) attracted widespread attention after the worldwide-web gave a global dimension to the words "accessibility" and "reuse" [2], and many curated repositories of OERs, such as MERLOT[1], were created. The important features of these repositories is that (i) they allow retrieval of material by discipline, language, school level

[1] https://www.merlot.org/

and other features and (ii) the open license of that material specifies the extent to which anyone can reuse, revise, remix and redistribute the resources (the "4Rs" of OERs) [3]. In addition, in most cases the quality of the resources on offer is assured to some degree by the (curating) institution in charge of the repository. Hence, teachers do not need to reinvent themselves as multimedia developers, and students themselves can search and take advantage of material that satisfies their learning needs, provided they are self-regulated enough.

Research on OERs has shown that students using OER perform as well as, or better, than those using traditional materials [4,5,6]. In particular, Tlili and colleagues' meta-analysis [5] found that OER use has a positive significant (yet small) effect on learning outcomes, moderated by several variables, including subject, level of education and others. In addition, OERs (compared to traditional material) can reduce educational costs for students and institutions [7]. Finally, OERs have the potential to foster equity in education by providing access to learning material regardless of geographical location or socioeconomic status. However, research suggests that to ensure relevance and accessibility on a global scale, there is a need to consider diverse cultural and linguistic contexts in OER development and dissemination [2].

Research has also addressed concerns about the quality and sustainability of OER by proposing quality assurance mechanisms for OER repositories and exploring models for sustaining OER initiatives over time [8,9].

In spite of these efforts, OER adoption is not as widespread as we could expect, and much of it takes place "under the radar" [10,11]. Hence, researchers have explored factors influencing faculty adoption of OER and perceptions towards these resources [12, 13], while international organizations like UNESCO have issued recommendations [14] concerning national policies that could foster OER adoption. In a similar vein, the European Commission (EC) is also promoting the openness of EC-funded projects results by encouraging, and in some cases requiring, that their outputs be issued with an open copyright license, in line with the open science and principles. This is also true of any educational material produced within the framework of the Erasmus+ programme[2], whatever its format. In spite of these important policies, [15] commentary "calls for a wider discussion to remove a number of barriers to mainstreaming OER in teaching and learning and argues for a rethinking of the idea of 'open' to make it more inclusive by redefining the concept" ([15], p.369). In line with this call, in this paper we argue that we should be as flexible as possible when developing OERs to anticipate problems that might prevent uptake.

Against the above-described backdrop, this paper discusses a number of different nuances that the term *open* can take when the OER is a complex innovative resource comprising tangible, software, and hardware components intended for use in schools. The discussion will revolve around the '4Ts Game' [16, 17,18], which was developed to support groups of teachers while designing collaborative teaching/learning activities for their students. We will maintain that, when schools are the target, extra caution is needed to make sure teachers will be able to use a resource, even before they can reuse

[2] https://erasmus-plus.ec.europa.eu/programme-guide/part-a

it. Hence, in the following we will first describe the game and then illustrate the different facets of openness that were dealt with to make sure it can be used in different educational contexts. Finally, we draw some conclusions concerning the importance of making OERs as flexible as possible so as to minimize the effort required of teachers to use (and reuse) them.

2 The 4Ts Game

The '4Ts Game'[3] has been under development since 2015 and tested (via a user-centered design approach) with different international cohorts of teachers within two Erasmus+ projects: PLEIADE[4] and SuperRED[5]. Both of these projects sought to develop the competence of European teachers in the design of collaborative learning activities for students, so the game was at the core of the respective teacher training interventions.

The game is based on the 4Ts theoretical model [19], which frames the design of collaborative learning activities as a complex decision-making process that encompasses four variables: the 'Task' (what students are asked to do); the 'Team' (how students will be grouped to perform the task together); the 'Time' (phases and schedule for accomplishing the task); and the 'Technology' (the technological tools and resources needed to do it).

According to the 4Ts model, designing a collaborative activity means making decisions concerning these four variables in order to achieve the learning aims in the educational context at hand. As choices concerning each of these variables have an influence on the others, the design process is iterative and may require several rounds to fine tune and optimize the design. According to the literature on collaborative learning, designers' decisions can be made in accordance with well-established techniques [20]), that is, content-independent patterns that help to structure collaborative learning activities. To clarify the concept, Fig.1 shows an example of a technique, namely peer review, and a schematic representation of how it can be implemented using the 4Ts model.

[3] https://sites.itd.cnr.it/4TsGame/
[4] https://pleiade-project.eu/
[5] https://www.superred.eu/

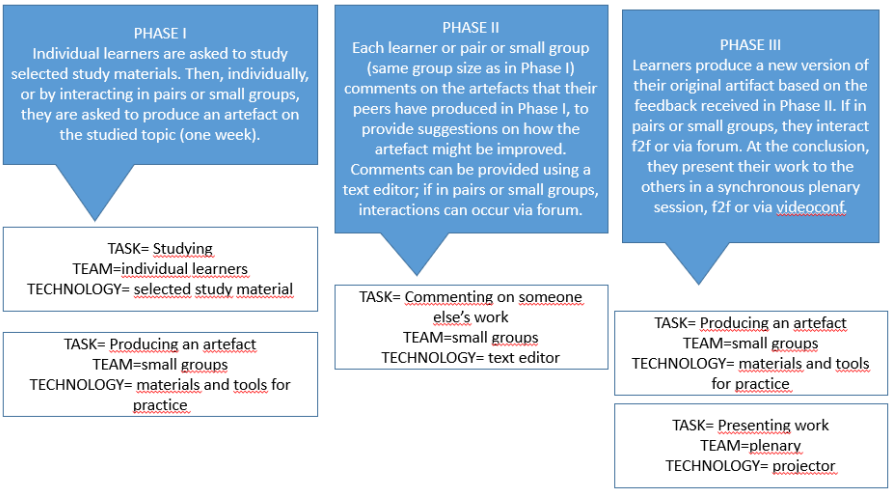

Fig.1 How the peer review can be represented according to the 4Ts model.

The 4Ts game is a board game engaging groups of teachers in an interactive, reflective decision-making process centered around the four variables (the 4Ts) of the model and their interrelations. While the board represents the timeline of the activity being designed (that is the time variable), with each column representing one week, the techniques and the other three variables of the 4Ts model are represented by four different decks of cards (blue cards for techniques, red for tasks, yellow for teams, green for technology). The different cards contain indications on how they can be combined on the board. The first version of the game [18] is paper-based and can be played by groups of teachers standing around a table where the board lays. When playing the game, teachers make their decisions about the four variables by reading the cards, discussing what card combination is best suited for the activity at hand, choosing the agreed cards from the four decks, and positioning them on the board, as shown in fig. 2. In this version of the game, a tutor is needed to assist teachers during gameplay and to provide feedback about their choices.

Fig.2 Teachers playing with the paper version of the 4Ts game.

This version of the game was tested and fine-tuned in the course of a number of real-life experiments [22]. This phase paved the way for development of digital and hybrid versions of the game that reduces the need of tutor assistance while making sure the playing teams receive instant feedback on their game moves. These two game versions also allow players to save a persistent configuration of the board, so that gameplay can be easily paused and resumed, an affordance not featured in the paper version.

In the digital version of the game, the board is reproduced on an Interactive White Board (IWB). The teacher group standing by the IWB (fig.3) can choose the cards they wish to play from virtual decks of cards displayed on the screen(fig.4). Whenever a card is played that is not compliant with the board configuration the game software provides feedback (fig.5) and, upon request, offers suggestions about what cards can be played. The digital game can also indicate whether the technique representation is complete (fig.6).

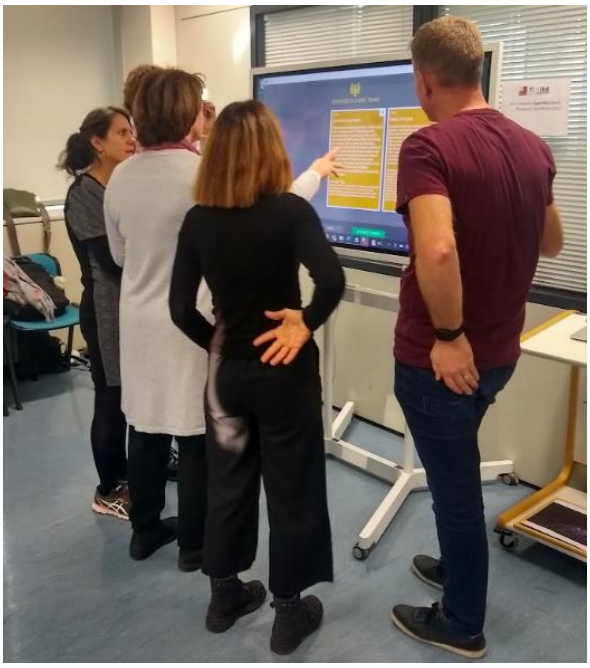

Fig.3 Teachers playing with the digital version of the 4Ts game.

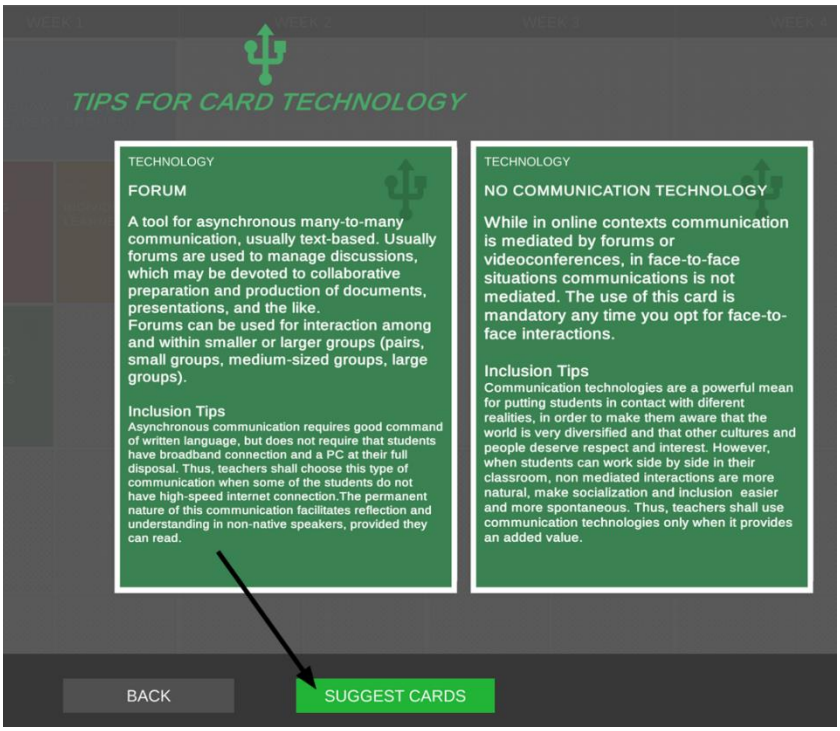

Fig.4 Choosing from a deck of cards in the 4Ts game. After clicking the 'suggest cards' button, the game displays only those cards that are compliant with the state of the board.

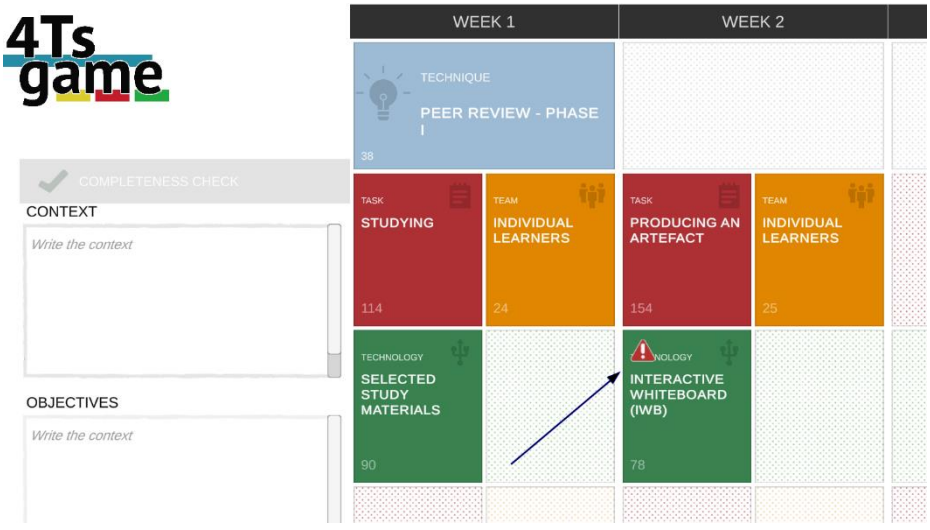

Fig.5 The red triangle indicated by the arrow shows when the wrong card has been played.

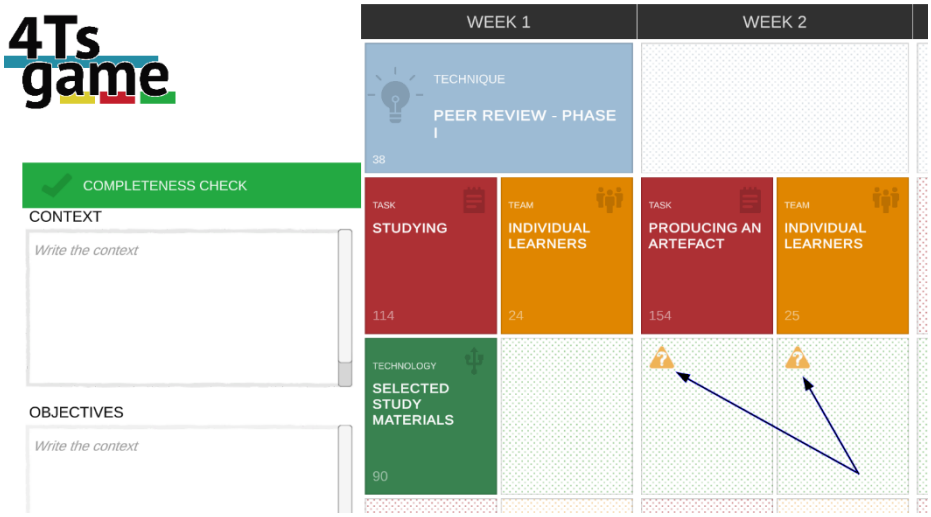

Fig.6 The completeness check indicates the next board slots to be filled in.

Finally, the hybrid version of the game (fig.7) allows teachers to play using the physical board and decks of cards, just like in the paper version. Here, however, players receive automatic feedback as in the digital version. To achieve this, both the board and the cards have ArUco Markers QR codes and a camera hanging above the board detects the cards as soon as the teachers place them on the board. In this way, the software component of the game can process players' moves and activate the same type of feedback as in the digital version. This is displayed on a PC, positioned to the side of the board, where the board configuration is replicated. A more detailed description of the digital and hybrid versions of the game is provided in [16].

Fig.7 Teachers playing the hybrid version of the 4Ts game.

The digital and hybrid games can be played at three progressive levels of difficulty. At each new level, the degree of freedom teachers are afforded in decision making progressively increases, while the guidance provided decreases. Further details of the digital game functionalities and architecture are provided in [21].

As mentioned above, game development has been carried out through a user-centered approach, entailing play sessions conducted during several training interventions with different teacher cohorts. So far, the whole process has involved, more than 150 teachers from six different European countries (Italy, Bulgaria, Cyprus, Greece, Spain and Belgium). These real-world experiments with the game allowed us to assess game acceptance, ascertain the effectiveness of the approach, and compare both of these aspects across the different versions of the game. These qualitative and quantitative data are provided and discussed in previous publications concerning the game [22, 23] and have informed game design choices up to now. However, the focus of this paper is not on game acceptance or effectiveness, but rather on ways to facilitate its uptake by teachers working in different contexts. Evidence of success in this regard can only be collected in the long term, well after the end of the two projects (PLEIADE and SuperRED) that provided the conditions for its development. At the time of writing, we can only say that the teachers involved found customizing the game to their local context to be rather quick and easy, as discussed in the following.

3 Facets of Openness of the 4Ts Game

As mentioned in the introduction, this paper proposes the authors' reflections concerning a number of facets of the term *open*, as interpreted during the development of the 4Ts game. Clearly, this particular OER is a complex one, not just because it is a game, but because it is a complex and cutting-edge piece of technology intended to be used in teacher professional development, possibly in schools or in teacher training institutions, with or without the support of a teacher educator.

As [15] posits, the original thinking behind OERs was "to create universally available educational resources that can improve the quality of teaching and learning" (p.369). The expression "universally available" also means "universally usable", where the concept of "usability" necessarily relates to typical contexts of use and adoption by typical users. If OER features clash with the needs and affordances of the operational contexts of prospective users (in our case, teachers and their schools), endowing them with an open license has little meaning, given the risk that usability barriers will prevent (or at least severely inhibit) adoption.

In the case of the 4Ts game, there are at least four facets that need to be considered in order to make sure the game can be (re-)used by teachers in schools, teacher training institutions and the like: the format, the content, the software, and the hardware.

3.1 First Facet: Format

As mentioned above, the 4Ts game has been developed in three different formats. The paper format allows the teacher team playing the game to manipulate the cards and

"see" the design as it is being produced on the board. In our preliminary experiments with this version of the game [24] it was soon clear that teachers welcomed the possibility to use the cards as mediating artefacts of their discourse around the design choices. The game stimulated collaboration among the teachers around the design, and this is per se an interesting result, given that designing for student learning is all too often an individual task. The collaboration, in turn, triggered reflection on the content of the cards, that is, the way Tasks, Teams, and Technology can be combined and laid on the board to form a coherent collaborative technique.

In terms of user-friendliness, this game format is the easiest to use because it does not require any complex technological set up and there is no interaction envisaged with the technology.

However, the need to have a tutor at hand to provide feedback and guidance on design choices poses a limit on the usability of the paper format. In addition, the persistence of the set up is generally limited to a single game session. In the above-mentioned projects where the game was tested, the game was used by teacher groups in different European countries and the constant presence of a teacher trainer could not be guaranteed. Hence the decision to implement the digital and hybrid versions capable of providing feedback, e.g. when a card is put in the wrong position of the board or to advise teachers when they get stuck and do not know how to proceed.

Both these formats have their affordances and limitations, in terms of usability. As mentioned above, when playing the game in its full-digital format, an Interactive Whiteboard (IWB) is highly desirable because playing the game on a PC would unlikely trigger the desired collaborative dynamics. IWBs are now found in many European schools, and teachers can often gain access to them outside class hours (this, at least, was the case in the two European projects where the game was tested[6]). In our experiments with the hybrid and digital versions of the game [16], the usability of the digital version was judged positively by teachers. However, the full-digital version does not offer the 'mediating artefact' power of physical cards and board.

By contrast, the hybrid version incorporates the chief technological affordances of the digital format, like the possibility to receive real-time feedback or suggestions, along with the advantages gained from manipulating the physical cards and positioning them on the paper board. Here, technological component is limited to a laptop positioned close to the board (fig. 3). Although in our experiments the hybrid game was also evaluated positively for usability [16], it was regarded as slightly more cumbersome in comparison with the digital one. This was due to some difficulties caused by the setup, which sometimes turned out to be somewhat unsteady, e.g. due to accidental collisions with the camera or the table.

In summary, the availability of the game in three different formats allows teachers to choose the one best suited to the specific context / school, thus potentially widening adoption.

[6] The schools involved were located in Belgium, Bulgaria, Cyprus, Greece, Italy and Spain.

3.2 Second Facet: Content

As stated, 4Ts Game cards contain a text with prompts / indications on how the card (be it a Technique, Task, Team or Technology card) can be coherently combined with the other cards on the board. Teachers are expected to read these indications and make their choices accordingly. For example, if the learning task students are expected to carry out is 'debating', then the card is preferably combined with multi-person groups (a Team made up of one person cannot carry out this task) and videoconferencing systems (or face-to-face settings). Conversely, if the task is to 'study', individual work is deemed preferable (although studying in pairs or in a group is also possible) and the technology needed consists in the material to be studied (and some type of communication technology when the task is carried out in online groups). These 'rules of the game' are made explicit on each card but also incorporated in the digital component of the game as part of feedback (see the 'Third Facet: Software' section below.

As not all teachers are necessarily fluent in English, provision has been to facilitate translation of the card content (originally in English): card text is not embedded in the game code, but rather separately stored in a Google sheet. In the above-mentioned projects, this feature was essential as in the different experiment contexts involved (particularly Bulgaria, Greece and Italy) the need clearly emerged to have the cards in end-user languages. The cards were translated by English-fluent teachers who volunteered their services. This task did not require any coding skills, but only respect for the positioning of the text in the spreadsheet cells, strict adherence to the original text, and consistent adoption of terminology. Thus, one of the frequently mentioned barriers to the adoption of OER, that is, the lack of resources in languages other than English [24], was addressed and overcome.

Moreover, it should be noted that the degree of flexibility provided by this simple expedient has much more to it than just facilitating production of translated game contents. Actually, it also provides the possibility for localization to counter cultural barriers: for example, aspects of content that are unsuitable in one culture can be modified instead of being literally translated, and some non-trivial repurposing can also be done. This surfaced in response to emergent needs within the two projects, where the remits of game use included focus on inclusive pedagogical approaches. Here, the content of the cards was more extensively modified by enriching the text with 'inclusion tips' concerning inclusive potential. The purpose of these tips is to explain how each Technique, Task, Team or Technology should be used in an inclusive manner. An example of a card with 'inclusion tips' is provided in fig.8. Thus, thanks to this feature, the content of the cards can be easily customized, according to the specific needs of the contexts. This demonstrates the potential for adoption in training contexts that address different issues.

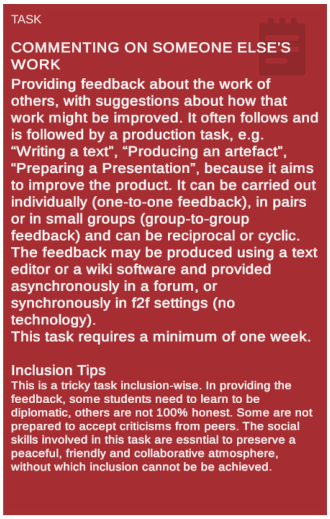

Fig.8 Example of a Task card with related 'inclusion tips'

In addition, there is another form of open content embedded in the game: the so-called collaborative techniques. These are fully fledged "design patterns" [26, 27] that, once understood and appropriated by a teacher, can be reused in a number of different educational contexts to suit different learning aims and disciplinary contents. For example, teachers can use the well-known Peer Review technique to engage students in a three-phase collaborative pattern of activity. Here, two groups of students working in parallel each produce an artefact. Then, in the second phase, the groups swap artefacts to provide each other with feedback. Finally, in the third phase, each group, based on the feedback received, makes modifications to their original artefact with a view to improving it. This technique can be used effectively in any discipline, provided the teacher applies it appropriately. This practice, according to some authors, can be termed an Open Educational Practice [28].

3.3 Third Facet: Software

As far as open software is concerned, the open-source paradigm [29] is embraced worldwide and extensively adopted by several software developer communities. This paradigm is underpinned by principles that are similar to those sustaining open education.

In the case of the digital and hybrid 4Ts Game, openness is a distinguishing factor. The game architecture comprises three layers [17].

The top layer, i.e. the user interface, handles the board and the cards, and although it is implemented in Unity™ (a proprietary game engine), its code is open source. To

implement the augmented features of the hybrid version, the OpenComputerVision library of ArUco markers was used[7]. These are printable square markers composed of a wide black border and an inner binary matrix that acts as identifier. Basically, these markers work like QR codes but are smaller and openly available.

The middle layer handles the business logic: system initialization, persistence management, syntax checks, output formatting, etc. This layer is implemented in C#, whereas queries and responses returned to the business logic are expressed in XML syntax.

The bottom layer implements the rules describing how the cards can be combined on the board and performs all the checks needed to identify errors in gameplay. This layer is the game knowledge base and it is implemented in SWI-Prolog. The code is open source and hosted on GitHub. The knowledge base is located in a separate network node (a cloud server) and can serve different interface clients in parallel. From an openness perspective (customizing the game), Prolog programming competence is needed to add cards or change the rules of the game.

The game runs on macOS or Windows with the latest OS and with at least 8GB of RAM. The complete user guide is provided in [30]. Moreover, Appendix 2 of [31] contains the complete technical documentation for developers, with all the information needed to customize the game software. All code is released under a General Public License.

As mentioned in the introduction, the open science requirement applying to all outputs from the two projects is in line with the principles of equity and democratization inspiring the whole open education movement. However, few teachers possess the skills to modify or customize a complex software system like the 4Ts Game. Hence, personalizable features have been built into the system, at least for those aspects that our experiments revealed as potentially requiring personalization or localization. So, similarly to what has been done with the card content (see section above), some blank wild cards were included in the game so that users can add whatever Task, Team, Technology or Technique they wish. Hence, teachers who do not possess programming skills can significantly customize the game to meet their needs.

3.4 Fourth Facet: Hardware

As far as hardware is concerned, once again the game developers made an special effort to meet the needs typically arising in the target area, i.e. primary or secondary schools. Here, expensive equipment and facilities are often beyond reach.

For the paper-based game obviously no hardware is required; only the board and cards need to be printed. These are freely available online in PDF format. Hence, they can be easily downloaded from the game website[8], printed out on the school printer and cut out with scissors. The board can also be printed ‘in house’ using A4 paper, but in this case the sheets will need to be assembled to form the whole board. Alternatively, a

[7] The “OpenComputerVision” library of ArUco markers by Oleg Kalachev can be found here: https://github.com/okalachev/arucogen

[8] https://sites.itd.cnr.it/4TsGame/

more durable long-lasting board can be printed out at relatively low cost by a professional printing service; cardboard, fabric or low-density polyethylene cardboard can all be adopted for this purpose.

As already mentioned, the digital version of the game is expected to run on an IWB or a smart TV with a touch screen. The hybrid format requires printing out of the cards and board, just as for the paper version. These are laid out on a table, to which a camera on an extender stick is affixed. The camera image of the table from above does not need to be high definition, so an inexpensive model is sufficient. A cheap microphone holder (available online for less than €30) is ideal for use as an extender stick.

Thus, while in principle all three versions of the game can be adopted even in schools with limited resources, each school is free to choose the set up which fits better with its own aims, equipment and facilities.

4 Conclusive Remarks

A plethora of studies has focused on OERs and their definition, as well as on enablers and barriers to their adoption in diverse educational contexts. In parallel, research agencies funding projects at national and international level have adopted policies intended to foster Open Education practices [32]. While there is no disagreement that adoption needs to be encouraged [33], "open education often does not live up to its own vision: in practice, unequal access to communications technology, unequal distribution of basic study skills, and unavailability of resources in certain languages mean that open approaches can act as a force for exclusion rather than inclusion" [25].

In this contribution, we discussed the approach adopted in developing a serious game for training school teachers that has been developed in two Erasmus+ projects. The belief behind this approach is that when developing advanced technological tools for use in schools, open-source software and open intellectual property licenses are not enough. Uptake should be facilitated with a very pragmatic approach by developing material which has built-in features for localization and adaptation to different contexts, and do not pose unrealistic equipment or facility requirements. It is well known that not all schools have plentiful technological and economic resources, and face a range of educational challenges. For this reason, both the digital and the hybrid versions of the game described in this paper were developed with an eye to low-floor requirements and hardware that schools are likely to have or can purchase with limited budget. For example, the hybrid version could easily have been implemented for digital tabletops or touch tables, but this was deliberately avoided because these technologies are usually not part of school equipment. As we have mentioned, the resulting game set up presents some weakness, so we believe further research needs to be conducted to develop and deliver innovative educational solutions that leverage technology which can be realistically adopted in schools on a large scale.

Finally, it should be recognized that ICT competences are frequently not part of teachers' skill sets. Hence, even before making sure that software can be modified and personalized, it is important that proposed tools are flexible in terms of format, content,

software and hardware so that adoption and adaptation require little effort and regular teacher competences.

5 Acknowledgements

The work presented in this paper has been carried out with the support of the PLEIADE and SuperRED projects, co-funded by the Erasmus+ Programme of the European Union (respectively agreement numbers 2020-1-IT02-KA201-080089 and 2021-1-IT02-KA220-SCH-000034442). The European Commission's support for the production of this publication does not constitute an endorsement of the contents, which reflect the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein. The funders had no role in the design of the study, in the collection, analyses, or interpretation of data, in the writing of the manuscript, or in the decision to publish the results.

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