Facets of Openness in a serious game: opening format, content, software and hardware

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Abstract. This paper advocates the claim that Open Licences 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 to support the training of learning design skills of teachers, to exemplify how four different facets of Openness could be dealt with. These are the Format, Content, Software and Hardware facets. In fact, 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

Research about 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 archives that would make self-consistent chunks of reusable educational material easily retrievable and accessible by instructional designers and teachers, in such a way that they could be reused and repurposed for different contexts. The need addressed was to make multimedia development easier, increase its 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 because the world-wide-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 they allow to retrieve material by discipline, language, school level and other features and that the open license of such material specifies the extent to

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

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 is somewhat warranted by the 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 their use has a positive significant (yet negligible) effect on learning outcomes, moderated by several variables, like subject, level of education and others. In addition, OERs (compared to traditional material) can reduce educational costs for students and institutions [7]. Finally, OERs hold a promise for promoting equity in education by providing access to learning material regardless of geographical location or socioeconomic status. However, research has pointed out the need for considering diverse cultural and linguistic contexts in the development and dissemination of OER to ensure their relevance and accessibility on a global scale [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 "below the radar" [10,11]. Hence, researchers explored factors influencing faculty adoption of OER and their perceptions towards these resources [12, 13], while international organizations like UNESCO promulgated 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 are issued with an Open copyright license, in line with the Open Science principles. This is also true of 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 propose that we should be as flexible as possible when developing OERs to anticipate problems that might prevent OERs 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, hardware components intended to be used in schools. The discussion will revolve around the case of a game developed to support groups of teachers while designing collaborative teaching/learning activities for their students, called the "4Ts game" [16, 17,18]. We will maintain that, when schools are the target,

[2] https://erasmus-plus.ec.europa.eu/programme-guide/part-a/important-characteristics-of-the-erasmus-programme#:~:text=Erasmus%2B%20Open%20Access%20Requirement%20for%20educational%20materials&text=The%20materials%20should%20be%20easily,Educational%20Resources'%20(OER).

extra caution is needed if the aim is to make sure that the teachers will be able to use a resource, even before they can reuse 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, to minimize the effort needed by the teachers who want to reuse them.

2 The 4Ts Game

The "4Ts game"[3] has been developed since 2015 and tested (based on a user centered design approach) with different cohorts of teachers, comprising two international cohorts participating in two different Erasmus+ projects: PLEIADE[4] and SuperRED[5],. Both projects shared the need to develop the competence of European teachers in the design of collaborative learning activities for their students, so the game was at the core of the related teacher training interventions.

The game is based on the 4Ts theoretical model [19], framing the design of collaborative learning activities as a complex decision making process concerning four variables: the TASK (what students are asked to do); the TEAMs (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 any of these variables have an influence on the others, the design process is iterative and may require several rounds to fine tune the design in an optimal way. 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 provide a structure to the collaborative activity. To clarify the concept, Fig.1 shows an example of technique, namely the peer review, and a schematic representation of how it can be implemented according to the 4Ts model.

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

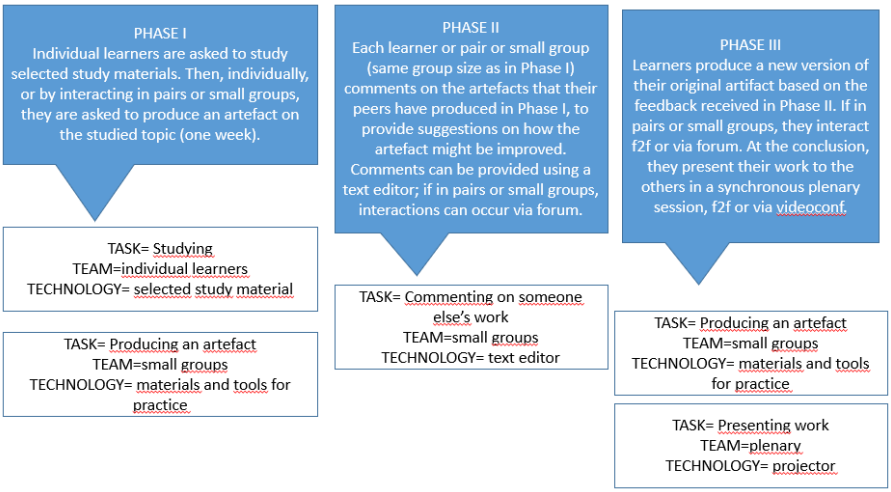

Fig.1 How the peer review can be represented according to the 4Ts model.

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 inter-relationships. The four variables, in the game, are represented by four decks of cards (blue cards for techniques, red cards for tasks, yellow cards for teams, green cards for technology) containing indications on how they can be combined on the board. The board represents the timeline of the activity being designed. 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. Playing the game entails that teachers make their decisions about the 4 variables by reading the cards, discussing among themselves what card combination is most desirable for the activity at hand, choosing the agreed cards from the four decks and positioning them on the board, as in fig. 2. In this version of the game, a tutor is needed to assist teachers during gameplay and provide feedback about their choices.

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

Once this version of the game was fine-tuned based on a number of real-life experiments [22], the development of a digital and hybrid version of the game started, in order to do without the assistance of the tutors while making sure the teams of designers receive instant feedback on their moves in the game. These versions of the game also allow users to save a persistent configuration of the board, so that gameplay can be easily paused and resumed after a significant lapse of time (this was not so easy with the paper version).

The digital version of the game reproduces the board on the screen of an Interactive White Boardand provides groups of teachers, standing around it (fig.3), with virtual decks of cards from which they can choose which cards they wish to put on the board (fig.4). The software provides feedback whenever a card that is not compliant with the board configuration is played (fig.5) and provides suggestions about what cards can be played upon request. Upon request, the digital game also indicates whether the technique representation is complete (fig.6).

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

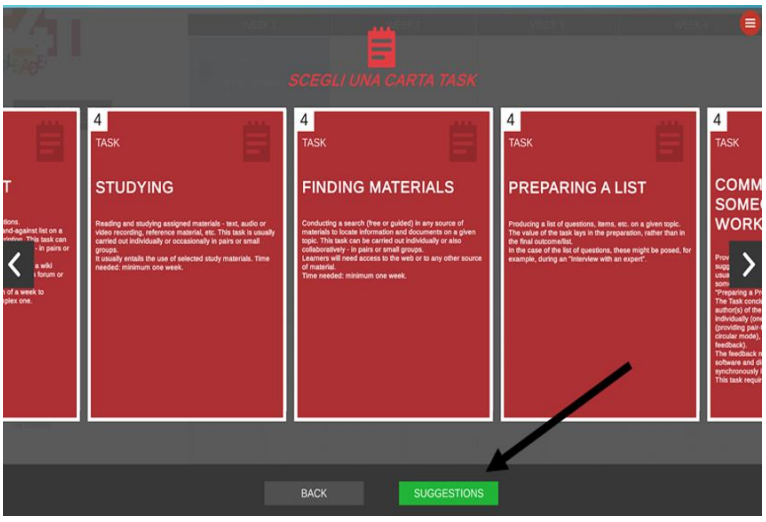

Fig.4 Choosing from a deck of cards in the 4Ts game. Clicking the suggestion button one sees only cards that are compliant with the state of the board.

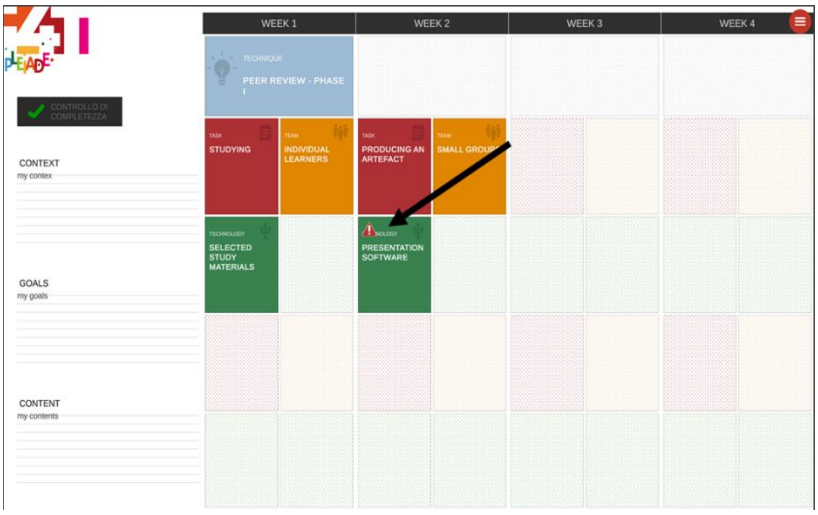

Fig.5 Feedback when a wrong card is played consists in the red triangle (indicated by the arrow).

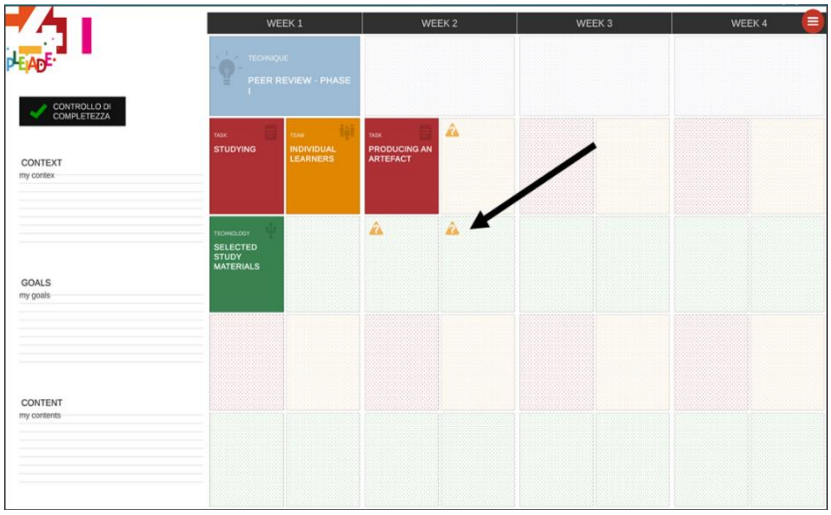

Fig.6 The completeness check indicates the next board slots to be filled in.

The hybrid version (fig.7), finally, allows teachers to play with the physical board and decks of cards like in the paper version and, at the same time, receive automatic feedback as in the digital version. To this end, both the board and the cards are featured with ArUco Markers QR codes that allow a camera, hanging above the board, to detect the cards as soon as they are placed on the board by the teachers. The camera informs the software component of the game of the

moves of the players, and the software activates the same type of feedback as in the digital version, displaying it on a PC 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 with the hybrid version of the 4Ts game

The digital and hybrid games can be played with three increasing levels of difficulty. When the level increases, the degrees of freedom in the choices that teachers can make progressively increase and the guidance provided by the system decreases. Further details of the digital game functionalities and architecture are provided in [21].

As mentioned above, game development was carried out through a user-centered approach, entailing sessions of use with different samples of teachers during several training interventions. The whole process has involved, so far, more than 100 teachers from six different European countries (Italy, Bulgaria, Cyprus, Greece, Spain and Belgium). These real-world experiments with the game allowed to assess game acceptance, ascertain the effectiveness of its 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 that provided the conditions for its development. At the time of writing, we can only say that, for the teachers involved, customising the game to their local context was rather quick and easy, as discussed in the following.

3 Facets of Openness of the 4Ts Game

As mentioned in the introduction, this paper aims to propose the authors' reflections concerning a number of facets of the term Open, as it has been 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 it, the original thinking behind OER 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" must relate to the typical contexts of use, by the typical users. If an 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 is useless as the risk that usability barriers prevent adoption prevails.

In the case of the 4Ts game, there are at least four facets that should 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 formats. The paper format offers the possibility to manipulate the cards and to "see" the design being produced on the board to all the teachers of the team working on it. From our preliminary experiments with the paper 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 students' 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, Technology can be combined among each other and laid on the board, to form a coherent collaborative technique.

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

However, the usability of the paper format can be limited by the need for the presence of a tutor who provides feedback and advice on the teachers' choices. Besides, the persistency of the setting is generally limited to a game session. In the context of the above-mentioned projects where the game was tested, the game was to be used by teachers in different European countries and its usage could not be bound to the constant presence of a teacher trainer. Hence the decision to implement the digital and hybrid versions, capable of providing feedback when a card is put in the wrong position of the board and advise the teachers when they are stuck and do not know how to proceed.

Both these formats have their affordances and limitations, in terms of usability.

As mentioned above, to play the game in its full-digital format an Interactive Whiteboard is strongly desirable, because playing the game on a PC would hardly trigger the desired collaborative dynamics. Interactive Whiteboards are frequently found in many European schools and teachers can gain access to them in their spare time (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 version 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 the physical cards and board.

The hybrid version, instead, takes the most from the technological affordances of the digital one (like the possibility to receive feedback from the system), along with the advantages of manipulating the physical cards and positioning them on the paper board. The technological component, in fact, only serves the purpose of providing real-time feedback or suggestions on a laptop close to the board (fig. 3). In terms of usability, although in our experiments [16] also the hybrid game was evaluated positively, this was regarded as slightly more cumbersome in respect to the digital one, due to some difficulties caused by the setting, which sometimes turned out to be 'delicate' (e.g. due to accidental collisions with the camera or the table).

The availability of three formats of the game allows teachers to choose the one more fitting with the facilities available in the specific context / school at hand, thus potentially widening its adoption.

3.2 Second Facet: Content

As said, the 4Ts game cards contain a text with prompts /indications on how the card (be it a Technique, a Task, a Team or a Technology card) can be combined with the other cards on the board in a coherent manner. Teachers are expected to read these indications and make their choices accordingly. For example, if the task students are expected to carry out is to "debating", then the card is preferably combined with groups of any size (Team made up of one person cannot carry out this task) and videoconferencing systems (or face-to-face settings), while if the task is to "study", individual work is deemed preferable (although in the game studying in pairs or in group is also possible) and the technology needed consist in the resources to be studied (and communication technology when the task is carried out in groups). These "rules of the game" are made explicit on each card but also incorporated in the digital component of the game, so that feedback is built upon them (see section "Third Facet: Software" below.

As in many countries teachers are not necessarily fluent in English, the cards content (originally in English) can be easily translated into other languages. This is allowed by the fact that the text of cards is not embedded in the game code, but rather it is separately stored in a Google sheet. We experimented this feature during the above-mentioned projects, as in these contexts the need clearly emerged to have the cards in different languages (particularly in Italian, Greek and Bulgarian). The cards were easily translated by some English-fluent teachers who volunteered to do so for their colleagues. This task did not require any coding skills, but only respect for the positioning of the text in the spreadsheet cells and strict adherence to the original text, as well as adoption of a coherent terminology. This way, one of the frequently mentioned barriers to the adoption of OER, that is, the lack of resources in languages other than English [24], can be overcome.

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

Moreover, it should be noted that the degree of flexibility provided by this simple expedient has much more to it than just allowing easy translations. In fact, it provides the possibility to overcome cultural barriers as well (for example, aspects of content that are unsuitable in one culture can be changed instead of being just translated) and some non-trivial repurposing can also be done. For example, in response to the needs of the two projects where the game was used to focus also on inclusive pedagogical approaches, the content of the cards was more significantly modified by adding to the text a number of "inclusion tips" concerning the inclusive potential of each card. These tips are intended to explain how each Technique, Task, Team or Technology should be used in an inclusive manner. An example of card with "inclusion tips" is provided in fig.4. Thus, thanks to this feature, the content of the cards can be easily customized, according to the specific needs of the contexts. This allows for further adoption even in training contexts that address different issues.

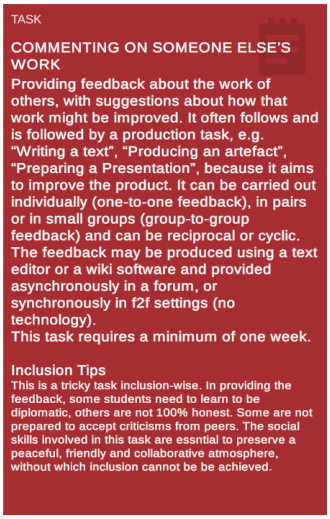

Fig.4 An example of Task card with related "inclusion tips"

In addition, there is another form of Open content actually 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 by changing the learning aims and disciplinary contents. For example, the well-known technique of Peer Review can be used by a teacher to engage students in a three-phases collaborative pattern of activity whereby two groups of students produce two artefacts working in parallel, then, in a second phase, one group provides feedback to the other group to help them improve their artefact and vice-versa, and in a third phase each group changes their original artefact based on the received feedback. This technique can be used in all disciplines, provided the teacher apply it appropriately. It is like applying the same algorithm in different software applications,

by changing the input data to which it is applied. 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 worldwide embraced and adopted by several software developers' communities. This paradigm is underpinned by principles that are similar to those sustaining open education.

Specifically, the architecture of the digital and hybrid 4Ts game 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 synthetic square markers composed by a wide black border and an inner binary matrix that determines its identifier. Basically, they work like QR codes, but they are smaller and openly available.

The middle layer is in charge of 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 server in the cloud) and can serve in parallel different interface clients. Prolog programming competence is needed in order 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, in Appendix 2 of [31] the complete technical documentation for developers with all the information needed to customize the game software is provided. All code is released under a General Public License.

As said in the introduction, the Open Source requirement of all project outputs is certainly in line with the principles of equity and democratization inspiring the whole Open Education movement. However, few teachers possess the competence needed to amend or customize a complex software system like the 4Ts game. Hence, personalizable features have been built in the system, at least for those aspects that our experiments revealed as potentially in need for personalization or localization. So, similarly to what has been done with the card content (see section above), in the game a number of "Jolly cards" was included, that users can fill in with whatever Task, Team, Technology or Technique they wish to add to the list of pre-defined cards. This allows teachers who do not possess programming competences to significantly customize the game.

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

3.4 Fourth Facet: Hardware

As far as hardware is concerned, again, the game developers made an effort to meet the needs of their target, i.e. primary or secondary schools, bearing in mind that in general they cannot count on expensive equipment and facilities.

As far as the paper game is concerned, of course there is no hardware required, only the board and cards need to be printed. They are freely available online in PDF format and can be easily downloaded from the game website[8]and then printed. Cards can be printed by any printer usually available in schools (and then be cut out with scissors). The board too can be printed 'in house' using A4 papers, but in this case A4 papers will need to be 'assembled' to form the whole board. As an alternative, a more long-lasting board can be printed with relatively low cost by a professional printing service, which can also use cardboard, fabric or Low Density Polyethylene Cardboard.

As far as the digital version of the game, as already mentioned, the game is expected to run on an Interactive Whiteboard (usually available in schools) or on smart TVs, possibly with touch screens.

Regarding the hybrid format, while the cards and board need to be printed exactly in the same way as for the paper version and then laid on a table, the setting also requires a camera (an inexpensive model is allowed, because high precision is not needed) and a stick to fix the camera above the table (it can be a cheap microphone holder, that can be bought on the internet for less than 30€).

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

4 Conclusive Remarks

A plethora of studies has focused on OERs, their definition as well as enablers and barriers to their adoption in all 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 intended for use by school teachers during training which has been developed in the framework of two Erasmus+ projects. The belief behind this approach is that when developing advanced technological tools for use in schools, Open Source software and 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 require unrealistic equipment or facili-

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

ties in the context of use. It is well known that not all schools have plenty of technological and economic resources and face different difficulties in terms of educational challenges. For this reason, both the digital and the hybrid versions of the game described in this paper were developed to be run on operating systems with basic requirements and relying on hardware that is likely to be already part of any school facilities or can be purchased with limited budget. In particular, as far as the hybrid version is concerned, an alternative solution could have been implemented relying on digital tabletops or touch tables, but this was avoided on purpose considering that these technologies are usually not part of a typical school equipment. As we have mentioned, the resulting setting of the game presents some weakness, so we believe further research should be conducted to find solutions that strike the balance between providing cutting- edge technological tools and ones that can realistically be adopted in schools on a large scale.

Besides, computer science competences are not frequently part of teachers' skills. Hence, even before making sure that the software can be amended, it is important that the tools proposed are flexible in terms of format, content, software and hardware requirements in order to make use and adaptation possible with little effort and average teachers' competences.

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