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JEM Inventor: A Mobile Learning Game Authoring Tool Based on a Nested Design Approach

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Abstract

The expansion of mobile devices (e.g. tablets, smartphones) and their educational and recreational applications have contributed to the emergence of Mobile Learning Games (MLGs). MLGs show great potential for increasing engagement, creativity and authentic learning. Yet, despite their great potential for education, the use of MLGs by teachers, remains very limited. This is partly due to the fact that MLGs are often designed to match a specific learning context, and thus cannot be directly reused in other situations. In addition, the existing authoring tools are either simple to use but do not offer enough features for designing MLGs that meet the teachers' needs, or much too complex to be used without programming skills. To tackle these problems, we propose JEM Inventor, a MLG authoring tool, based on a nested design approach, progressively revealing functionalities, depending on users' skills and needs. JEM Inventor and its nested design model were evaluated through two experimentations with more than twenty teachers, from a wide range of fields and expertise with the use of MLGs. We also conducted field experimentations with more than 1500 students in order to evaluate the quality of the MLGs created with JEM Inventor as well as their impact on learners.

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1- Introduction

1.1 Context

Nowadays, most teenagers and young adults have access to mobile devices such as smartphones and tablets. In the United States for example, 88% of teenagers between the age of 13 and 17 own a mobile phone (of which 73% are smartphones) and more than half have access to a tablet, according to a study conducted by the Pew Research Center in 2015 (Amanda Lenhart, 2015). From a global perspective, 44% of individuals worldwide owned a smartphone in 2017, according to the "Strategy Analytics" portal[1]. As for tablets, 77 million units were sold worldwide in 2017 and an increase in sales of 6.3% is predicted by 2022[2]. In this context of a rapidly expanding market for mobile devices, Mobile Learning Games (MLGs) have become a hot research topic. Researchers have shown that MLGs can effectively foster the learning process by using game mechanics and incorporating advantages that come with mobility. Despite these findings, their use in educational contexts remains very limited.

In this paper, we firstly define MLGs and their properties, then we analyze why so few MLGs are used in educational contexts. This is related to our previous literature review on MLG authoring tools. Subsequently, we detail our proposal, called the Nested Design Approach for Mobile Learning Games and present JEM Inventor, the authoring tool supporting this approach. We then detail the experimentations with 21 teachers and 1500 students.

1.2 Defining Mobile Learning Games

Since the appearance of mobile devices, the definition of mobile learning (m-learning) has evolved. Definitions given in 2005 assimilated m-learning to consulting resources "anytime and anywhere" (Motiwalla, 2007). M-learning is now redefined as not only learning via mobile devices but also as contextual, formal and informal learning (Gikas & Grant, 2013). From this perspective, several researchers explored new learning approaches such as MLGs. It is quite important to specify that we do not consider MLGs as simply being Learning Games that can run on mobile devices. Indeed, thanks to all the functionalities provided by modern mobile devices, such as GPS location, QR Code readers, media capture and recording, timers, NFC transfer, or Augmented Reality, we consider that MLGs are much more. These functionalities, we refer to as mobility assets, have opened new possibilities for place-based education that takes place in schools via field trips or school outings (Gruenewald & Smith, 2014). Therefore, we define a Mobile Learning Game as *a mobile application, used in place-based education, which makes use of game mechanics and mobility assets in order to enhance the learning process.*

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1 https://www.strategyanalytics.com/ « 44% of world will Own Smartphones in 2017 » Linda Sui

2 https://www.strategyanalytics.com/ « Global Business Tablet Forecast » Gina Luk

1.3 Mobile Learning Games Advantages

According to several researchers, MLGs have great potential to enhance the learning process. Indeed, **MLGs can improve critical thinking** as is the case for *Kiwi Mobile,* a game to introduce business consulting (Lee *et al.*, 2016). In this game, players must solve financial problems by exploring different departments of a fictive company. During the game, they have access to real (to be seen on site) and virtual (in the form of videos) learning content. Through physical and cognitive challenges, *Kiwi Mobile* enabled a group of learners, who received content asymmetric pedagogical approach, to better develop their critical thinking through implicit cooperation during the game. **MLGs can also foster engagement and knowledge acquisition**. For example, a mobile game used in an archeological museum in Cyprus allowed students to be more engaged and have better learning outcomes than those who experienced traditional mobile learning, (i.e. a non-gamified visit of the museum) (Ioannou & Kyza, 2017). In another example, the MLG *Frequency 1550* allowed 232 students to have better learning outcomes than the students having theoretical courses on the subject (Admiraal et al., 2011). The literature offers many other examples that show that MLGs can improve the learning process by fostering engagement, reflection and knowledge acquisition. However, this success depends entirely on the quality of the pedagogical scenario imbedded in the game. In the following subsection we identify the issues that teachers are faced with when implementing those scenarios and producing MLGs in general.

1.4 Issues related to Mobile Learning Game Design

Despite the advantages cited above, the use of MLGs in educational contexts is still very limited for several reasons. First of all, the creation of a MLG is often too expensive. According to the *Yeeply* mobile app building platform[3], mobile games are the most expensive type of mobile applications, costing between 40.000 € and 100.000 €. Additionally, the design of MLGs requires the collaboration of many different actors (*e.g.* teachers, game designers, graphic designers, developers). Moreover, once a MLG is created, it is rarely reusable in other contexts than the one for which it was designed initially. For example, a MLG designed to present the Louvre museum, could not be used in another museum.

For all these reasons, we believe that the best way to increase the use of MLGs in schools is to provide teachers with authoring tools to create and customize their own MLGs. In order to make teachers truly self-sufficient, these authoring tools need to offer functionalities that replace part of the game designers and developer's knowledge necessary to help teachers develop their MLGs. In the following section, we briefly summarize a state of the art of MLG authoring tools and their functionalities.

3 https://en.yeeply.com/blog/how-much-does-it-cost-to-make-an-app/

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2- Related Work

2.1 Focus on Place-based Learning

As we mentioned in section 1.2, m-learning nowadays, goes beyond the "*anytime and anywhere*" character, enabling interactions with the physical environment in which it takes place. In fact, while MLG is a recent research area, on-site learning is much older. It has actually gone through many appellations from "experiential learning" (Dewey, 1986) to "outdoor education". It is today known as "place-based learning" (Gruenewald & Smith, 2014). Thus place-based learning is an education concept whose main message is derived from the local environment, whether it is cultural, physical or historical. In the words of Woodhouse and Knapp (2000), it is interdisciplinary in nature, experiential, and emphasizes the particular attributes of an environment to connect them with the community. In a previous state of the art (Karoui et al., 2015), we found that almost all of the most cited MLGs where actually Location-Based. Back in (2006), *Schlieder et al.* already praised the great potential of "GeoGames" and the recent success stories such as Pokémon-Go seem to confirm this prediction.

2.1 Analysis of Mobile Learning Game Authoring Tools

Given that MLGs are quite recent, we performed an analysis of five m-learning authoring tools, available on the internet and accessible by teachers, that can enable them to design MLGs (Karoui et al., 2016). In order to study the creation possibilities offered by these tools and their limitations, the analysis included the three following criteria: available features, usability and end-user testing. The latter was performed with five teachers who regularly organized educational field trips. The analysis of the criteria and the qualitative feedback of the five teachers, led us to identify two main categories of authoring tools. The first category called the "**complex authoring tools**", refers to rich authoring tools with a wide variety of features, which are complex to use for teachers without programming skills or without any knowledge in game design. For example, authoring tools such as *MIT AppInventor* (Patton et al., 2019), *ARIS* (Perry, 2018), *Pocket Code* (Slany, 2014) and *ARLearn* (Ternier et al., 2012) can be included in this category. The second category, called the "**light authoring tools**" refers to authoring tools that are simpler to use but that offer very few features. Typically, these authoring tools do not allow teachers to create MLGs with rich multimedia resources or context tailored scenarios as those cited in the introduction. For example, authoring tools such as *Furet Factory*[4] and *mLearn4web* (Zbick et al., 2016) can be included in this category.

2.2 Teacher Profiling

The MLG design process is closely linked to the teacher's profile and skills. According to "digital competence model" proposed by Krumsvik (2008), the more teachers are digitally aware, the more they will adopt digital learning tools and the less they are digitally aware, the less they will adopt these tools. We verified this theory with an online questionnaire that was filled in by 24 teachers who regularly organize field trips (Karoui *et al.*, 2016). When analyzing the responses, we found that teachers with the most game-design experience were willing to spend much more time creating

[4] https://furetfactory.com

MLGs (four days or more) than teachers who were beginners in mobile games, and who were not willing to devote more than one day on average, to the creation of a game. We can therefore identify two extreme profiles who have different expectations regarding the functionalities offered by authoring tools: *MLG novices* and *MLG experts*. The teacher profiles should be seen as a continuum because, as they are working on designing theirs MLGs, *MLG novices* will gradually become *MLG experts*.

2.3 Research Questions

Taking into consideration the previous results about authoring tool categorization and teacher profiling, our research questions are the following:

- Q1. How can we design a MLG authoring tool that is both feature-rich and user-friendly?
- Q2. Which MLG design method would be adapted to the different profiles and needs of teachers?

In order to answer these research questions, we combined two methodological approaches: Design-Based Research (DBR) and User-Centered Design (UCD). The objective is to improve practice and theory at the same time, so that they are mutually enriched. As part of the DBR method, we present in the following section, the hypothesis as they emerged according to the state of the art (section 2). As part of the UCD, we carried out an iterative development phase throughout experiments with 20 teachers and 1500 students that we present in section 4.

3- Hypothesis and Contributions

In this section, we propose three hypotheses to answer the first research question and two hypotheses to answer the second research question.

3.1 A Basic Template for Location-Based Learning Games

In order to simplify the design of MLGs and make it more accessible, we propose a system that automatically deals with a basic game design and its development and therefore only requires the pedagogical expertise brought by teachers. To validate this idea, we performed exploratory interviews with five teachers from various teaching levels (middle-school, high-school and college) and fields (botany, history, biology…) (Karoui *et al.*, 2016). These teachers confirmed that it would be easier for them to start using a new authoring tool by recreating one of their classic field trip scenarios and later enrich it with game mechanics. Therefore, we formulate the first hypothesis **H1** as following: **“A MLG model, based on a basic template, will allow teachers to intuitively gamify existing field trip scenarios”**.

As mentioned in our previous work (Karoui et al., 2017), we believe that providing a basic MLG structure will be helpful, especially to novice designers, who do not yet have experience in game-design. We decided to start by providing a basic template for one of the most common types of MLG: the educational Treasure Hunt.

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We propose the following model, that was established as a result of a previous study on the most cited MLG (Karoui et al., 2015) and a co-design session with teachers (Marfisi-Schottman et al., 2016). We found that the analyzed MLG scenarios had a common recurrent structure. Indeed, they are all composed of a sequence of ***Mobile Game Units*** (MGU) that need to be achieved on a specific **Point Of Interest** (POI). Each MGU is composed of a ***clue*** (indications to find the POI to look for), a ***learning content*** (information shown at the POI) and finally one or several ***on-site activities*** (answering questions, resolving a riddle, exchanging learning content with team members, taking notes...). This template is found in most MLGs we came across, even out of the context of the studies mentioned above.

The *clue*, the *learning content* and the *on-site activity*, follow one another, as shown by the arrows in green in Figure 1. Their sequence is conditioned by the internal events of these main components. For example, the teacher can choose between four modes to validate the fact that the player has reached the POI and therefore show the *learning content*:

- GPS validation *i.e.* the mobile artifact is in the right location
- QR-code scan, previously printed and installed on the POI by the teacher
- Single-answer question (SAQ) such as "what is the color of the building?"
- Manual validation *i.e.* the player clicks on a button

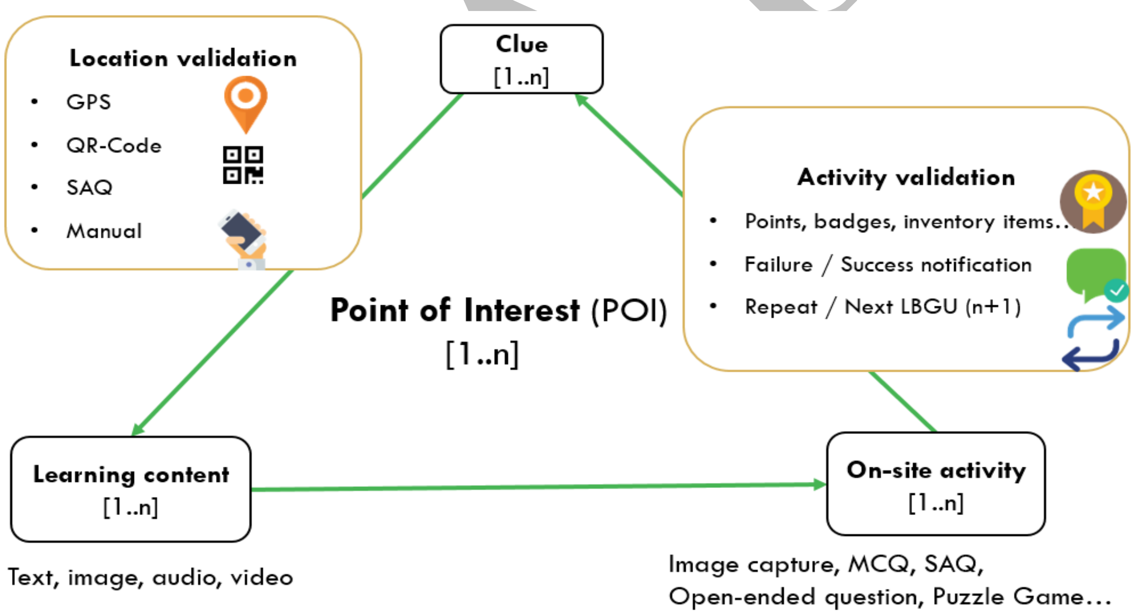

Figure 1: Sequence of events within a Mobile Game Unit

The sequence of MGUs is also conditioned by the result of the *on-site activities* such as open-ended questions, single-answer questions (SAQ), multiple-choice questions (MCQ), image capture or audio and video recording. If the student completes these activities correctly, the system displays a success message, updates the student's score and shows the *clue* of the next MGU. Otherwise, the system displays a failure message and offers to redo the same *on-site activity*. Furthermore, if the MGU contains several *on-site activities*, the trigger of the next unit is activated when the system indicates the end of these activities. More details about triggers are provided in Figure 2, which represents the detailed structure of the MGU.

Figure 2 shows a partial view of the MLG class diagram (represented by Figure 4). It details the structure of the *learning content* component within the MGU. The *learning content* incorporates a trigger for its display, which corresponds to validating the arrival on the POI as mentioned above. The *learning content body* contains the educational resources that will be uploaded by the teacher. After the students see the *learning content*, they can start the *on-site activity*. The latter is composed of three elements: a *trigger* that corresponds to the validation of seeing the learning content, a *body* that indicates the type of the *on-site activity* (MCQ or image capture, etc.) and the *activity validation* with the correct answer.

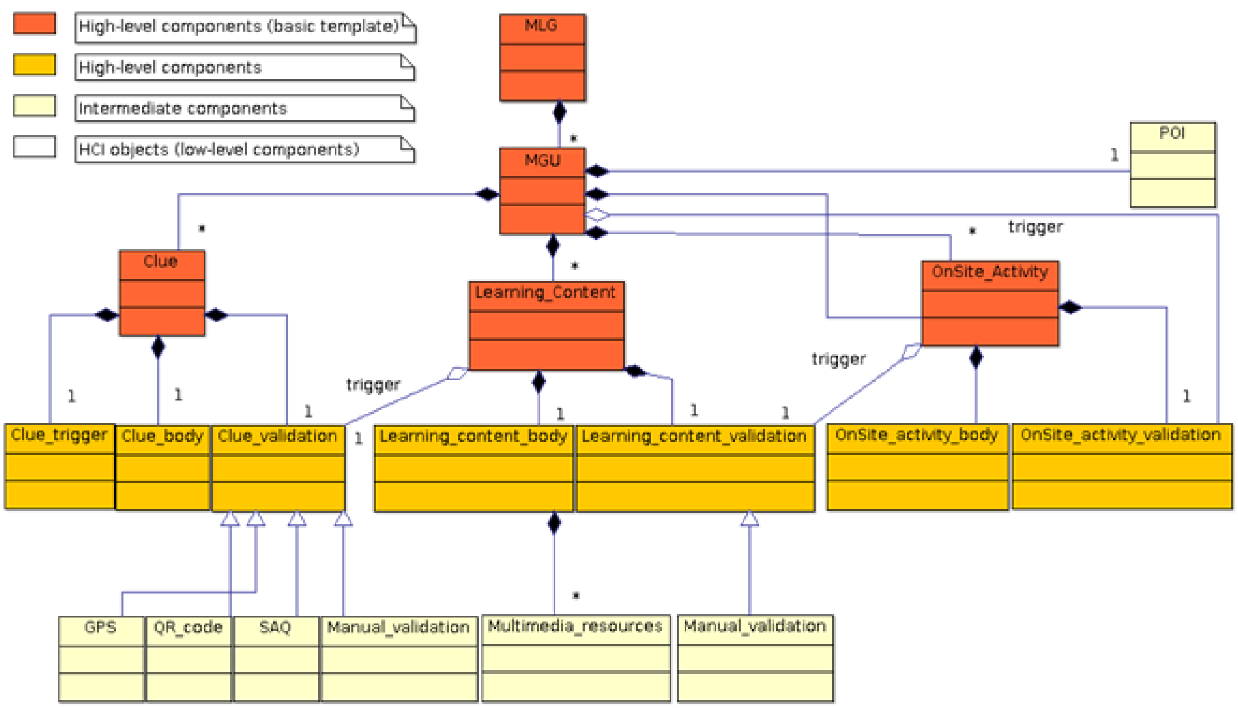

Figure 2: Partial view of the Mobile Game Unit structure

The *Basic Template* presented above, and the vocabulary chosen for its components were validated by our interviews with teachers, who confirmed that it fit their needs. In the following, we present our proposals to extend and modify this *Basic Template*.

3.2 Flexible Mobile Learning Game Model

3.3.1 A flexible structure

The structure of the *Basic Template* was established, as explained above, from invariant elements observed in MLG scenarios. However, in order to cover a wider spectrum of scenarios, this structure must be flexible and adjustable to the teachers' needs. It should be possible to add steps to the basic trio (*clue, learning content and on-site activity*) and adjust the internal structure of these components (trigger, body and validation mechanisms). We therefore propose a flexible and editable structure for the basic components that will enable teachers to redesign the internal structure of their MLGs in order to fit their pedagogical needs. As a result, we formulate the second hypothesis **H2** as following: **"A MLG model proposing a flexible structure and editable components will cover a wide variety of MLG scenarios"**.

The *Basic Template* presented above is composed of high-level components. In the following, we explain the different component levels and the variety of settings they offer.

3.3.2 Component settings and levels

The process of designing Technology-Enhanced Learning environments requires the ability to conceptualize and structure high-level concepts (Murray, 2015). Indeed, a MLG scenario must consist of sequences that are conceivable and understandable by teachers.

In our case, we call ***high-level components***, the most familiar concepts to MLG novices, such as clues, activities or POIs (Point Of Interests). To operationalize the high-level concepts of the basic template, they need to be linked to technical components, called ***low-level components***. In our case, *low-level components* are basic HCI objects such as buttons, labels, checkboxes, multimedia resources (images, soundtracks, videos, etc.) that are supported by all mobile development environments (*e.g*. Android Studio, Xcode). However, it is very difficult to orchestrate and configure these low-level components. Thus, to facilitate the design process, we propose the concept of component incorporation that links the low and high level components through ***intermediate-level components***.

3.3.3 Component Incorporation Concept

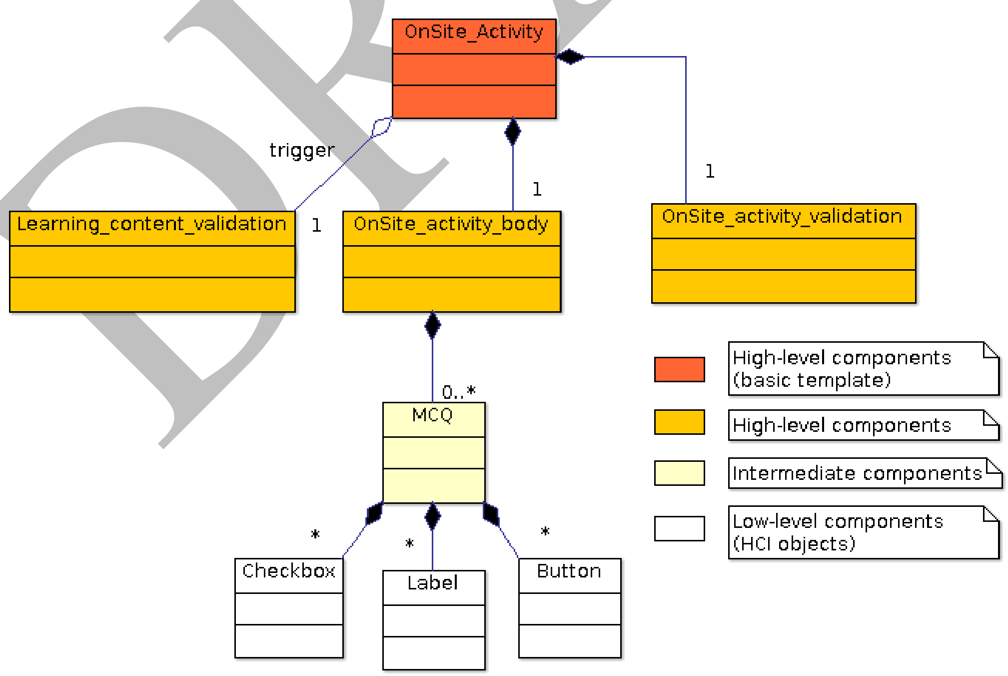

Figure 3: Incorporation concept (a MCQ example)

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Based on the exploratory interviews we lead with teachers and the authoring tools analysis (Karoui *et al.*, 2016), we estimate that orchestrating intermediate-level components, such as an MCQ, within a learning activity, would be much easier for teachers than orchestrating the dozen HCI objects (buttons, labels, etc.) necessary to make an MCQ. To explain this concept, Figure 3 shows the static structure of the *intermediate component MCQ,* which incorporates several *low-level components* such as *labels, buttons* and *checkboxes*. As shown in Figure 3, the *intermediate component MCQ* is also incorporated into an upper component which is the Body of the *even* higher level component *on-site activity*. The same principle applies to all components of the *Basic Template* (image capture, video recording…)

The incorporation concept thus makes it possible to extend or modify the *Basic Template* by adding components at different levels. However, these components need a specification of their behavior in order to be operational.

3.3.4 Operationalization of the Component Incorporation Concept

In order to make the high and intermediate-level components operational, it is necessary to specify their behavior. For example, the *Clue* component, presented in 3.2, will be triggered at the beginning of the next MGU when the *on-site activity* is validated. Similarly, the on-site activity's *validation* component will check the answer of the on-site activity, update the player's score and display the next MGU or a failure message. However, since all the components are editable, the teacher can, for example, configure the *on-site activity's validation* component to trigger different activities depending on the player's answer. In order to operationalize these different behaviors and implement their algorithms, we have developed operationalization functions for each high and intermediate-level component. As a result, we formulate the third hypothesis **H3** as following: "**Operationalization functions, linking high, intermediate and low-level components, will automate the execution process for MLG scenarios on mobile devices**". The code in these operationalization functions will be presented in the "reification" part (section 4.3).

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3.3.5 Full diagram

A full view of the relationship between these components is illustrated in Figure 4. All links are not shown in the diagram due to the large number of interconnected components. For example, the *label* element is linked to all components including text, such as questions (multiple choice, single answer and open question), clues, success messages, scores, etc. The same applies to other components, such as buttons. Figure 4 shows the full class diagram of the MLG model presented in this section. In this diagram, components are divided into three frames, corresponding to the three components levels presented above (section 3.3.3). The component colors illustrate the nested design process and will be explained in the following section.

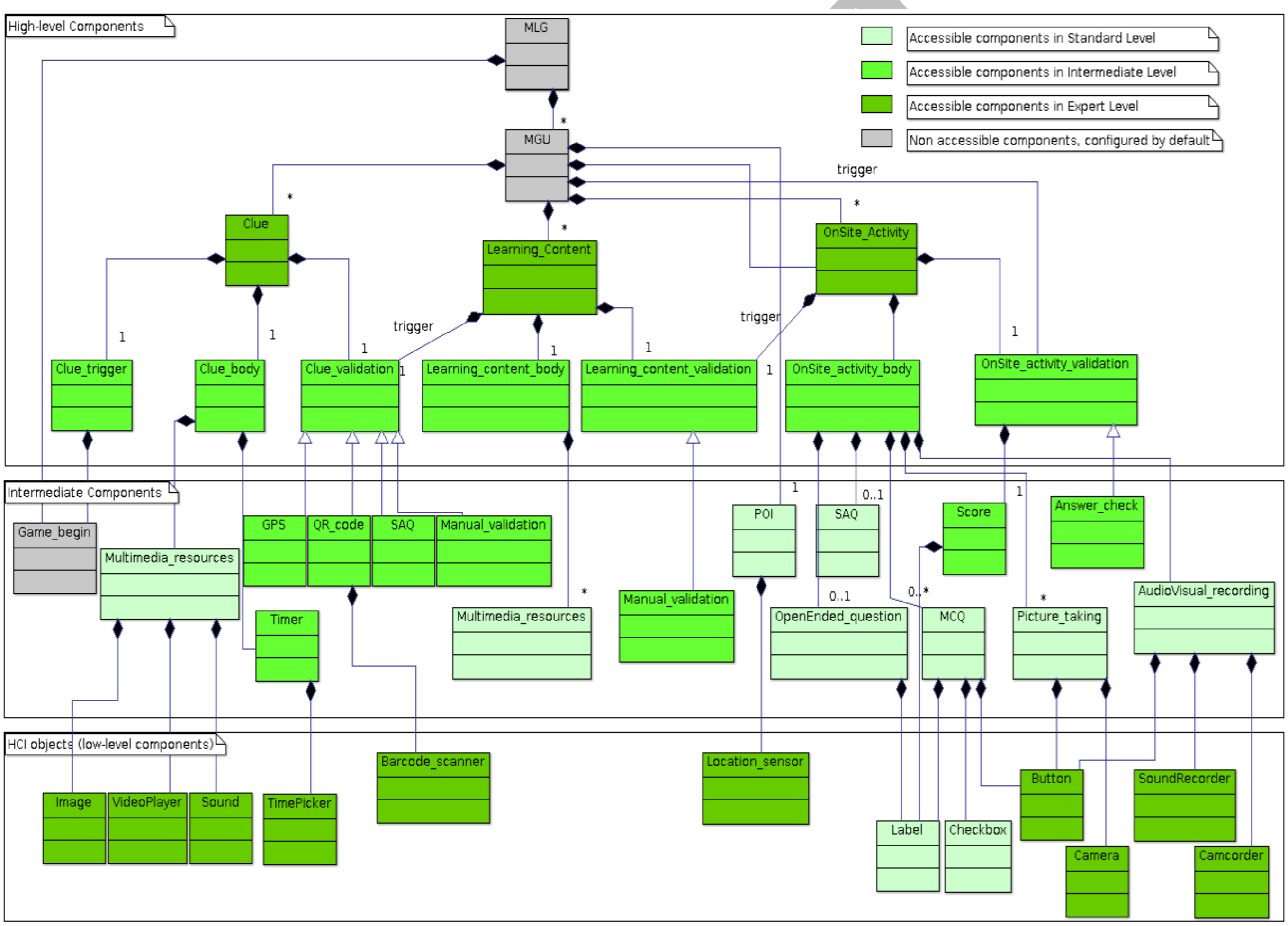

Figure 4: Full view of the MLG model

3.4 The Nested Design Model

After presenting our first three hypotheses to answer the first research question Q1. This section presents our hypotheses to answer the second research question Q2: "Which MLG design method would be adapted to different profiles and teacher needs? ».

In order to answer this research questions, and since MLG authoring tools are fairly recent, we study research on usability in a broader context, including TEL authoring tools.

3.4.1 Addressing Authoring Tool Complexity in TEL

Although the majority of research studies focus on the usability of the educational software itself, some provide insight on the usability of the educational software authoring tools. Murray (2004) identifies three main issues related to creating authoring tools: power, usability and cost. Power concerns the functionalities provided by the authoring tool as well as the diversity of the educational software produced. Usability conveys two concepts: the ease of use of the tool itself and the productivity of an experienced user. Finally, cost refers to the resources required to create educational software (*i.e.* staff, expertise and time). In order to address the complexity of educational software authoring tools, Murray presents two alternatives.

The first alternative points to the trail of collaborative authoring tools. These tools often provide good performance, as they combine various features intended for the various expertise of the members of the design team. Generally, they do not present usability problems, as they are intended for experts, who do not have difficulty managing their part in the design process. In the same vein, Ritter *et al.* also recommends the collaborative design methods and propose to design different interfaces for each collaborators instead of having a huge monolithic tool (Ritter et al., 2003). While we agree on the usefulness of this first approach, we nevertheless believe that collaborative design does not optimize the cost. Indeed, as mentioned in the introduction, involving several experts is expensive and not affordable for most teachers.

The second alternative proposed by Murray (2004) is to hide the tool's advanced features and only show them, on demand, for experienced users. However, the problem with this approach is that it does not allow novices to design complex artifacts. A few years later, inspired by the hierarchical complexity theory, Murray proposed to adapt the complexity of authoring tools to the users' capacities and the complexity of tasks they want to achieve (Murray, 2015). The teacher profiling, described in the previous section, can be considered as a first step in this direction. In order to overcome the complex design level, we introduce the Nested Design Model.

3.4.2 Nested Design Model

In the second section of this paper, we highlighted a continuum of existing profiles among teachers (from novice to experienced MLG designers). Accordingly, the solution of offering several design levels in a single authoring tool seems relevant to us. Therefore, we propose, as a first step, two design levels that we call ***Standard Level*** and ***Expert Level***, intended respectively for teachers who are novice in MLG design and experienced in MLG design. These levels offer two different interfaces with specific functionalities. The *Standard Level* provides an uncluttered interface, including a map showing markers of the POIs to setup and customize. The *Expert Level* provides visual programming mechanisms to manage the MLG components in detail such as MGU sequences and score calculations. However, it is clear that there will be a learning curve to go from the *Standard Level* to the *Expert Level*. In order for this learning curve not to be too steep and dissuasive, we propose an ***Intermediate Level***. Indeed, a passage through an intermediate level, allowing to configure some components already manipulated in the first level, has the advantage of revealing features in a progressive way to the teachers, without disorienting them. Thus, the Nested Design Concept consists in gradually revealing features according to the designer's profile and needs, but also as their degree of mastering the tool itself increases. However, even if the three levels offer more or less features, their interfaces must offer the same landmarks, to ensure a smooth transition between levels. Furthermore, teachers should be able to navigate freely between them. For example, they could use the standard level to design most of their MLG but switch to intermediate or advanced level to access richer functionalities in order to customize one specific component. We therefore formulate the fourth hypothesis **H4** as following: "**A nested design method, based on the Mobile Learning Game model, will allow teachers to gradually implement richer scenarios**".

3.4.3 The Three Design Levels

As discussed above, the nested design approach aims to facilitate the transition between several design levels. However, from a conceptual point of view, it does not impose a fixed number of levels and could very well offer more. In the context of MLG design, we propose three levels.

The Standard level: Modifying a Basic MLG Template

The Standard Level allows teachers to make slight modifications on a few components, to quickly create linear MLGs and predefined game mechanics (a treasure hunt scenario with points). Therefore, the Standard Level mainly displays high-level components of the Basic MLG Template such as the *POIs* on the map, *Clues*, *Learning Content* and *On-site activities* (light green components on figure 4).

This level is clearly intended for teachers who are novice in MLG design or for those who just want to create a MLG quickly. Teachers can create a new scenario based on the Basic Template initially provided, or start from an existing scenario by modifying only the data (title, indications, resources, etc.). Their task is therefore to setup or edit the POIs on the map, fill in the clues to get there, upload their own pedagogic resources and edit the *on-site activities*. The intermediate components, which are incorporated in the Basic Template are managed automatically with default values and therefore not editable at this level. Thus, the MGU order is linear and giving the correct answers (in on-site activities) allows players to have a fixed number of points (50 points for a correct answer on the first try, 30 points on a second try and so on...).

The Intermediate Level: Orchestrating MLG Components

This level is intended for teachers who are more experienced and who feel the need to modify the Basic Template and create customized scenarios as explained in section 3.4.2. The *Intermediate Level* gives access to advanced features for each MLG component (*e.g*. radius of POI and scores configuring), but also MGU triggers and validators in order to free teachers of the imposed linear sequencing proposed in the *Basic Template*. This level therefore makes it possible to orchestrate the different MGUs with conditional sequencing (*i.e*. if the player answers this then go to MGU A otherwise got to MGU B). In addition, teachers are able to extend the basic model by deleting or duplicating the three high-level components initially proposed (*Clue, Learning Content and On-Site activity*) or adding other components (*e.g*. other screens). All this while remaining on the same

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editing model (*e.g*. menus, palettes, etc.) in order to keep as many landmarks as possible within the transition between the first and the second design levels. The components accessible in the Intermediate Level are colored in green in figure 4.

The Expert Level: Creating Custom-Made MLGs

This last level is mainly intended for teachers who are experienced in MLG design. It includes access to all the components previously presented. In addition, it allows the creation of custom-made components, which can be added to the *Basic Template* components or even replace them. However, once the initial components have been completely deleted, default operating mechanisms, such as scores and sequencing MGUs will no longer be in place. It will therefore be necessary to orchestrate very low-level concepts to recreate something similar. This process can be handled by programming (variable management, conditions, loops, etc). For this type of design, we believe that visual programming can be advantageous. This also seems appropriate for teachers who are experienced in mobile games, because they are willing to invest as much time as necessary into their MLG design. Figure 4 displays the accessible components (dark green color) to the designer in the *Expert Level*. The few elements still in grey (e.g. MGU, GameBegin, etc.) belong to the game engine core and are mandatory for making the MLG work. For example, it is mandatory to have a starting screen for the MLG and also each game unit, even if their content can be completely modified. Following the hypotheses and proposals presented above, we formulate the fifth hypothesis **H5: "The Mobile Learning Game model and the Nested Design Approach can be supported by an authoring tool"**. In the following section, we present JEM Inventor: the authoring tool created to reify those hypotheses.

4- Reification in JEM Inventor

4.1 Building on MIT App Inventor

Since we are confronted with an engineering and reuse problem, we propose not to start from scratch. Indeed, to reify the proposals discussed above, we propose to build a MLG authoring tool over MIT App Inventor, one of the existing tools analyzed in our previous research (Karoui *et al.*, 2016). This tool meets all our criteria as it offers a wide range of technical features, it is open source and provides explicit and detailed documentation. In addition, a study conducted in 2014, Rouillard *et al.* recommend App Inventor for rapid prototyping of MLG (2014). In their study with 116 IT students, App Inventor allowed to develop 79 mobile apps within 10 hours, of which 14 apps were considered as interesting MLG prototypes. From a technical perspective, our feature analysis in the state of the art (Karoui *et al.*, 2016) confirms that App Inventor offer all the main functionalities to design MLGs. App Inventor also has the advantage of integrating visual programming through the open source library *Blockly*. An inconvenience of this tool was the fact that App Inventor could only produce Android apps. However, given the high usage rates of Android worldwide (84.1% of the global smartphone market (Dutta et al., 2017)), we figured that this limit was acceptable.

4.2 JEM Inventor

The name "JEM Inventor" includes the acronym "JEM" (Jeux Éducatifs Mobiles) equivalent to Mobile Learning Game (MLG) in French. We kept the word "Inventor" to refer to MIT App Inventor, the authoring tool that we choose to build on.

As part of a User-Centered Design Approach (UCD), we produced several mock-ups models of the interface for the two first modes of JEM Inventor (Standard and Intermediate Level) in collaboration with the five teachers we met during the exploratory interviews (Karoui *et al.*, 2016). Discussions around the first mock-ups revealed that it was not necessary, for example, to keep certain elements in the standard mode such as score management. On the other hand, the presence of the map on all mock-ups was a consensus among all the interviewed end-users. In terms of development, we iteratively created several prototypes that were used for the experiments to be presented in the next section. Figure 5 illustrates the final version of JEM Inventor (v1.2).

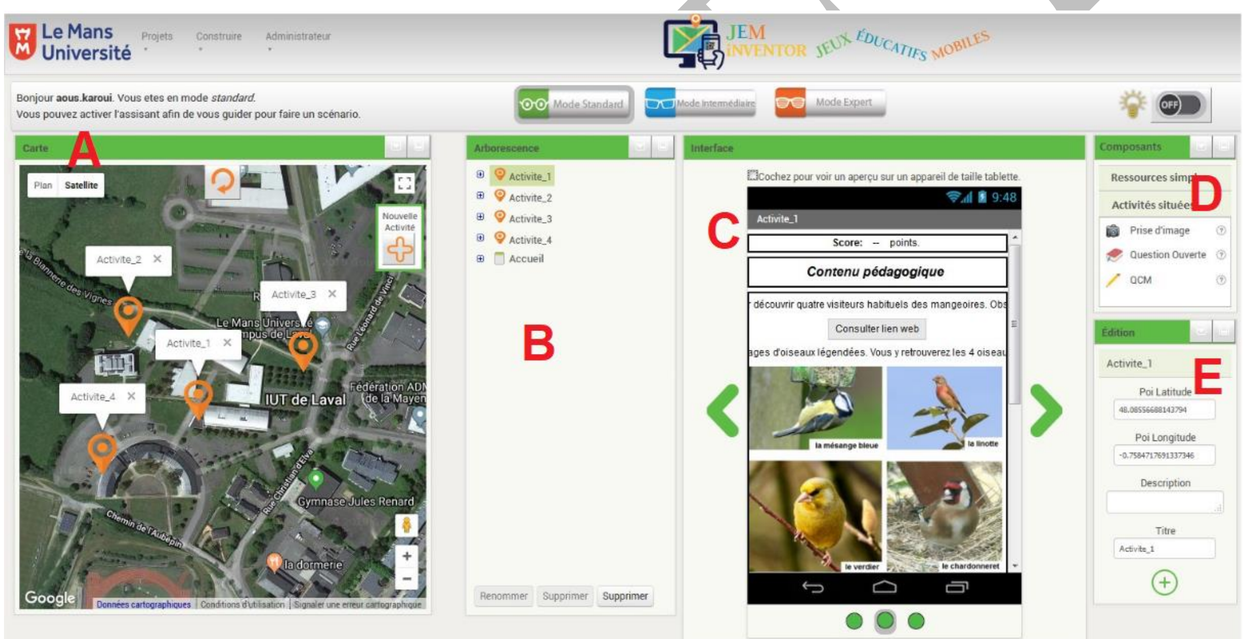

Figure 5. Overview of the current JEM Inventor interface (prototype v1.2)

Figure 5 is divided into five zones representing the five boxes of the Mobile Game Units edition. Hence, zone A includes the map for creating POIs. In zone B, we can find the created MGUs and their internal high-level components (Clue, Learning Content and On-site activity), represented in the form of a tree structure. Zone C shows the content created by the teacher, as it will be visible on the players' mobile device. The lateral arrows allow to navigate between the screens corresponding to the three high-level components of each MGU. By default, there is one screen for the Clue, another for the Learning Content and another for the On-site activity. Zone D contains the design components, ranging from HCI objects (*e.g.* label, image, video, etc.) to intermediate components (*e.g.* MCQ, open-ended question, image capture, etc.) that can be added to the phone's screen with a simple drag and drop. Finally, zone E allows to edit the properties of the selected component. The three buttons in the top crossbar correspond to the three design modes provided by JEM Inventor, that are described below.

4.3 Automated Block Management

The execution logic in the original version of App Inventor is performed through visual programming, by manipulating algorithmic blocks. Thus, the teacher works at the algorithmic level throughout the entire scripting process (e.g. creating a button, associate a function with algorithmic blocks). In JEM Inventor, we propose components with operationalization functions, i.e., which already integrate algorithmic blocks. For example, when creating a new MGU, Jem Inventor automatically creates a POI embedded in the unit, with algorithmic blocks specifying that the *Learning Content* screen can only be displayed after having detected that the mobile device is in the vicinity of the POI. If the teacher chooses a manual validation for the arrival on the POI, the existing blocks will automatically disappear and give way to new algorithmic blocks that display the *Learning Content* after manually pressing the "Next" button. The same applies to the choice of "QR-code" mode for validating the arrival on the POI. In general, all interactions in JEM Inventor (*e.g.* adding or removing new components) involve changing algorithmic blocks in an automated way. Figure 6 shows the example of calling the “displayLearningContent” function through the "Next" button of the Clue screen in the manual trigger mode. Changing to the GPS trigger mode will automatically change the whole sequence of blocks with another one.

Figure 6. Algorithmic blocks visible in expert mode

4.4 The Three Design Modes

JEM Inventor proposes three design modes related to the three design levels of the "Nested Design Approach" (section 3). ***The Standard Mode*** essentially contains high-level and intermediate components. This will allow teachers to manipulate simple high-level components which are "ready to use" thanks to the automated block management.

The ***Intermediate Mode*** is also based on the automated block management. The principle of these two modes is that the teachers do not have to worry about the algorithmic blocks and that all the choices they make lead to an automatic rearrangement of these blocks. Additionally, the Intermediate Mode has the same landmarks as the Standard Mode. The only difference is that the editing boxes expand to provide additional features. Figure 7 summarizes this principle by illustrating how the editing box gives access to more and more properties of an on-site activity according to the three modes. The palette of the Standard Mode (left) displays the minimum features necessary for MGU description and POI coordinates. The palette of the Intermediate Mode (middle) displays some additional features related to the trigger (manual, GPS or QR-code) and the next MGU (linear or custom mode). Finally, the palette of the ***Expert mode*** (right) gives access to all possible features. It also gives access to the algorithmic blocks (Figure 6) in order to give maximum freedom and functionality through visual programming. This mode therefore allows, in accordance with the principle of the Expert Level (section 3.4.3) the creation of components from scratch.

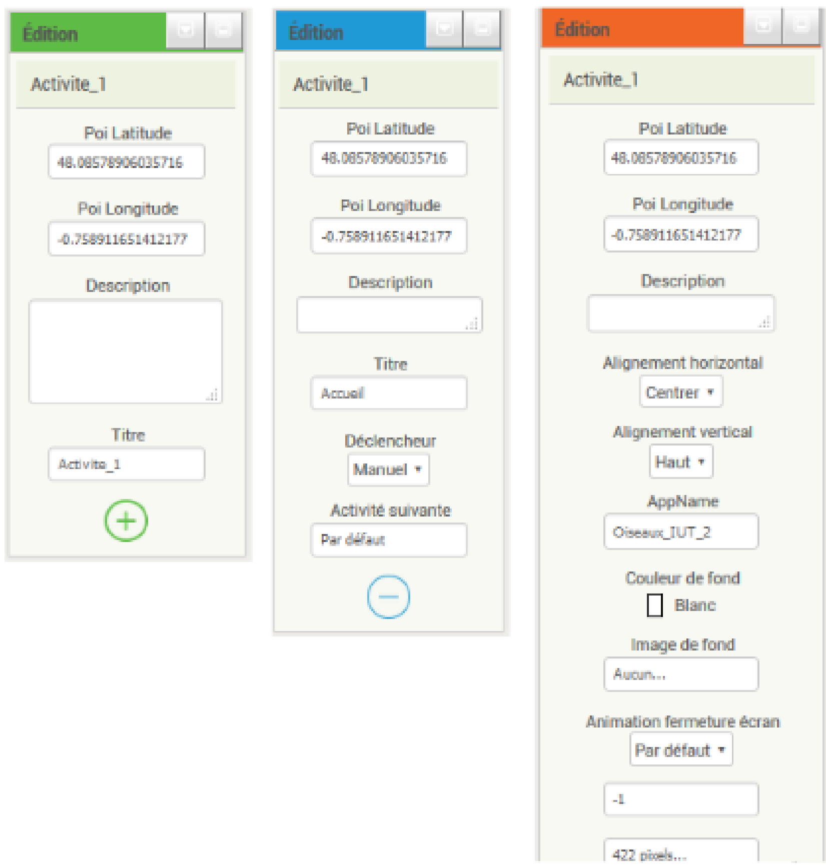

Figure 7. Feature’s evolution on the editing palette along the three modes

5- Assessment

In the previous sections of this paper, we presented five hypothesis related to our theoretical proposals: the Mobile Learning Game model and the Nested Design Approach. These proposals were built into the JEM Inventor authoring tool. Thus, in this section, we present the assessment of JEM Inventor and the evaluation of the five hypothesis (section 3). In parallel to these evaluations, we also propose to evaluate several MLGs, created by teachers with JEM Inventor, in various learning contexts, in order to know if these MLGs meet their objectives.

In this section, we firstly present the assessment criteria. Then, we present each experimental study by describing their objectives, context and protocol. For each experiment, we then present an analysis of the obtained results.

5.1 Experimental Methods

5.1.1 Assessment Criteria

We chose the Technology Acceptance Model (TAM) (Davis et al., 1989) to identify evaluation criteria. This model, widely used to predict whether an individual will use or refuse to use a software, is based on two main criteria: the perceived **usefulness** of the software and the perceived **usability** (ease of use of the software).

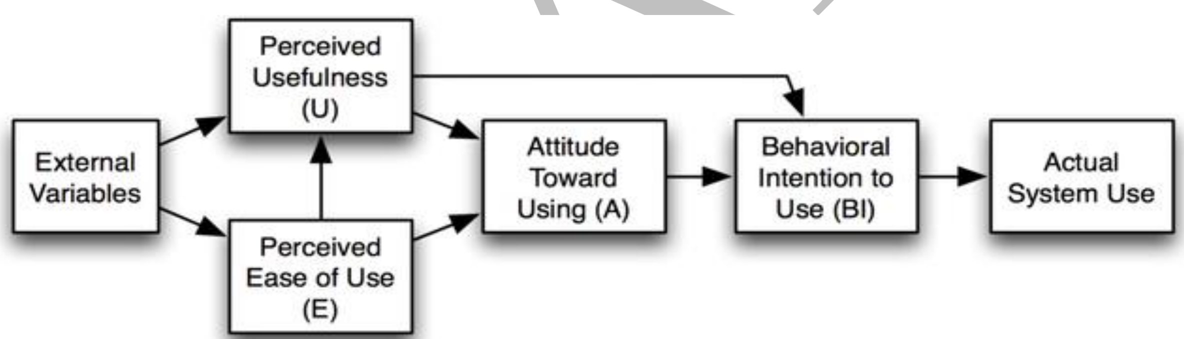

Figure 8. Technology Acceptance Model (Davis *et al.*, 1989)

Thus, we propose to evaluate JEM Inventor according to these two main criteria. In addition, as illustrated in Figure 8, the TAM indicates that the behavioral intention to use a technology also depends on the attitude towards using the technology. In our case, we consider that this attitude can be measured during the first use of the designed MLG in real context. This is a particularly important step, as it will involve teachers and their students and will determine whether the MLG authoring tool will be used in the long term. For this reason, we propose to evaluate the quality of some of the produced MLGs, in addition to usability and usefulness of the JEM Inventor authoring tool.

In the following sub-section, we specify the three assessment criteria mentioned above, according to the user-centered design approach (UCD) and to the characteristics of our case study.

5.1.2 Usability

The evaluation phase of the UCD consists in measuring the product's usability. In other words, validate user's satisfaction on performing the assessed tasks, which is perfectly in line with the first criterion we identified from the TAM model. Usability is defined by ISO 9241-11 59 as "the degree to which a product can be used, by identified users, to achieve defined goals with effectiveness, efficiency and satisfaction, in a specified context of use". Therefore, we propose to evaluate the usability of JEM Inventor according to these three sub-criteria.

Usage Logs

Being a Google App Engine application, JEM Inventor uses the Google Cloud Console platform to collect, filter and analyze user action traces, through logs, initially stored in the cloud, but they can be imported locally. This allows us to have data on connections, performed activities and navigation between the three modes. The analysis of these traces allows us to collect indicators about the efficiency (creation time) and the use of functionalities (component creation, deletion, navigation between modes, etc.). [5]

System Usability Scale

In order to obtain quantifiable results, we used the System Usability Scale (SUS) (Brooke & others, 1996). Indeed, the SUS takes into account the three criteria defined by the ISO standard (effectiveness, efficiency and satisfaction). The SUS questionnaire is based on 10 statements, for which the users have to give a 5-point Likert scale rating, from "not at all agree" to "strongly agree". The results of the SUS questionnaire are used to construct the satisfaction score between 0 and 100. Thus, a score is considered "correct" between 39 and 52, "good" between 52 and 72, "excellent" between 72 and 85. etc., as shown in Figure 9. This figure also displays interpretations of the different satisfaction scores. These interpretations represent rank types that are broader than the estimates of scores, thus making it possible to classify measures in ranges such as "marginal" for scores below 70 and "not acceptable" for scores below 50.

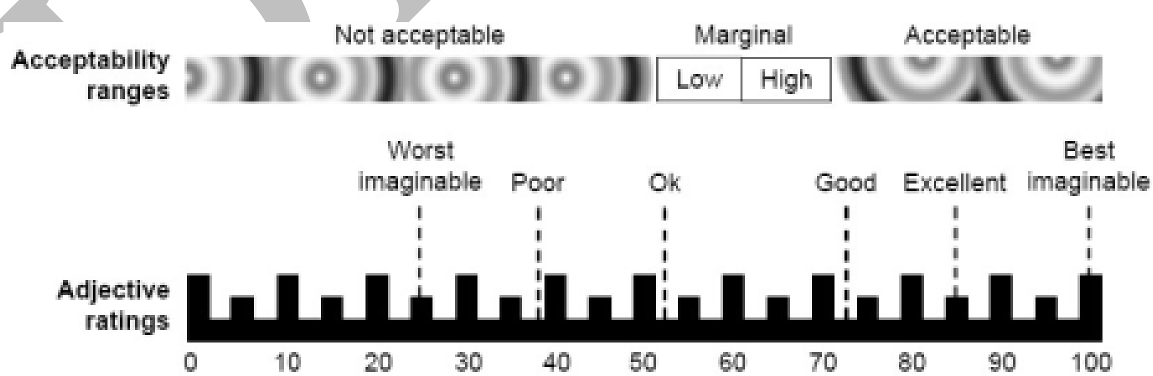

Figure 9. SUS score grid and equivalent interpretations

5 http://aous-karoui.com/phd/log_detail.png

5.1.2 Usefulness

Even though our DBR research approach, associated with UCD, insures the usefulness of JEM Inventor within the first two phases of analysis and design, we still wish to assess the usefulness of our theoretical proposals with large-scale user experimentations. In order to evaluate usefulness, we focus, during the following experiments, on two types of data: questionnaires and participants' productions.

We asked the teachers to answer with a five point Likert scale rating to several statements in the questionnaire, in order to collect their subjective perception of the system's usefulness. They were also invited to provide comments for each statement. The questionnaire used in the first experimentation included five statements, combined to the SUS questions[6]. The questionnaire used for the second experimentation contained 15 statements and was separated from the SUS questionnaire[7]. This difference between questionnaires is due to the different hypothesis evaluated in each experiment that we detail in section 5.3.

We also analyzed the teachers' productions via JEM Inventor (*i.e.* the MLG scenarios). The data from these productions provided us with information about the individual work of each participant and the implemented scenarios.

5.1.3 Mobile Learning Game Quality

Besides measuring the perceived usability and usefulness, we also wanted to verify if JEM Inventor allows teachers to create good-quality MLG that can really be used in educational context. To this end, we propose to assess a few samples of the teachers' created MLG during the experiments. We chose to use the *EGameFlow* questionnaire (Fu et al., 2009), which measures the level of pleasure experienced by the students as well as the level of knowledge they acquired. The *EGameFlow* is a specific measurement scale for educational games that was built on the basis of the *GameFlow*, a model proposed in 2005 by Sweetser and Wyeth, to evaluate games in general (Sweetser & Wyeth, 2005). The *EGameFlow* rating scale takes into account eight measures: concentration, control, clarity of objectives, challenge, feedback, immersion, social interaction and knowledge development.

5.2 Structure of the experiments

According to the assessment criteria presented above (usability, usefulness and quality of MLGs), our experiments are divided into two sessions as following.

- A **Design Session** to assess usability and usefulness. It consists in asking teachers to create their MLG with JEM Inventor and testing their productions on a mobile device. This session is mandatory for all participating teachers.
- A **Field Session** to assess the produced MLGs' quality. It allows teachers to test their MLG in real context; with students during a field trip. This is not mandatory for all participating

6 http://aous-karoui.com/phd/q_exp1
7 http://aous-karoui.com/phd/q_exp2

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teachers, as several of them did not have imminent availability to organize field trips. This session allowed us to assess the relevance of the MLGs created during the Design Session.

5.3 Experiments

5.3.1 Experimentation 1: Focus on Standard Mode

As a result of the pre-experiment and the feedback from the participants, we were able to make a number of improvements on JEM Inventor. Thus the following version, v1.1, includes technical adjustments for updating POIs on the map and linking them to MGUs.

Design Session

The objective of this experiment was to collect the subjective assessments of teachers, following the use of the Standard Mode. It allows us to validate the H1 and H3 hypotheses, presented in the third section of this paper.

- H1: A MLG model, based on a Basic Template, will allow teachers to intuitively implement existing field trip scenarios.
- H3: Operationalization functions, linking high, intermediate and low-level components, will allow the execution of MLG scenarios on mobile devices.

Participants and materials

We contacted the participants through an online questionnaire[8] [9]. The questionnaire targeted teachers organizing educational field trips and who would be interested in MLGs. A total of 14 teachers at different teaching levels (middle school, high school, university) agreed to participate in the experiment. Similarly to the pre-experiment, the Design Session consists of a half-day session to implement an educational field trip scenario on JEM Inventor without prior knowledge of this tool. We had to organize several sessions because the participants had different availabilities. Thus, the various sessions took place during the first quarter of 2017. Two participants (from the IUT of Montpellier and Michelet high school) participated remotely. All participants were equipped with an internet-connected computer, to access JEM Inventor v1.1 and an Android smartphone to test their scenarios directly.

Process

Before starting, participants filled out a pre-questionnaire for profile identification. Eight participants were considered as MLG novices and six were considered as MLG experienced designers. We recommended to all participants to watch a demonstration video of about three minutes to briefly explain the steps required to create a MLG[10], as many times as necessary. In order to validate the H1 hypothesis, we asked teachers to simply transcribe their field trip scenarios

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8 http://aous-karoui.com/phd/q_online_1
9 http://aous-karoui.com/phd/q_online_2
10 https://www.youtube.com/watch?v=7ntDVX-yr-M&t=1s

in JEM Inventor v1.1 by customizing the content and resources, and without any help. Once the scenario was created, they could test it on mobile. At the end, participants completed the usability and the usefulness questionnaires.

Results

According to the usage tracks, the design sessions lasted between 2h10 and 2h50. All participants succeeded in creating a personalized MLG.

Table 1. Average SUS scores in Experiment-1

	Average	Highest score	Lowest score
SUS score	76.07	87.5	60
Acceptability range	Acceptable	Acceptable	Marginal
Adjective ranking	Good	Excellent	Good

In terms of usability, we obtained an average of 76.07/100 with a standard deviation of 8.97 points out of 14 participants, the lowest score being 60/100 and the highest being 87.5/100. Table 1 presents the interpretations of the lowest and highest SUS scores. Based on these results, JEM Inventor v1.1 is considered "good" even in the worst case. The average obtained is ranked in the "Acceptable" range and rank type is "Excellent" according to SUS interpretations (see section 5.1.2). The complete results of the 14 participants are illustrated in Figure 10. We believe that these results validate the usability of the Standard Mode of the authoring tool JEM Inventor.

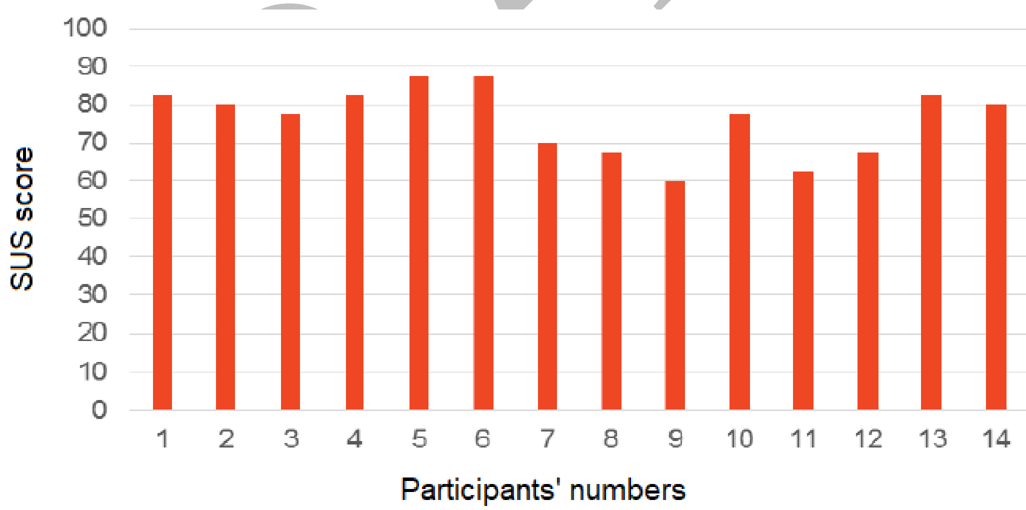

Figure 10. SUS Scores of all participants in Experiment-1

Regarding utility, as shown by Table 2, the teachers appreciated the proposed structure and functionalities. The average score for the statement "the proposed structure covers well my pedagogical scenario" is 4.07/5 with a standard deviation of 1.07 points. Similarly, the average score for the statement "I found the features I need in at least one of the proposed modes" is 4.28/5 with a standard deviation of 0.99 points. However, the highest average score is the average of the video viewing requirement to use the editor (4.57/5).

Table 2. Perceived usefulness results of JEM Inventor in Experiment-1

Affirmation	Mean score/5	SD
1- I was able to perform the desired tasks without any problems.	3.28	0.82
2- The proposed structure (Clue, Learning Content, On-site Activity) covers my pedagogical scenario well.	4.07	1.07
3- I have found the features I need in at least one of the three proposed modes.	4.28	0.99
4- The tutorial video seems necessary to me to perform my script.	4.57	0.75
5- The video was very clear to me.	3.85	1.16

Although the need to view the video tutorial was essential (average of 4.57/5), the fact that the teachers were able to complete their scenarios without any problems (average of 3.28/5) on JEM Inventor, proves the usefulness of this tool. Thus, we consider that these usability and utility results will support the assumptions outlined in the third section of this paper regarding the usefulness of the MLG model and the integrated Basic Template.

Field Session

Although this session was not mandatory due to organizational complications of organizing field trips, several teachers wished to test their MLG with their students in real contexts. However, due to the distance and lack of availability, we were not able to assess all field sessions. We present two of these MLGs below as a proof of concept.

MLG 1: Birds on campus

Learning aim and scenario

The game was designed to raise awareness about the birds on the Laval university campus (France). The game is composed of three MGUs. The first MGU is linked to the bird feeders (POI). Once players have found the feeders, the Learning Content is displayed on the mobile phone, giving access to an online video, images and information about the birds observed at this POI. At the end of the activity, players are asked to answer a MCQ about the birds they saw. The second MGU consists in finding the pond near the IT department. Once arrived, players can observe the "grey wagtail", a bird often in the vicinity of this POI, and have access to the Learning Content (i.e., the Wikipedia page of this bird). When they have finished reading the information, they have to answer a MCQ. The objective of the third MGU is to discover a nest box installed in a lime tree near the university restaurant. This time, players have access to a soundtrack that reproduces the bird song. At the end, players must identify the singing bird. Every time the players give a correct answer, they earn points. The points are assigned according to the number of attempts (50 pts for the first attempt, 30 pts for the second and 10 pts for the third). If the player still has not given the right answer after the third attempt, the following MGU is launched.

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Figure 11. Students from the agricultural high-school playing « Birds on campus »

Participants and results

The experiment took place in three sessions with biology undergraduates from the Laval IUT. The first field trip was carried out with six students who played the game individually. The second session was held six months later, with eight students who were divided into groups (two groups of three and one group of two). Finally, a third session was carried out with 12 students from the Laval agricultural high-school (figure 11).

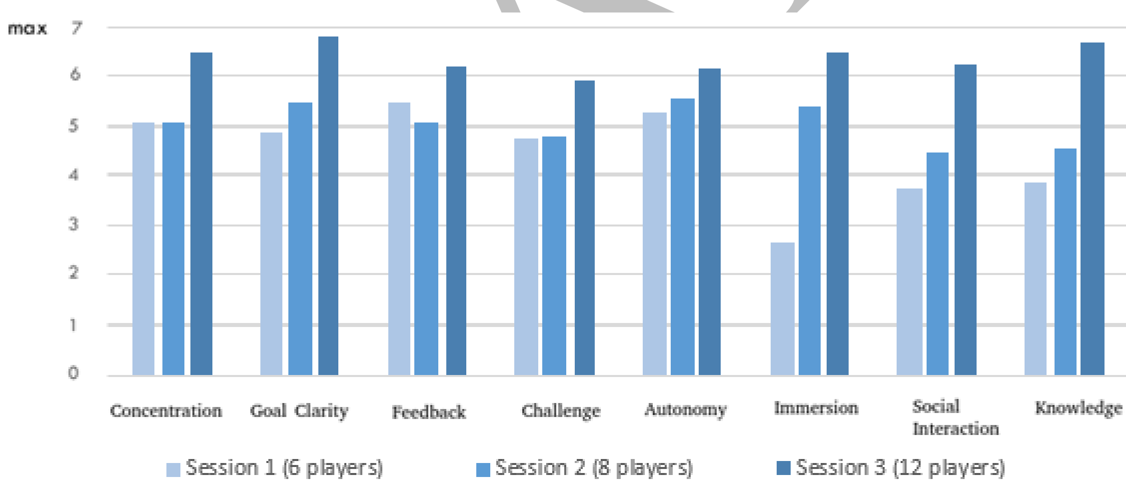

Figure 12. Results from EGameFlow questionnaire for the three sessions of « Birds of IUT »

Results of the three sessions were collected using the EGameFlow Questionnaire. According to the 7-element Likert scale, we consider the results to be positive from value 4. Thus, as shown in Figure 12, the last two sessions were significantly more successful in terms of immersion, social interaction and learning. We believe that this is due to the collaborative game mode. Indeed, in the last two sessions, players were divided into groups and results were higher for social interaction. According to Cairns *et al.* (2013), social interaction raises the level of immersion in digital games. Many other researcher show the positive effect of immersion upon learning performance, which explains the obtained results (Coulter et al., 2007; Dede, 2009; Hamari et al., 2016).

MLG 2: Biodiversity at the Park

Learning aim and scenario

The game was designed to promote physical activity while observing biodiversity in the Island of Saint-Germain (France). The game consists of nine MGUs. Each MGU proposed activities to do around POIs such as take pictures of beehives and answer questions on the mitochondria or specific plants (black poplar, herbaceous plants, etc.). When they arrive at each POI, players are given Learning Content on the subjects observed. In addition, some on-site activities are accompanied by physical challenges (*e.g.*, scoring basketball points, climbing trees, balancing on a turntable, etc.). Several teachers were present on the POIs to count the number of points acquired by the players for these challenges. Candies were also hidden in the trees and indications appear on the students' mobile screen to help them find them. At the end of the MLG, the number points acquired by each group during physical challenges were added to those won in the app.

Participants and results

The experiment was carried out with 15 students from the Oscar Michelet High-School in Paris, in June 2017. The students were divided into three groups of four and one group of three. For this MLG, we also used the EGameFlow questionnaire. The results, illustrated in Figure 13, show a very high level of satisfaction, especially in terms of challenge and social interaction.

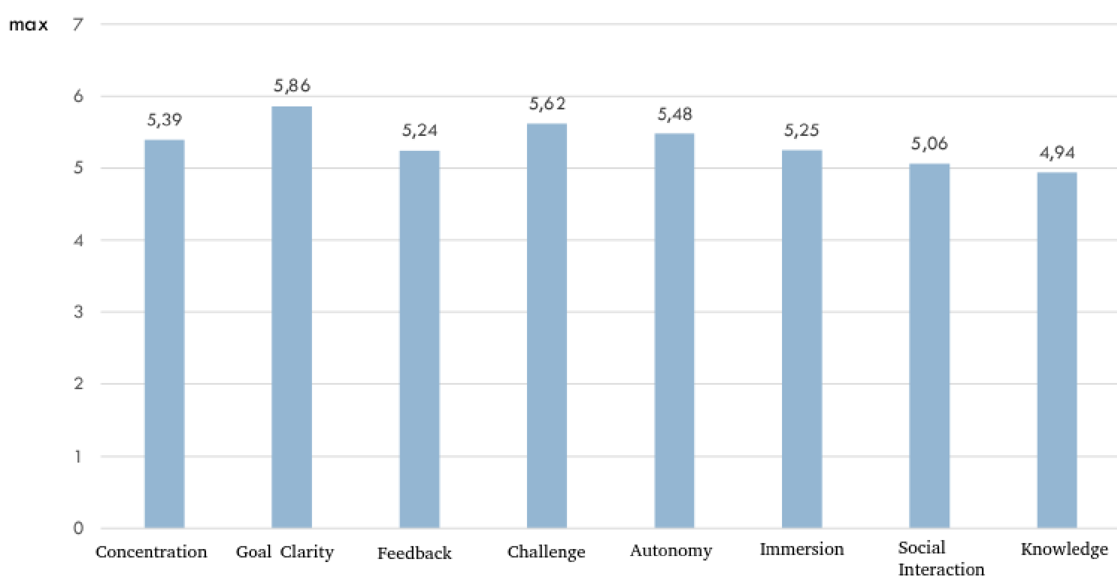

Figure 13. Results of EGameFlow questionnaire for the MLG Biodiversity at the Park

As shown in Figure 13, scores are quite close together and reflect overall satisfaction with the game (positive values if they are higher than 4/7). The experiment took place in a general atmosphere of enthusiasm and the physical challenges combined with on-site activities really fostered immersion. In terms of execution, players found navigation through the app's screens simple and fast. However, they found that the aesthetics should be improved, particularly by adding graphics. Apart from the remarks on the aesthetic qualities of the game, the students greatly appreciated the field trip and expressed their desire to do this type of MLG again on their next field trips: "it's great!", "our classmates who couldn't come will be jealous when we tell them about our trip", etc.

5.3.2 Experimentation 2: Focus on the Intermediate and Expert Modes

After the first experimentation, we noted some technical limitations of the prototype v1.1. For example, one teacher wanted a direct input field on the map to easily find the desired POI address. Another participant wished to be able to directly indicate the GPS coordinates of the POI. Other teachers regretted that the MGU's name could not be edited. Other teachers wanted to see more features in the Standard Mode such as changing the color and font size of the text. All these limitations were taken into account when developing the new version of JEM Inventor (v1.2).

Design Session

After assessing JEM Inventor v1.1 with a teacher panel largely composed of MLG novices and with a particular focus on the Standard Mode, the objective of this second experiment is to assess JEM Inventor v1.2 with teachers who are more experienced in MLGs, with a special focus on the Intermediate and Expert modes. Through this aim, we seek to validate the hypotheses H2 and H4.

- H2: A MLG model proposing a flexible structure and editable components will cover a wide variety of MLG scenarios.
- H4: A nested design method, based on the MLG model, will allow teachers to gradually implement richer scenarios.

Participants and materials

For this experimentation, we targeted teachers who had already created, or at least used learning games in their teaching. Seven teachers and instructors were selected, including four teachers who had already participated to the previous experimentation.

Process

This experimentation begins with an explanation of the three provided modes, in addition to the online video previously used. The teachers could then create their own MLG scenario with JEM Inventor, starting from the Standard Mode, which is displayed by default. Unlike the previous experimentation, the participants were willing to invest more time to create their MLG, and were therefore likely to improve their scenario by adding activities, game mechanics or adaptive scenarios. For example, two participants wanted to create a treasure hunt to discover the university library, in which players receive clues at the end of each MGU, to help them solve a final enigma, at the end of the game.

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At the end of the design session, the teachers answered two types of questionnaires: The first is the SUS usability questionnaire, as in the previous experiment, but this time used to assess the usability of the three modes of JEM Inventor. The second is a questionnaire evaluating the usefulness of each mode in terms of provided features, estimated mental workload of the performed tasks, and transitions between the three modes.

Results

Although this assessment concerns the three modes proposed in JEM Inventor v1.2, the average SUS score (75.41/100) is very close to that of the previous experiment (76.07/100). As illustrated in Table 3, the lowest usability score corresponds to the rank "Good" and the average score corresponds to the "Excellent" rank, and some participants even give the maximum score. These results show that the usability of JEM Inventor v1.2 remains good, even when using all three modes.

Table 3. Average SUS Scores in Experiment-2

	Average	Highest score	Lowest score
SUS score	75.41	100	60
Acceptability range	Acceptable	Acceptable	Marginal
Adjective ranking	Excellent	The best imaginable	Good

On the other hand, unlike the previous experiment, SUS scores are rather scattered. Indeed, the standard deviation is 13.26 for an average of 75.41/100 over seven participants. We explain these results firstly by the difference in the participant's number, which is smaller in this experiment. Secondly, we attribute this result to the heterogeneity of the profiles and skills of the participating teachers. Thus, a teacher with a digital mediator profile, with extensive expertise in visual programming and MLG design, found JEM Inventor v1.2 very easy to use and did not hesitate to give the maximum score on the SUS usability questionnaire. On the opposite, a teacher responsible for documentary research at the university Library, despite her experience in MLG design, experienced difficulties with the expert mode, which requires visual programming skills, and therefore gave the lowest SUS score (60). We attribute these scattered results to the difference in the perceived mental workload, during transitions between Intermediate and Expert mode as it is shown on the additional questionnaire (table 4), mainly measuring the ease of transitions between modes and the usefulness of the provided features of JEM Inventor v1.2.

Table 4 shows the results of the additional questionnaire. Overall, the ratings are very positive. Averages are equal higher to 4/5 for nine out of 12 questions. The lowest scores were given to questions number 8 "How do you rate the mental load/provided features ratio proposed in expert mode?" and number 10 "How do you rate the transition from intermediate to expert mode?". Similar to the usability results, these scores are explained by the heterogeneity of skills among participants. For example, the visual programming expert teacher found the transition quite smooth and therefore assigned the maximum score (5). On the opposite, the library instructor found the transition abrupt and therefore assigned to the minimum score (0).

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Table 4. Partial results on the usefulness of JEM Inventor v1.2

Category	Question	Average	SD
Effectiveness	1- Did you manage to complete your script?	4.14	0.89
	2- Did you manage to complete all the tasks even in detail?	4.42	0.78
Features	3- According to your needs, how would you evaluate the features offered in the standard mode?	4	1.41
	4- According to your needs, how would you assess the level of detail proposed in the intermediate mode?	4.14	0.69
	5- According to your needs, how would you evaluate the level of detail proposed in the expert mode?	3.57	1.13
Workload	6- How do you evaluate the workload/feature ratio proposed in the standard mode?	4	1.15
	7- How do you evaluate the workload/functionality ratio proposed in the intermediate mode?	4	1.15
	8- How do you evaluate the workload/functionality ratio proposed in the expert mode?	2	2
Transitions	9- How would you rate the transition from standard to intermediate mode?	4.57	0.53
	10- How would you rate the transition from intermediate to expert mode?	1.85	1.95
Storyboarding	11- Did the mechanism provided to modify the Basic Template seems appropriate to you?	4.4	0.54
	12- How do you evaluate the game mechanics provided by JEM Inventor?	4	1.09

Concerning the Basic Template modification, six teachers stated that they needed it and only one said that she was satisfied with the proposed template as it was. Furthermore, the average (4.4/5) obtained for question 11, related to the modifying mechanism, shows that teachers who needed to modify the template were able to do so. "*What interest me about the Intermediate Mode is the fact that I can modulate the given framework and adapt it to my students*," says one of the teachers. These results therefore validate the H2 hypothesis, according to which the MLG model, proposing a modifiable structure and configurable components, can cover a wide variety of JEM scenarios.

To check whether the nested method makes it possible to gradually design richer scenarios, we collected the perceived opinions of teachers on the provided features in each mode. The questions 3, 4 and 5, relating to the three modes' features, obtained above-average scores. This validates the fact that JEM Inventor offers, within its three modes, enough features to implement the scenarios desired by the participating teachers. In order to know if each mode provides enough features without overloading the interface and user experience, we evaluated the proposed mental workload / features ratio for each mode. The latter was assessed as suitable for the first two modes (4/5 and 4/5) and lower than the average for the Expert Mode (2/5). We therefore believe that the positive results related to the provided features in the Standard and Intermediate modes, as well as the acceptable rating for the transition between these two modes, partially validate the 4th hypothesis, according to which the Nested Design Approach makes it possible to design richer scenarios by gradually revealing more features.

Globally, all participants experienced the three proposed design modes. However, most of them spent more time in Standard Mode. Indeed, since the latter is proposed by default, participants took the time to create the MGUs, customize the Basic Template and upload their Learning Content. Some of them then asked about the more advanced functionalities. We therefore gradually introduced them to features of Intermediate and Expert mode. The two teachers who had already used visual programming quickly adopted Expert Mode and were able to add and modify existing functions, such as the scoring mechanism and customizing the MCQs. The other participants

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simply explored the Expert Mode, for about 5 to 10 minutes, without really using it's functionalities. Some of them stated that they understood the concept, but did not want to get involved right away. "*It takes more practice to use the Expert Mode, but it does not seem too complicated*", said one of the teachers. "*The Expert Mode bears its name well*", said another.

The participating teachers also highlighted some limitations and made a few proposals for technical improvements such as tracking progress and ranking players or including an emulator to see the MLG before running it on mobile. Others wished to access voice synthesis or animation features without having to resort to visual programming (Expert Mode).

Field Session

For the same reasons explained in section 5.3.1 (filed session), we present in this section, one of the seven MLGs designed in the second experimentation as a proof of concept. This MLG was created by an educational engineer and a documentary research instructor, from Le Mans University Library.

MLG: Visit Your Library

Learning aim and scenario

The purpose of the MLG is to introduce the university library and its various services to the first year University students. The game aims to introduce participants to the principles of documentary research. It is possible to play in groups (of two or three) or individually. In the game, students are given clues to find specific books or members of the library staff. Seven different scenarios, related to thematic were designed (science, sports, law, economics, human sciences, literature, multidisciplinary). Each scenario contains four variations in the sequence of missions in order to avoid simultaneous passages on the same POI. At the end of each MGU, each group receives a clue to solve an enigma that appears at the end of the game. Thus, students must complete all missions, win the largest number of points and solve the final enigma.

Figure 14. Two groups of students playing "Visit your Library", experiment 2

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Participants and results

The game was experimented with 1389 students from Le Mans University Campus. Due to the non-binding nature of the questionnaire, we made a short version of the EGameFlow, to maximize the number of responses. Among the 1389 participants, we were able to interview a sample of 468 participants via this satisfaction questionnaire.

Tableau 4. Results from "Visit your library" satisfaction questionnaire

Question	Not at all % (n)	Rather no % (n)	Rather yes % (n)	Absolutely % (n)
Did you enjoyed the activity ?	0.2% (1)	4.9% (23)	76.3% (357)	18.6% (87)
Was it motivating to visit the library by playing on a mobile phone?	0% (0)	4.1% (19)	28.9% (135)	66.8% (312)
Was the application easy to use?	0.9% (4)	3.6% (17)	36.6% (171)	58.9% (275)
Would you like to play this kind of activity again?	3.6% (17)	22.5% (105)	55.9% (261)	18% (84)

As shown in Table 5, 94.9% of participants found the MLG fun, 95.7% found this form of visit motivating and 73.9% would like to play it again. In addition, 95.5% of participants found the mobile app easy to use. Others found the game rather short (20 minutes on average for six MGU) and wanted it to last longer. Among the terms that emerged most frequently, the word "discover" appeared 45 times, the word "playful" 34 times and the terms "know" and "autonomy" 15 times among 420 spontaneous responses obtained for this question.

6- Discussion

Comparing to previous findings, this study focus on designing MLGs from the teacher's perspective. Indeed, studies generally address MLG authoring tools form a technical point of view, assessing provided features and capabilities, checking interoperability matters and such technical aspects (Godwin-Jones, 2014; Tabuenca et al., 2016). The study presented in this paper is based on a previous authoring tools feature study where the technical aspects were already taken into consideration (Karoui et al., 2016). Beyond the technical aspects, the proposed design approach addresses the problem of designing MLG through teacher's lens. So, the aforementioned results show a global satisfaction on the provided MLG model and authoring tool. Indeed, the first experiment validate the hypothesis H1 and H3 concerning the Basic Template and the MLG operationalization functions. The second experiment validate the hypothesis H2 and H4, related to the extending of the Basic Template and the usefulness of the Nested Design Approach. Positive results on both experiments validate the fifth hypothesis H5 according to which, the MLG model and the Nested Design Approach can be supported by an authoring tool.

Additionally, the MLGs produced by the JEM Inventor experimented prototypes (v1.1 and v1.2) were generally satisfactory from a motivation and a learning point of view. In particular, the teachers who created the three aforementioned MLGs wish to reuse JEM Inventor again, by further exploring the functionalities provided by Intermediate and Expert modes in order to enrich their first MLG prototypes, and take into account the comments of the players who answered the customized EGameFlow questionnaires. However, the evaluation process does not tell us about

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JEM Inventor's adoption on a long term. This is can be considered as a limitation of the TAM model, which actually predict intentions to use but does not precise how to investigate IT adoption (Benbasat & Barki, 2007). Recently, *Hui et al.* proposed two ways of assessing learning with digital platform on a long term and a framework to predict performance using learning attitudes. We suggest that such measurements could be used in the future to assess JEM Inventor's longitudinal adoption (Hui et al., 2018).

On the other hand, we have identified some limitations of the MLG model introduced in this paper. One of the observed limitations is the absence of a multiplayer mode. During the field experiments with the created MLGs, the method used to implement social interaction mechanisms, such as collaboration and competition, is a method of manually distributing players into groups, around a mobile artifact for each group. This method therefore allowed players to think collaboratively about solving problems and also to try to get better scores than the other groups. However, digital tools today make it possible to facilitate and support collaborative activities. Thus, from a technical point of view, such functionalities can be integrated into the first two modes of JEM Inventor using the communication components that have, so far, been reserved for the expert mode, such as access to SMS, or sending emails through the mobile app.

Still, from a conceptual point of view, designing collaborative scenarios is a complex task that involves multiplayer storytelling (Wendel et al., 2013). In this context, Wendel *et al.* propose an approach for scripting collaborative serious games. This includes several criteria such as the heterogeneity of the resources or virtual objects made available, in order to diversify individual tasks, the interchangeability of these resources between players to promote the social experience. Similarly, the individual collection of these heterogeneous objects leads learners to solve the collective missions of each group and thus promotes collaboration. However, this approach, tested in a 3D PC role-playing game, may not be suitable for other serious game contexts, such as MLGs, where other parameters, such as physical space, come into play.

Further work has been done to create collaborative scenarios, also known as CSCL (Computer Supported Collaborative Learning) scripts, dynamic and adaptive, allowing to set up upstream the initiation and structuring of collaborative activities, in order to support learners as far as possible in the completion of tasks (Dillenbourg et al., 2009; Jeong & Hmelo-Silver, 2016). CSCL scripts have thus evolved from simple formalisms of collaborative activities to tools for scripting collaborative scenarios. However, these tools are not adapted to mobile artifacts such as smartphones (Alharbi et al., 2014), where the process can take many forms due to the variation of devices and the physical distance between learners.

In addition, we would like to enrich JEM Inventor with a dashboard interface enabling teachers to visualize player's logs, progression and answers during the MLG sessions. This is a need that we identified during the experiments carried out with JEM Inventor. However, the indicators provided at the end of a MLG session are insufficient to perform a full analysis of the learner's performance. It is therefore necessary to set up, not only a follow-up of the player's actions, but also automatic analysis and diagnostic tools to process in collected tracks (Thomas et al., 2011). In this context, recent work has paved the way for processing the data collected, such as automating the detection of usage sequences (Vermeulen et al., 2017) or proposing contextual

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and adaptive dashboards (López Tavares et al., 2019) that integrate configurable indicators (Dabbebi et al., 2017).

7- Conclusion

In this paper we addressed the issue related to the adoption of MLGs (Mobile Learning Games) in schools, due to the high cost for their creation and the lack of design tools that are adapted to teachers' needs and skills.

Following the results of previous work (Karoui *et al.*, 2016), our objective was to provide a MLG authoring tool, both simple to learn, for MLG novice teachers, and with rich features, for teachers with more experience in MLGs. Beyond these results, we formulate the hypothesis that MLG novices have basic rapid prototyping needs, typical of a light authoring tool. However, as experience is gained, their needs evolve towards the design of more sophisticated MLGs and therefore, the need for a more feature-rich authoring tool.

This paper's first contribution is a MLG model, including a Basic Template as a way to avoid the "blank page syndrome" and provide scenarios that can answer to most common needs or serve as inspiration. Teachers can thus directly implement their classic field trip scenarios into a default educational treasure hunt template. The presented MLG model is based on an incorporation concept of low-level components such as mobile HCI objects (e.g. buttons, checkboxes, location sensor, etc.) into intermediate and high-level components, which are closer to teachers' vocabulary (e.g. activity, clue, point of interest, etc.).

This paper's second contribution is the Nested Design Approach. It consists in gradually giving access to more features, by showing more of the MLG model's components (high, intermediate or low). As a result, teachers navigate between modes to reveal features according to their needs and skills. We propose three levels of design: the "standard" level, which consists essentially in customizing the basic MLG template mentioned above, the "intermediate" level, which allows to create customized scenarios, and finally, the "expert" level, which consists in creating components from scratch with a visual programming interface, to obtain tailor-made MLGs. The proposed MLG model and Nested Design Approach are both integrated into the JEM Inventor authoring tool.

Our propositions were validated by two sets of experiments on JEM Inventor. The first was carried out with 14 teachers from different contexts (history, biology, documentary research, etc.) and education levels (middle school, high school, college). It validated the usability and the usefulness of Standard Mode proposed by JEM Inventor v1.1 as well as the assumptions related to the Basic Template and the MLG model operationalization functions. This experimentation was followed by a series of field experiments to test the created MLGs by participating teachers and their students. The results showed a general satisfaction with the these MLGs and a preference for collaborative game modes. The second experiment was conducted with seven teachers with an experienced profile in MLG design. It validated the usability and usefulness of the three modes proposed by JEM Inventor v1.2 as well as the assumptions related to the extendibility of the Basic Template, and the Nested Design Approach. In addition, the fact that one of the field experiments involved 1389 students, proves the scalability and robustness of the proposed tool.

From a broader perspective, we believe that the Nested Design Approach can be used in many other contexts. First of all, it seems fitting for creating serious games in general, which is a complex process, requiring various skills and authoring tools with various features. The Nested Design Approach makes it possible to spread these functionalities over several levels and present them to users according to their skills or needs. Globally, the foundation of the proposed approach is derived from several theories concerning TEL authoring tools design and HCI. In particular, it is inspired by research on hierarchical complexity theory and coordinating complexity issues between tools, tasks and users. Therefore, we believe that the Nested Design Approach can provide insight on these various fields and be used not only for TEL authoring tools, but also for authoring tools in any domain.

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