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JEM iNVENTOR: a Mobile Learning Game Authoring Tool based on a Nested Design Approach

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Abstract. Mobile Learning Games (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 limited. This is partly due to the fact that MLGs are often designed to match a specific learning context, and thus cannot be directly reusable for other contexts. Therefore, researchers have recently designed various types of MLG authoring tools. However, a recent study we led shows that these authoring tools are ill-adapted to the teacher's needs and competencies. The teachers find them either too poor to create MLGs that fit their teaching requirements, or too complex and overwhelming to use. In this paper, we introduce JEM iNVENTOR, an authoring tool based on a nested design approach. It offers three modes that adapt to the teacher's level of experience, and allows them to progress in time. JEM iNVENTOR's *standard mode*, designed for teachers with no experience in MLGs, was tested by 10 TEL researchers and 14 teachers. In under two hours, the teachers were able to design and deploy their custom MLGs, without any computer skills or game design experience.

Keywords: location-based serious game, authoring tool, mobile learning, education, usability

1 Introduction

1.1 Context

Today, playful learning has been enriched with the mobile dimension, taking advantage of the widely spread mobile devices among teenagers [1, 2] and the attractiveness of mobile gaming in general (e.g. *Clash of Clans*, *Pokémon Go*...). These rising phenomena are of course followed by continuously exponential statistics, statistics, directing marketing, gaming industry [3] and government investments [4]. The interest for mobile gaming in the educational sphere has been gradually rising and several researchers have added mobility to the serious game approach, which had already proven its effectiveness [5, 6]. So far, this combination has led to Mobile Learning Games (MLGs), showing also effectiveness in various domains of education. *Frequency1550* [7], for example, a MLG designed to learn about medieval Amsterdam, helped high-school students obtain higher scores on the knowledge test than regular lessons. Other

MLGs have also proven their effectiveness for improving engagement (e.g. *The MobileGame*, designed to introduce a university campus in Berlin to new comers, that students preferred to the classic visiting tour [8]) and creativity (e.g. *skattjakt*, a MLG co-designed with students to promote physical activity while learning a novel [9]).

The common advantage of these MLGs is their use of features typically available on mobile devices (e.g. geolocation, augmented reality, etc.). These mobility assets make MLGs pedagogically effective because learners are engaged in authentic, onsite learning, using role-play and solving complex real-world problems. Thereby, the challenges proposed by these MLGs are much more realistic and engaging than classroom exercises.

However, the common inconvenient of these MLGs is certainly the limitation of their reuse. Indeed, once a MLG is created for a specific learning context and location, it is difficult to reuse it in another one. Moreover, designing and developing a MLG is quite costly since it requires human and material resources and requires seamless collaboration between all involved pedagogical, game and computer experts.

1.2 Previous Work

Authoring Tool Analysis. In previous work, we shown that the use of MLGs in classrooms is currently limited because of the lack of tools to help teachers create their own MLGs [10]. In the same study, we listed the existing authoring tools which can create MLGs, and assessed them with the help of teachers, in order to determine their limitations. This analysis allowed us to distinguish two categories of authoring tools: those who are simple to use but very poor in terms of functionalities and those who are powerful but too overwhelming.

Teacher Profiling. During the same study, additional exploratory interviews we led with teachers, used to organizing educational field trips and interested in using MLGs, allowed us to divide teachers in two categories. The first one comprises teachers who do not have any game design experience but are quite interested in the topic and would like to create MLGs, if it does not take too much time. In this paper, we will refer to this category as “*beginner teachers*”. The second category comprises teachers who are motivated for using MLGs and would be willing to put in more effort and time into a tool if it allows them to create the type of MLG they want. We will refer to those teachers as “*experienced teachers*”. Therefore, in the next subsection, we present our approach for satisfying the needs of these two profiles and, more importantly, to help *beginner teachers* progressively become *experienced*. Furthermore, even if we detect two main users’ profiles, it can be seen as a continuum and intermediate profiles could exist.

1.3 Hypothesis

Multi-Modal Authoring Tool. Based on research on TEL authoring tool complexity [11–13], and in order to create a powerful yet simple authoring tool, so that it could be suited for both *beginners* and *experienced teachers in MLGs*, we took inspiration in

differentiating interfaces and hidden complexity theories [12–14]. Consequently, our authoring tool will contain multiple interfaces as well as it can match different users’ profiles. Hence, as we have at least two teacher profiles, our authoring tool will contain at least two different interfaces. Then, as the objective of these interfaces will be quite different – creating basic games very quickly vs. creating complex custom games – we consider each interface as a completely different mode. This implies a transition mode that we detail in the next subsection.

The Nested Design Approach. Based on the exploratory interviews discussed above, we believe that, once a *beginner teacher* have created a basic MLG and experimented it with students, he would try to go further on editing and improving that basic MLG. Therefore, we intend to assist *beginner teachers* so that they can progressively have access to more features as far as they gain experience from using the previous mode. To allow such personal progression, we suggest an intermediary mode with more accessible features. This mode will keep the landmarks (i.e. interface organization, functionalities, vocabulary, game structure) that teachers will have acquired by using the first mode and make the *experienced teachers’* mode not too overwhelming after the transition. The ultimate objective is to help *beginner teachers* becoming *experienced*. However, this objective will not be assessed in this paper. At this stage, our priority is to assess if the authoring tool enable *beginner teachers* to easily create MLGs prototypes.

In the next section, we introduce JEM iNVENTOR, a multimodal authoring tool intended to teachers without computer skills or game design experience.

2 JEM iNVENTOR

2.1 Underlying Model

Focus on Location-based Learning Games. As a subcategory of MLGs, Location-based Learning Games (LBLGs) can be considered as a pertinent example of successful MLGs. In a previous study that we did about common features of what we consider prevalent MLGs [15], four of the five most cited MLGs were based on the geolocation asset. Even in the field of Lucrative Mobile Games, GeoGames, as early called by Schlieder [16] are very promising from now on. Yet, *Pokémon-Go*¹ affirmed so far this prediction.

For our purpose, we believe that providing assistance to *beginner teachers* to design MLGs, has to go through providing a formalized MLG structure to them. Indeed, designing learning games requires experience in game-design. Therefore, providing *beginners* with a common structure acting as a template would be quite helpful. Still, as this is a quite complex task, we decided to focus on LBLGs for the time being.

Formalizing Location-based Learning Game Structure. Following to our previous work about most cited MLGs common features, we have found that the four analyzed

¹ <http://pokemongo.nianticlabs.com>

LBLG had a common recurrent structure for each quest/activity, going from a clue – indicating the point of interest POI to look for – to a learning content that would be shown on the POI itself, to finally an evaluation task that can be given in several ways (simply answering questions, exchanging pedagogic information within team members, ...). This structure is recurrent in most of the LLBG that we came across even out of the study. In a second time, the structure was validated by our interviewed teachers who actually affirmed that it could perfectly fit their needs.

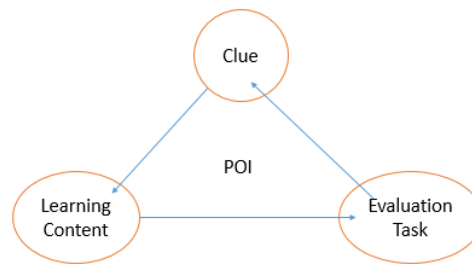


Fig. 1. Simplified Schema of the proposed Location-based Learning Game structure

As shown in figure1, this structure enable teachers to directly transcribe their learning content and evaluation tasks on POIs. However, it does not take into account any game mechanic, and that is done on purpose as we want *beginner teachers* to focus only on their pedagogic content at this level.

The Three Proposed Modes. As discussed in the introduction, we introduce our three modes as following:

- A “*standard mode*” providing a couple of object types that can be slightly ad-justed (e.g. gps coordinates of points of interest (POI), learning and questions content). This view will allow *beginner teachers* to rapidly design a basic playful scenario with preconfigured game mechanics (e.g. a linear game unit order, a standard way of counting scores).
- An “*intermediate mode*” allowing designers to go further in details, in order to better adjust their scenarios. This time, the teachers can configure the score mechanisms, the radius of POI, game unit triggers and dependencies.
- An “*expert mode*” allowing the most expert designers to go even further in de-tails. We aim to provide custom component creation at this level and programming features to create the logic between them.

The aim of creating three modes is to enable a transition between the elementary structure that we propose in “*standard mode*” and the entire personalization of a scenario that we would provide in “*expert mode*”. Even though, we decided to begin with three levels, this number is not definitive and surely can be adjusted according to intended users, especially if we generalize the use of this approach outside the MLG design field.

High-level Linking to Low-level Components Model. From a conceptual perspective, and as suggested by Murray in [14], the authoring task requires the ability to conceptualize and structure concepts from a high level so that it could make sense to user who is novice with the authoring tool’s design process. In a previous work [16], we have already presented a high-level modeling language for MLGs. The established model enabled us to cover botanist teacher scenarios in ReVerIES² French project. The difference here is that JEM iNVENTOR’s model goes beyond the high-level modeling until the elementary mobile items provided by mobile operating systems (e.g. Android, iOS etc.) in a kind of arborescence. Thereby, JEM iNVENTOR is based on mapping high-level conceptual notions (e.g. POIs, Activities, Clues, Tasks ...) to low-level mobile components (e.g. buttons, text items, media players ...).

Figure 2 shows a part of the class diagram including the main high-level components provided by JEM iNVENTOR. The arborescence starting from the LBLG entity, and going through Activity which is then divided into the formalized structure presented in the previous subsection.

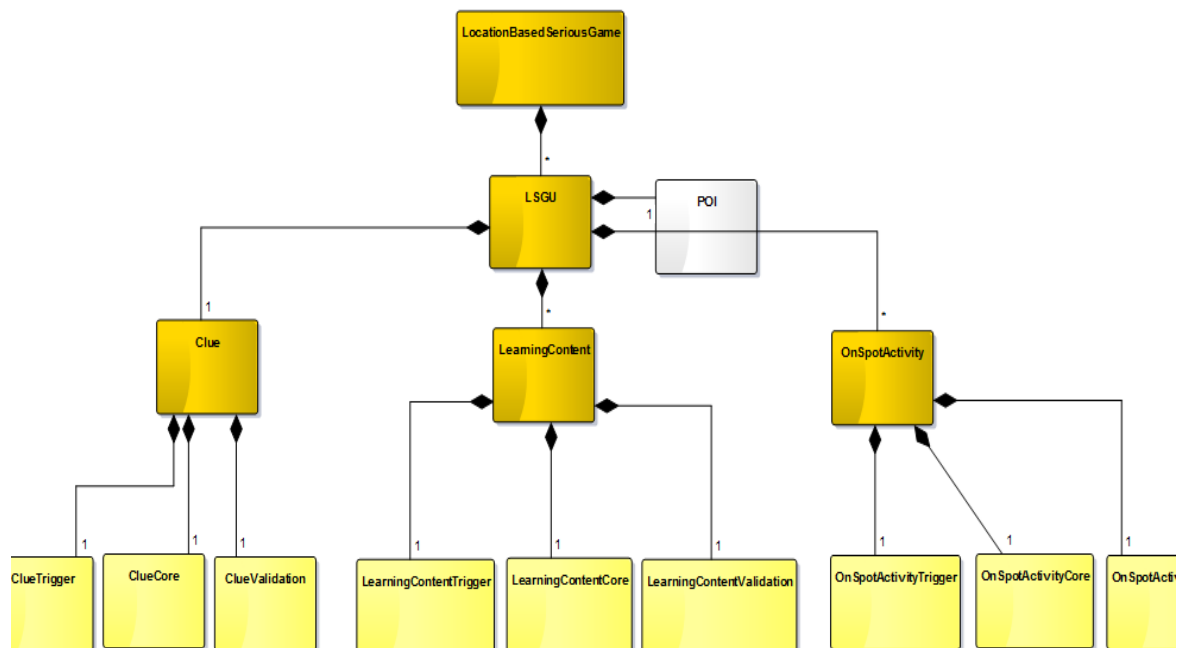


Fig. 2. Class Diagram

Figure 3 details even more the composition of the high-level components provided with JEM iNVENTOR with the example of a multiple choice question, a pattern of evaluation task. In this example, components in green are Android classes for elementary mobile items. These classes represent the lowest-level items of our model and can vary depending on the mobile OS (Android, iOS, windows phone...).

² <http://reveries-project.fr/>

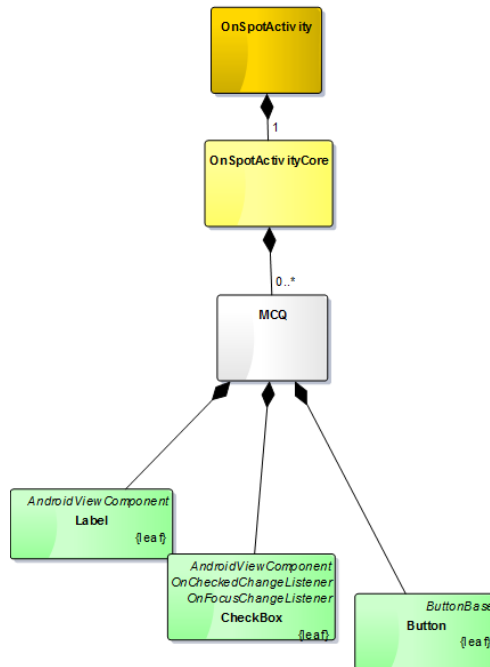


Fig. 3. A Multiple Choice Question component on Android OS

2.2 The Technical Choice

Following to our previous work on MLGs authoring tools, and given the interesting research work done so far, even not corresponding to our authoring vision, we decided to reuse an existing open-source authoring tool and setup thereby our scientific solutions. This way could actually make us gain time and focus on reification of previously discussed models.

MIT App Inventor 2³. From a set of six deeply analyzed authoring tools, our choice was set on MIT App Inventor 2. Indeed, in a study performed in 2014 [17], Rouillard and his colleagues from Université de Lyon observed that App Inventor 2 enabled 116 students to develop 79 MLG prototypes in an average of 10 hours, of which 14 prototypes were considered prevalent to learn relevant information. In our MLGs authoring tools study [10], App Inventor 2 has been ranked as the most powerful authoring tool. Furthermore, as we intend to design to allow configuring the elementary mobile items in *expert mode*, blocs programming could be very advantageous to this purpose. Indeed,

³ <http://appinventor.mit.edu/explore/>

blocs programming is henceforth taught in most of French middle-schools⁴ and so, students would be able to further co-design MLGs made by their teachers on JEM iNVENTOR. Moreover, as App Inventor 2 is a widely used authoring tool around the world, we intend to keep the structure of projects made by JEM iNVENTOR in the current App Inventor format (.aia) so that interoperability between both editors could be possible. However, the main limitation with reusing MIT App Inventor 2 is the fact that the created MLGs will be executable only on Android device. As this iteration of JEM iNVENTOR is considered as a first research prototype, we accept this limitation in order to benefit from the other advantages discussed above.

2.3 From Idea to Reality

JEM iNVENTOR was designed in a User Centered Design Approach [18]. Indeed, this method keeps the target user in the core of the design process and may imply several iterations, however guarantees producing acceptable software. Therefore, we went through mock-ups co-design with the interviewed five teachers.

Mock-ups Co-design. As discussed above, the five firstly interviewed teachers participated to the design process through a co-design collaborative sessions. Furthermore, we asked them whether the proposed formalized structure can fit their pedagogic content, whether they approve the idea of the three proposed modes and the nested design process. Finally, they helped us to adjust graphical mock-ups in order to enhance interfaces from the usability perspective. Still, we will assess usability by of *standard mode* in the next section of this paper.

Figure 4 is an example of the co-designed mock-ups with the five teachers.

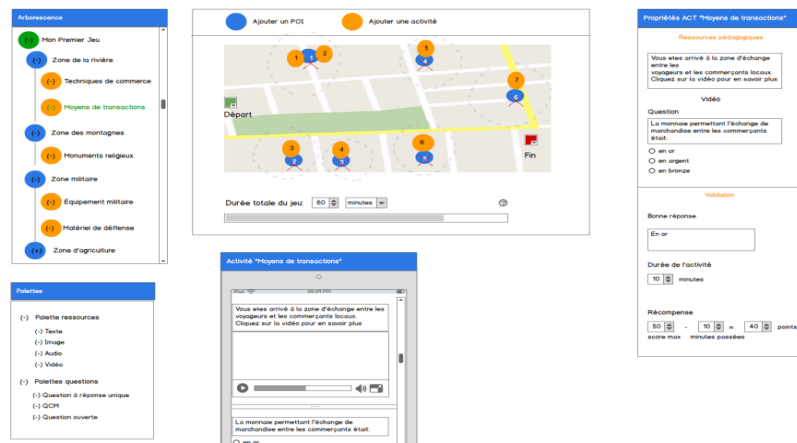


Fig. 4. A sample of co-designed mock-ups with interviewed teachers

Current Prototype. JEM iNVENTOR includes the acronym JEM which means Mobile Learning Game in French. We kept the word “inventor” to refer to MIT App Inventor 2, the authoring tool that we chose to over build our system. Furthermore, if we are currently working on LBLG, we chose JEM or MLG appellation because we plan to extend JEM iNVENTOR’s assistance to every kind of MLG creating, as discussed in this paper’s introduction.

JEM iNVENTOR⁵ is currently deployed on Google Appengine service and source code is available on Github⁶.

Figure 5 shows a screenshot of current JEM iNVENTOR’s prototype from the standard mode.

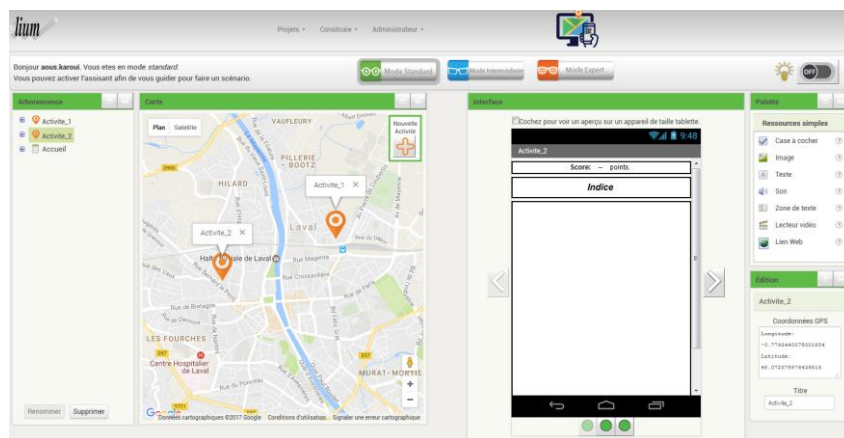


Fig. 5. Current JEM iNVENTOR Standard Mode

3 Assessment

3.1 Method

Protocol. As part of the User Centered Design [18] method, we relied on ISO 9241-11 guidance⁷ to measure JEM iNVENTOR usability, which includes measuring effectiveness (task completion by users), efficiency (task completion in time) and user satisfaction.

Firstly, to measure effectiveness, we asked participants whether they could perform the intended tasks without problems, whether the proposed structure (clue, learning content, evaluation) covered their teaching needs and whether they found the functionalities they needed in *standard mode*.

⁵ <http://lium-jem-inventor.appspot.com/>

⁶ <https://github.com/jem-inventor/>

⁷ https://en.wikipedia.org/wiki/ISO_9241

Secondly, to measure efficiency, we filmed the design process and recorded the time of all the important actions in log files (creating a new project, creating a new activity, switching between modes, compiling the APK).

Finally, to measure satisfaction, we used the System Usability Scale⁸ (SUS) in order to get quantitative results about usability. In addition, we added a feedback case to each SUS question in order to obtain more details about each aspect evaluated by the SUS (e.g. mental effort, dialogue clearness, perception facility ...). The figure below explain how the quantitative results can be deducted from the obtained SUS score for each user.

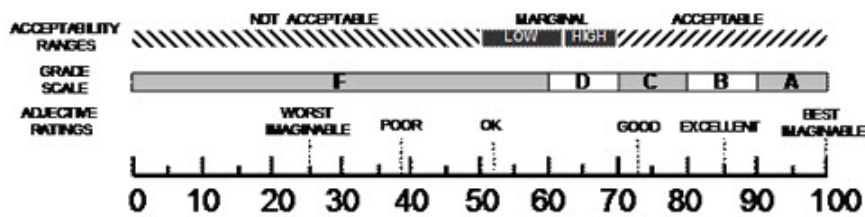


Fig. 6. System Usability Scale (SUS) rating

Process. In each of the following studies, participants were asked to connect to internet, watch the tutorial video⁹ and perform a situated learning scenario on JEM iNVENTOR a priori on *standard mode*. Of course, participants can use *intermediate* and *expert* modes if they feel comfortable with them. Nevertheless, our aim remains to check whether the *standard mode* would make *beginner teachers* embrace it or not. This is due to the fact that the major part of our target audience are rather *beginner teachers*.

Participants are equipped with an Android smartphone to test their created apps. However, they are not mandatory asked to go outside and perform the learning scenario. During the design process, we did not intervene unless to fix technical problems such as a page not properly loading.

3.2 Pilot Study

As soon as we rounded off the first prototype of JEM iNVENTOR, a pilot study was performed with 10 researchers working on Technology Enhanced Learning (five associate professors, a doctor and four PhD students). The aim of this study was to evaluate the system's usability with 10 first time users and get their feedback as TEL specialists. Of course, the participants here are not performing educational fieldtrips so we gave them a scenario established by botanists from ReVeRIES project about discovering plants in Laval (France). The scenario consist in creating three learning activities on three POIs and was feasible in *standard mode*. To anticipate technical problems, participants were encouraged to change learning content, resources and POI locations in the given scenario.

⁸ https://en.wikipedia.org/wiki/System_usability_scale

⁹ <https://www.youtube.com/watch?v=7ntDVX-yr-M>

Results. Though the participants were computer scientists working on TEL, the majority of them were not working on Serious/Learning Games and so were not *experienced* in location-based game-design.

Globally, effectiveness was attained as everyone was able to realize the given scenario via JEM iNVENTOR *standard mode*. Efficiency was also quite good since participants took from one to two hours to implement the given scenario and execute it on their mobile device. The difference in time was due to searching for online resources to personalize the given scenario rather than for difficulties. The SUS score was acceptable as it varied from 47.5 to 85, with an average of 70/100.

Technically, this preliminary study provided us feedback to improve the interface. For example, the buttons visible on the game screen preview (intended for players) were confused with the buttons allowing navigation between screens on the web interface. We also got recommendation to adjust some palette boxes in order to make them more coherent with the other elements (e.g. combining the arborescence box with the map to show the link between map and activities).

Globally, this preliminary study enabled us to anticipate several technical bugs and to improve the prototype for the study involving teachers.

3.3 User Study

The second version of the prototype was experimented with 14 teachers who organize educational fieldtrips at least once a year. Participants¹⁰ were from different teaching level (middle-school, high-school and college). For logistic reasons, three teachers participated remotely using Google Hangout. According to information provided by the teachers, we consider that five of them are *experienced in MLG* design and the others are *beginners*.

As explained above, the teachers who did not know how to go about creating a MLG simply transcribed their usual outing via JEM iNVENTOR *standard mode*. Thereby, we explained to them the proposed structure (clue, learning content, evaluation) that needs to be used in the *standard mode*.



¹⁰ http://perso.univ-lemans.fr/~akaroui/user_study_1.htm

Fig. 7. On the left, a middle-school teacher, setting up a scenario in biology. On the right, literature research teacher setting up a MLG to discover the library

Results. Results on effectiveness were positive since the 14 participants were globally able to implement their scenarios. Some needs have been reported and will be taken into account for the next iteration of JEM iNVENTOR. We detail these aspects in the Lessons Learned section.

Results on efficiency were quite lower than with the LIUM researchers but remains positive since they took between one hour and half and two hours to transcribe their scenarios varying from three to five activities.

Probably due to technical enhancements, the SUS Score was quite higher than in the previous study. Indeed, results varied between 60 and 87.5 with an average of 74.64/100, which means that JEM iNVENTOR's usability is between good and excellent, according to the SUS rating system.

Below three snapshots of a history MLG made by one of the teachers.

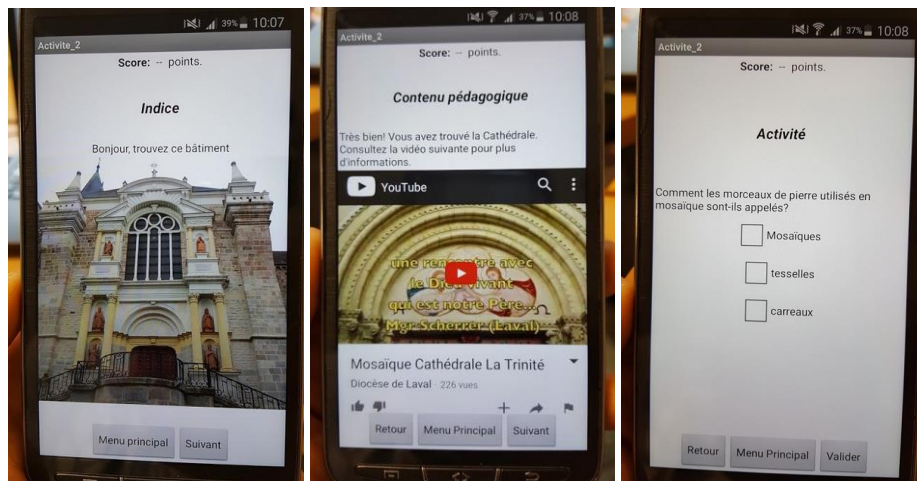


Fig. 8. A sample of MLG made by a history teacher

4 Lessons Learned

During the pilot study, some of the participants felt curious about the other modes so they took a look at the *intermediate* and *expert* modes without doing too much changes, since their scenario did not require having too much configuring. The majority of participants from the user study reported that they did not feel concerned by the other modes. Most participants did not even click on the switch buttons to discover the other modes. On the other hand, *experienced teachers* from the second study reported that there were some lacking functionalities in *standard mode* (e.g. changing the activities' order, making players upload media content, validating arrival by QR code scan instead of GPS auto recognizing). As JEM iNVENTOR uncover MIT Appinventor 2 features

progressively through *intermediate* and *expert* modes, their needs could be thus accomplished. However, *experienced teachers* have not succeeded handle *intermediate* or *expert* mode. Perhaps, because too many options were dropped in one time on the *intermediate* mode and certainly because the *expert mode* requires programming skills to be handled. It is worth reminding that *experienced teachers* were actually experienced in game-design but not in computer science. This fact makes us think again about the teacher profiling. Therefore, we could create sub categories for *experienced* ones to distinguish game designers from computer skillful and a third subcategory for persons having both competences. Even though, it was not the aim of the study, this first results would make us enhance transition between modes for the next iterations.

On the other side, the encouraging signs of this studies are that all the participants were first time users. Particularly, even the *beginner teachers* who scored lower than others in SUS reported that it was probably due to the first time use and that they expect that their experience would be much faster on next use. Globally, all participants were volunteers and expressed their delight to experiment JEM iNVENTOR without considering the outcomes. Indeed, there is a growing need for teacher today to get assistance on TEL and mobile gaming.

At the end, the both studies helped us to measure the system usability and the usefulness of the formalized structure for LBLG. According to the results, these two criteria seems to be satisfying. However, our next challenge will be to ease the transition between the *standard* and the *intermediate* mode. This would be possible by making game mechanics such as collaboration easily implementable in *intermediate mode* rather than with blocs programming (*expert mode*). Our advantage is that MIT App Inventor 2 offers a large number of features: Bluetooth connectivity, proximity sensors and message exchanges to favor collaboration. Another example is the data visualization question and tracking player progression during the game. Fortunately, App Inventor storage components will help us to make it possible too. Thus, we will be working on facilitating the implementation of these features in the *intermediate mode*. In future work we will evaluate how facilitating the transition between JEM iNVENTOR modes, can make *beginner teachers* join –according to subcategorization- *experienced teacher* categories.

5 Conclusion and Perspectives

In this paper we presented JEM iNVENTOR, a MLG authoring tool based on a nested design approach among several modes corresponding to different end-users profiles. For this first evaluation, we focused on Location-based Learning Games LBLGs as a subcategory of MLGs. Thus, we firstly exposed a formalization of LBLGs structure, in order to provide design assistance to teacher without game design experience. Secondly, we introduced JEM iNVENTOR's underlying model, mapping high-level components to low-level mobile items. Through a User Centered Design approach, we assessed JEM iNVENTOR's *standard mode* with 10 TEL researchers in a pilot study, then with 14 teachers used to organizing educational field trips in a user study. Usability

results for the *standard mode* were encouraging since the average of the System Usability Score (SUS) of the user study was “acceptable”. This can be a first step to make a large number of teachers - without game design experience or computer skills – get involved into MLGs design. Yet, according to self-reported feedback, *standard mode*’s features were quite limited for teachers that we consider as *experimented* in MLG design. Paradoxically, those teachers were not able to get through the proposed *intermediate* and *expert* modes. Therefore, in future work, we will focus on adapting JEM iNVENTOR’s advanced modes to end-users through a more precise profiling. This would enable teachers with different competencies to meet their different requirements in the different proposed modes. Also, our nested design approach will make *beginner* teachers progress until becoming MLGs expert designers.

More generally, as we took inspiration from TEL research work on authoring tool complexity [11–14], we believe that the nested design approach that we exposed could be useful not only for MLGs design, but also for other TEL systems in general.

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