Assessing an Authoring Tool for Meta-Design of Serious Games

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Abstract: In order to help teachers to adopt serious games, we explore the problem of applying the meta-design principles to this context. The goal of meta-design is to enable end-users to act as designers as well as at design stage than at use time. We focused our work on helping teachers adapt educational aspects of serious game scenarios to their pedagogical needs. Our research leads us to design an authoring tool named APPLiq based on a generic model for serious games scenarios named MoPPLiq. In this paper, we first describe the three main aspects of the model MoPPLiq. First, we introduce the concept of meta design. Second, we introduce MoPPLiq and how it models scenarios by sequences of discrete black boxes named "activities". Then, we describe the "output states" that allow model the critical choices of the serious-players that can modify the course of the scenario. At last, we describe "input states" that aim to model the dynamic adaptation to serious-players, i.e. when an activity changes its behavior depending on the serious-player's model. After detailing MoPPLiq, we introduce APPLiq and its main features. APPliq is meant to design and adapt educational and recreational serious game scenarios. Therefore, we describe the main features of APPLiq: On one hand it depicts with a graphical representation the scenarios modeled with MoPPLiq. On the other hand, it provides a graphical user interface to change connection between output and input states of activities. APPLiq also provides a checking system that is able to check a serious game scenario for inconsistencies in the pedagogical scenario or in the game design. This system is also able to compensate automatically the non-pedagogical inconsistencies thanks to "buffer activities". Finally, we describe the protocol and the results of a qualitative assessment that we conducted with about 20 teachers for several weeks on APPLiq and MoPPLiq. The discussion of the results shows that the graphical representation of MoPPLiq helps teachers to understand the ins and outs of the serious game they had to use during the experimentation. On the other hand, despite some ergonomics problems on the prototype of APPLiq tested, the results show that the authoring tool allowed teachers to create and to modify serious game scenarios that they declare relevant for their use.

Keywords: serious games, meta-design, authoring tools, scenario, game-design

1. Introduction

The educational prospects of serious games (SGs) for learning are interesting, yet their adoption remains scarce (Azadegan et al., 2012).

MoPPLiq and *APPLiq* are two contributions to the problem of meta-design for SGs. A fundamental objective of meta-design is to create a socio-technical environment allowing users to assume the role of co-designers by adapting systems (Fischer et al., 2004). To facilitate adoption of SGs, the meta-design approach aims to foster instrumental genesis by teachers (Rabardel, 2003).

MoPPLiq is a model describing educational (i.e. pedagogical) and recreational aspects of scenarios of the SGs that break down into distinct levels. This model aims to facilitate instrumentation of SGs by teachers. In a model-driven engineering approach, APPLiq implements MoPPLiq. APPLiq is an authoring tool meant to adapt SGs in order to help teachers instrumentalize SGs without damaging their recreational consistency (Marne & Labat, 2014b).

We conducted a qualitative experiment for several weeks with teachers in order to inform the design of these two tools. We had two objectives. On the one hand, we tested if APPLiq and MoPPLiq enabled teachers to adapt the educational scenario of an SG, and if they were considering the adapted scenarios ready to be used with students. On the other hand, we tested if MoPPLiq and APPLiq helped the teachers to master the SG itself.

In the first section of this paper we introduce the meta-design for SGs. Then, in the second section we briefly introduce MoPPLiq and APPLiq. Then, in the third section we present the SG used for our qualitative experimentation. In the fourth section we define the indicators that we monitored to assess MoPPLiq and APPLiq. In the fifth section, we detail the protocol and the recruitment of teachers for the experimentation. Finally, in the last part, we present and discuss the results before concluding.

2. Serious games, authoring and meta-design

SG design involves several classes of experts. On the one hand there is knowledge engineers, teachers, educators, domain experts and so on (that we broadly group as pedagogical experts), and on the other hand there is game and level-designers, game producers, sound and graphic designers and so on (broadly grouped as game experts). Various authors point out that multi-expertise design is one of the main challenges of SG design (Marfisi-Schottman, 2012; Mariais et al., 2012; Marne et al., 2012; Kelle et al., 2011; Marne, 2014). This can be addressed with several approaches detailed in previous research work. There are merely two different classes of approaches: participatory design and meta-design.

Participatory Design (PD) approaches intend to place the end-users as full participants of the design (Muller, 2003). For SGs, there are two classes of users. On the one hand the real end-users are the "serious-players". On the other hand, the teachers (or trainers and tutors), who are the prescribers, are not really the end-users, but still are users of SGs, because they use them for teaching. We choose to focus our research on teachers-users, mainly because we wish to help them introduce more SGs in their courses. Accordingly, PD approaches tackle the issue of multi-expert design by helping several classes of designers (i.e. pedagogical and game experts) to work with users.

However, PD only addresses the design stage. (Rabardel, 2003) showed that the appropriation of artifacts so called "instrumental genesis" is also involving the end-users as designers far beyond the initial design stage: "instrumentalization" when end-users are adapting the artifact to their needs, and "instrumentation" when end-users are learning the workings ("schemes") of the artifact. Meta-design is another approach than PD, which reconciles the latter with instrumental genesis and with the use stage. Indeed, Meta-design covers all the methods that allow end-users (so called "owners of the problems") to act as designers both at the design stage and throughout the use stage (Fischer et al., 2004). This approach leads our research in order to help the teachers to introduce more SGs in their teaching. Meta-design implies the development of frameworks and models to be used as boundary objects, and authoring tools to operationalize them in order to allow end-users to act as authors. MoPPLiq and APPLiq are examples of a model and an authoring tool meant to enable teachers to act as designers during the use stage by instrumenting and instrumentalizing SGs.

In the following section, we introduce a model and an authoring tool meant to help teachers to meta-design SGs and that we tested with some of them.

3. The MoPPLiq model and the authoring tool APPLiq

The MoPPLiq model is meant to describe educational and recreational aspects of discrete scenarios of SGs (Marne & Labat, 2014a). This model is based on three main features derived from other research on interactive tutoring systems, video-games and SGs. The three features are:

- Scenarios are broken down into components named "activities" (e.g. levels, exercises, case studies). Activities are black boxes that are only defined with goals for the serious-players (Dalziel, 2008; Koper & Olivier, 2004).
- For each activity, the serious-players' possible choices that have an impact on the whole scenario are described with output states. Those output states allow building branched scenarios (Marfisi-Schottman, 2012).
- If an activity has several behaviors depending on the serious-players' profile or previous actions, these behaviors are described with input states. Thus, input states allow the description of the dynamic adaptation of activities to serious-players (Brusilovsky, 1996).

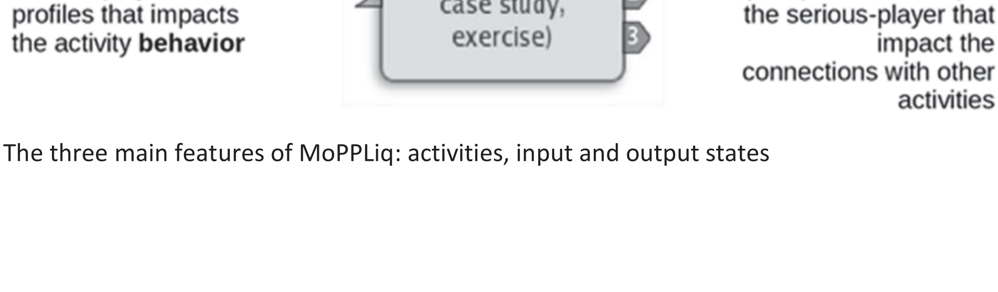

Figure 1: The three main features of MoPPLiq: activities, input and output states

Input and output states are characterized by educational and recreational goals for the serious-players. Input states are indexed with "prerequisited" goals, output states are indexed by "worked on" goals. Each output state can be connected once to input states in order to build a scenario. Figure 2 depicts the graphical representation of the MoPPLiq model of the SG "Les Cristaux d'Éhère" (described in the next section).

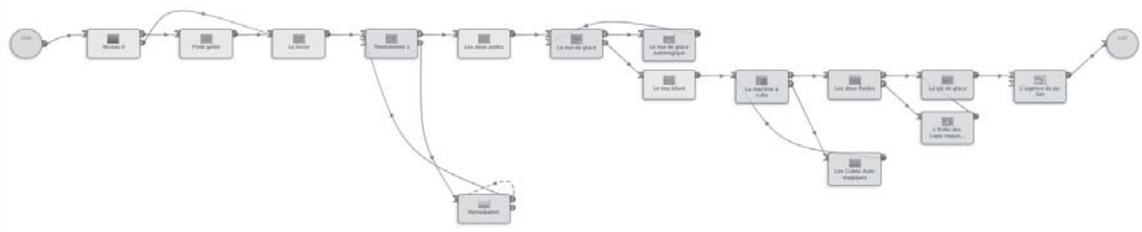

Figure 2: Shape of the scenario of "Les Cristaux d'Éhère" modelled with MoPPLiq

MoPPLiq is also a formal model expressed in XML, which allows us to embed it into an authoring tool meant to enable teachers to adapt SG scenarios. The Authoring tool, named APPLiq, provides a graphical user interface (GUI) to (1) display scenarios of SGs (e.g. Figure 2 is a part of APPLiq GUI), (2) enable users to create and modify connections between input and output states, (3) automatically verify the consistency of the scenarios, (4) provide a semi-automatic consistency correction for storyline issues. The consistency is checked with a set-theoretic operation that verifies that the set of "prerequisited" goals is necessarily included in the intersection of the sets of possible "worked on" goals. If a teacher builds or adapts a scenario and an inconsistency is detected on educational goals, APPLiq raises an alert, and lets the user decide whether or not to correct it (a scenario that seems inconsistent inside the SG may be consistent when orchestrated by its author with its students). However, if the inconsistency is on recreational goals, APPLiq will provide a set of "buffer activities" meant to add the missing goals to the scenario.

4. An SG prototype for testing: Les Cristaux d'Éhère

In order to make a qualitative testing of MoPPLiq and APPLiq we designed a prototype of SG named "Les Cristaux d'Éhère". This SG is a static puzzle game (Karhulahti, 2013) meant to teach matter phases and their change to French middle school pupils[1]. Figure 3 shows a screenshot of the SG. In the game, the serious-players play an avatar and have to solve matter phase based puzzles in order to exit a dungeon broken down into several rooms (i.e. levels of the SG). Each room (level) has its own pedagogical and recreational goals.

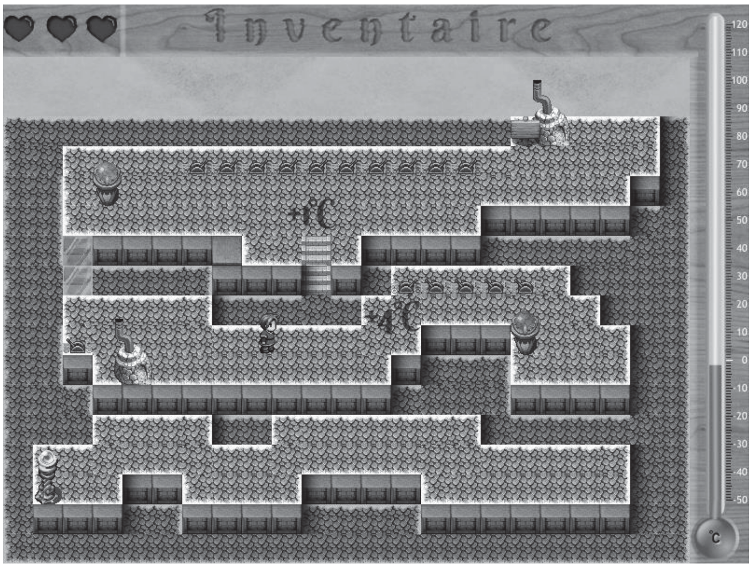

Figure 3: screenshot of a level of the SG prototype "Les Cristaux d'Éhère"

5. Assumptions tested and indicators used to experiment on them

To test and to improve MoPPLiq and APPLiq we made an experiment involving real users: teachers. We had two main assumptions to test with this qualitative experiment:

[1] The prototype is available online: http://seriousgames.lip6.fr/Cristaux_Ehere/

- Assumption #1: the graphical representation of the MoPPLiq model provided by APPLiq helps teachers to understand the ins and outs of the SG scenario
- Assumption #2: APPLiq enables teachers to design and modify SG scenarios in order to obtain new scenarios that they consider suitable for their classroom.

In order to test each assumption, we defined several indicators described in the following sub-sections.

5.1 Indicators for the assumption #1

We compared the teachers' understanding of an SG scenario in two different situations: before having seen the MoPPLiq model and after. For this purpose, we decided in a first step to let the teachers play Les Cristaux d'Éhère and then describe some specific aspects of the scenario after they had finished the game. The questions aimed to test if they have played all the levels and if they had a wide understanding of the scenario. In a second step, we gave the graphical representation of the scenarios to the same teachers, and then we asked similar questions. We also asked them to discuss how the graphical representation helped them understand some aspects of the SG.

5.2 Indicators for the assumption #2

Our first indicator to test the second assumption is to assess the consistency of the scenarios designed and modified with APPLiq by the teachers. Our second indicator is to ask the teachers to assess their own scenarios and to tell us if they are willing to use them with their students. For this purpose, we gave them the opportunity to create new scenarios with a specific pedagogical purpose and to adapt a suboptimal scenario to some pedagogical constraints. In the next section we detail how we managed that with the experimental protocol.

6. Protocol, recruitment and conduct of the experiment

The major issue for this experiment was to recruit some teachers that had a wide knowledge of the targeted curriculum and had enough time to discover the SG, test APPLiq in various situations and report the results to us. This led us to choose to design a remote experiment (online) broken down into six steps detailed below.

6.1 Experiment protocol

The protocol is broken down into 6 steps.

Step #1. Introduction: On the one hand, the experiment is presented to the participants. On the other hand, the participants have to fill out a questionnaire about themselves.
Step #2. Quick start and assessment of the SG: The participants have to play Les Cristaux d'Éhère and consider how they might use it with their students. Afterwards, we submitted a survey about their assessment and understanding of the SG (assumption #1).
Step #3. Discovering the graphical representation of the scenario: The participants are allowed to study the MoPPLiq graphical model of the SG. They are asked to search for the activities that are meant to teach some specific competencies. Afterwards, they have to fill up another questionnaire meant to test their understanding of the scenario and to survey their thoughts about the graphical representation of MoPPLiq (assumption #1).
Step 4 and 5. Creating a new scenario and adapting another one: The participants are allowed full access to APPLiq and its documentation. At the step #4 they are asked to create a new scenario meant to teach a specific content. At the step #5 they are asked to modify a suboptimal scenario to meet some specific pedagogical needs. Eventually, at the end of each step, they are surveyed on whether or not their scenarios are suitable for their students. (assumption #2)
Step #6. Ending: A last survey is made to collect information on the second assumption.

All the experiment was done remotely through the internet. Accordingly, we developed a website to provide a dashboard to the participants in order to read the instructions, gather information, fill up and submit the forms, play the SG and use APPLiq. At the end of each step, the form submission unlocks the next step.

We are aware that having a remote experiment is a bias: the participants had to fill up static questionnaires, which is far from an interview that allows to ask some adapted questions, especially to avoid some evasive or incomplete answers. Besides that, several of our indicators rely on their claims. Even if we tried to ask proper questions to minimise wrong declarations, we think that we have to be careful with the results. Nevertheless, in order to experiment MoPPLiq and APPLiq on numerous real users, we had no other choice but to conduct our experiment remotely.

6.2 Recruitment

To recruit suitable participants for our experiment we used the mailing lists of the teachers of physics and chemistry from middle school (target of the SG). Therefore, all participants were voluntary and unpaid. This may also be a bias because the teachers willing to test an SG are not representative.

6.3 Conduct of the experiment

36 teachers contacted us to participate, and only 31 really started the experiment. Yet, only 27 submitted the first questionnaire at the end of the step #1.

During the experiment, all remaining participants were followed on a daily basis. This means that sometimes they were helped when they needed, they were reminded to go further when they were idle for a long time. Given that processing the 6 steps in a row took us about 4 hours, but that all participants had a very busy life, we gave them four weeks to finish all the steps. Unfortunately, despite the inducements and comforting messages there have been several dropouts. Table 1 shows the evolution of participant number during the experiment.

Table 1: Number of participants stuck at each step

Steps	Step #1	Step #2	Step #3	Step #4	Step #5	Step #6
Remaining participants for each step	4	7	2	6 (3 did not create any scenario)	3 (2 did not adapt any scenario)	9

Despite an encouraging number of participants, we were able to test our first assumption with only 18 teachers, and our second assumption with only 9 teachers.

7. Results and discussion

The results we present in this section are a sub-part of the whole results of the experiment conducted and are discussed from the point of a qualitative analysis meant to help us improve the design of both MoPPLiq and APPLiq.

7.1 Results for assumption #1

The results showed in Table 2 are made from two sets of questions asked to the participant at the end of the step #2 (playing the SG) and the step #3 (exploring the MoPPLiq model).

Table 2: Comparison of the understanding of the scenario after steps #1 and #2

7B7Baliases	**8B8B**Step #2 : Reminding the scenario after playing it (on 2)	**9B9B**Step # 3 : Reminding the scenario after studying the model (on 2)	**10B10B**Differences between steps #3 and #2	**11B11B**Claims that the model helped to understand (on 4)
B	1	0	-1	2
E	1	2	1	4
G	1	1	0	3
J	1	1	0	3
K	1	2	1	4
L	2	2	0	4
M	1	2	1	4
N	1	1	0	1
O	2	1	-1	4
P	0	1	1	1
Q	1	2	1	4
R	1	1	0	4
S	0	1	1	3

7B7Baliases	**8B8B**Step #2 : Reminding the scenario after playing it (on 2)	**9B9B**Step # 3 : Reminding the scenario after studying the model (on 2)	**10B10B**Differences between steps #3 and #2	**11B11B**Claims that the model helped to understand (on 4)
T	1	2	1	4
V	1	2	1	3
X	2	2	0	3
Y	2	2	0	3
Z	1	1	0	2

Our analysis shows that the participants better remembered the scenario after studying the MoPPLiq model (step #3) than after playing it thoroughly (step #2). Only 4 out of the 18 participants of both step #2 and #3 claimed that they had a good understanding of the SG at the end of the second step. Whereas 9 out of the 18 claimed at then end of the step #3 to have a good understanding of the scenario. Moreover, the table shows that 8 out of the 18 had a better understanding of the SG after the third step than after the second one. Accordingly, 14 of them claim that studying the MoPPLiq model helped them to remember and understand the scenario. It also means that it is not the case for four of them.

The participants were allowed to justify their choices with responses (Figure 4). In a nutshell they said that the graphical representation and the input and output states of MoPPLiq helped them understand the scenario of Les Cristaux d'Éhère.

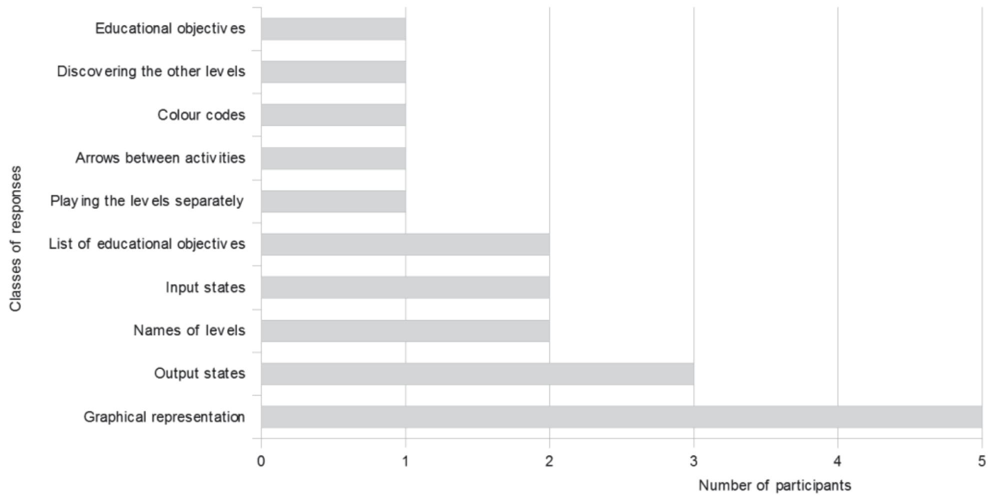

Figure 4: Responses of participants regarding their understanding of the SG scenario viewed in APPLiq. Responses are grouped into classes

Regarding the first assumption, the teachers' testimonials show that graphical representations of input, output states and their links especially helped them understand the scenario. Their detailed responses also lead us to conclude that they had a better understanding of the scenario after viewing it rather than after playing it. These results may seem obvious, nevertheless they increase our belief that our first assumption is true, i.e. the graphical representation of MoPPLiq provided by APPLiq helps the teachers grasp the scenario of an SG.

7.2 Results for assumption #2

In order to test the second assumption we assessed the scenarios designed by the teachers by seeking the presence of 7 features: (1) the scenario must embed activities dealing with solid water (ice) , (2) there isn't any inconsistency in the storyline, (3) there is no significant educational inconsistency, (4) the scenario has branches, (5) the scenario has buffer activities, (6) the scenario has more than 3 activities (buffer activities excepted), (7) the scenarios has at least one activity (buffer activities excepted). We decided to quantify the features by summing their presence (last column of Table 3)

Table 3: Assessment of newly designed scenarios

Aliases	1	2	3	4	5	6	7	Sum (on 7)
B		yes	yes		Yes			3
E	yes	yes	yes		Yes	yes	yes	6
K	yes	yes	yes		Yes		yes	5
M	yes	yes	yes		Yes			4
O	yes	yes	yes	Yes	yes	yes	yes	7
Q	yes	yes	yes	Yes	yes	yes	yes	7
V	yes	yes		Yes	yes		yes	5
X		yes	yes		yes			3
Y	yes	yes		Yes	yes		yes	5

Teachers also had to modify an already existing suboptimal scenario. We assessed these modified scenarios by seeking the presence of 7 features: (1) the sequence of activities has been changed, (2) there isn't any inconsistency in the storyline, (3) there isn't anymore educational inconsistency, (4) every activity of the scenario is connected. Features are summed in the last column in Table 4.

Table 4: Assessment of modified suboptimal scenarios

Aliases	1	2	3	4	Sum (on 4)
E	Yes	Yes		yes	3
K	yes	Yes		yes	3
M	yes	Yes			2
O	yes	Yes			2
Q	yes	Yes	yes	yes	4
R	yes	Yes	yes		3
Y	yes	Yes		yes	3

Analyzing both tables, on the one hand the newly designed scenarios (

Table **3**), and on the other hand the modified scenarios (Table 4), shows that they both have not any inconsistencies in the storyline. This seems to enforce our confidence in the automatic inconsistency compensation system provided by APPLiq. Moreover, we regard the scenarios with high scores as suitable for being used with students. Therefore, 7 out of the 9 newly designed scenarios are suitable for being used with students. 5 out of the 7 modified scenarios are also suitable for being used. These elements increase our belief that the second assumption is true.

The analysis also shows that the number of participants that choose to design branched scenarios is small (4 participants out of the 9), and that they all tended to build very short scenarios (between one to three activities).

The questions asked at the end of the steps #4, #5 and # 6 provide more insights (Table **5**). The questions refer to whether or not the participants were satisfied with their scenarios (end of steps #4 and #5), and if they think that they are ready to be used with students. Table **5** also includes the sums presented in the last columns of Table 3 and Table 4

The analysis of the result shows that 6 out of the 9 participants are quite satisfied with their newly created scenarios (step #4). Paradoxically, the 3 participants (M, O and Q) that claim to be the most unsatisfied of their newly created scenario, are the one that have made the best scenarios (

Table **3**), and they claim that their scenarios are usable with students. The responses (Figure 5) they gave do not help us to solve the paradox. The analysis of the results also shows that the 6 participants also regard their scenarios as usable with students. This is very close to our own measurement (Table 3)

We have made similar findings with the modified suboptimal scenarios (step #5). Most of the participants (4 out of 7) are satisfied. Here again, the unsatisfied participants (E, Q and Y) are the one with the best scenarios (Table 4), and they also consider them as usable with students. Therefore, the participants that design good scenarios struggle to convince themselves of the quality of their work (even if they also consider the work usable with students). The results equally show that for newly designed scenarios and for suboptimal scenarios.

Table 5: Claims of the participants about usability of their own scenarios

Aliases	Step #4 : newly designed scenarios			Step #5 modified scenarios		
	Previous sum (on 7)	Claims		Previous sum (on 4)	Claims	
		Satisfied with the scenario (on 4)	Usable? (on 6)		Satisfied with the scenario (on 4)	Usable? (on 6)
B	3	4	1	0	4	1
E	6	4	1	3	1	6
K	5	3	6	3	4	2
M	4	2	4	2	3	3
O	7	2	5	2	3	2
Q	7	2	5	4	2	5
R	0	4	1	3	4	1
V	5	3	1			
X	3	3	6	0	4	6
Y	5	3	4	3	2	4

Furthermore, the participants seem harsher with their modified scenario than with their newly created one. Indeed, only 4 out of the 9 participants claim their modified scenario as usable with students. This is also harsher than our assessment (Table 4).

Figure 5 is based on the responses provided by the participants.

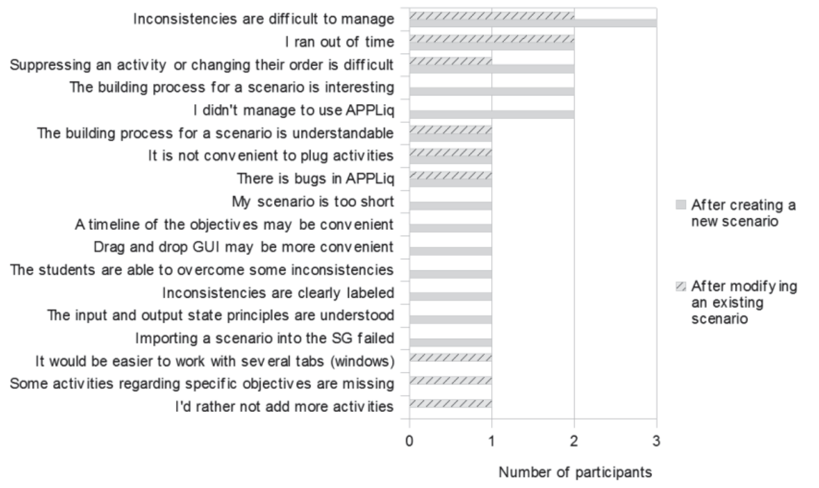

Figure 5: Responses made by the participants about the scenarios they provided. Responses are grouped into classes

The two most popular responses are about the difficulty managing inconsistencies (mainly educational ones). Moreover, the participants frequently claimed to lack of time in order to provide decent scenarios. These responses are also clustered by themes in Table 6.

Table 6: Themes of the responses made by participants regarding their scenarios

Themes	Classes of responses
Usability of APPLiq	Inconsistencies are difficult to manage Suppressing an activity or changing their order is difficult It is not convenient to plug activities I didn't manage to use APPLiq It would be easier to work with several tabs (windows) Inconsistencies are clearly labeled Drag and drop GUI may be more convenient
MoPPLiq model and methodology	The building process for a scenario is understandable The input and output state principles are understood

Themes	Classes of responses
	The students are able to overcome some inconsistencies
APPLiq features	The building process for a scenario is interesting A timeline of the objectives may be convenient There is bugs in APPLiq
Les Cristaux d'Éhère (SG)	Some activities regarding specific objectives are missing Importing a scenario into the SG failed
Scenarios produced	I'd rather not add more activities My scenario is too short
External elements	I ran out of time

The analysis of the responses themes shows that most comments (7 occurrences, including only one positive) are related to ergonomics. As the version of APPLiq tested was a prototype this seems very appropriate. Many responses are related to the model and the scenario design methodology (3 occurrences, including only one negative) and to the features of APPLiq (3 occurrences, including only one positive). In these responses the participants give us some ideas to improve APPLiq's features and GUI. The participants insisted on the fact that the GUI should allow more direct manipulations, and on the fact they need more assistance in the process of solving educational inconsistencies.

We can draw several conclusions from the analysis of the tracks collected to test the second assumption. On the one hand, the assumption is supported by the analysis of the scenarios provided by the participants because they are rather usable with students. On the other hand, the assumption is also supported by the analysis of the responses of the participants that are considering the scenarios usable.

8. Conclusion

Despite the small number of participants and that several indicators rely on their claims, the results of our experimentation give some insight on the design of APPLiq and MoPPLiq.

The analysis of the tracks of the participants shows that a graphical representation such as MoPPLiq helps them understand the scenario of an SG (assumption #1) and supports the instrumentation process (Rabardel, 2003). The analysis of the scenarios made by the participants shows that APPLiq enables them to design scenarios that are usable with students (assumption #2) and thereby that instrumentalization (Rabardel, 2003) of SGs is possible. These results regarding our assumptions #1 and #2 are interesting because they allow us to conclude that APPLiq is involved in SG appropriation by teachers. Indeed, on the one hand, APPLiq helps them understand and master the SG. On the other hand, it enables them to adapt the SG to their educational needs. MoPPLiq and APPLiq are contributions to meta-design that enhance appropriation of SGs by teachers, and may also support their adoption.

The results also draw new avenues of research for APPLiq. Thus, we are working on new support systems to help teachers to manage educational inconsistencies. We are also working on tools to help them assess the quality and the relevance of the scenarios they are working on. We are introducing new features related to the GUI that provide some more direct manipulation. And finally, we are working on the features that some participants suggested such as a timeline of the scenario objectives.

In a broader sense, the work presented in this paper shows that on the one hand it is possible to provide meta-design tools to help teachers to master and adapt SG scenarios to their needs. On the other hand, it shows a reproducible example of a remote experiment to inform the design of such tools.

Acknowledgements

We wish to thank the 36 teachers who volunteered for this experiment for the time they have spent testing our contributions. This project is partially supported by grants from Région Île de France, and a from BPI France (Programme d'Investissements d'Avenir) that the authors also wish to thank.

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