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To cite this version:

Muriel Ney, Celso Goncalves, Nicolas Balacheff. Design Heuristics for Authentic Simulation-based Learning Games. IEEE Transactions on Learning Technologies, 2014, 7 (2), http://dx.doi.org/10.1109/TLT.2014.2316161. 10.1109/tlt.2014.2316161 . hal-00999005

HAL Id: hal-00999005

https://hal.science/hal-00999005

Submitted on 14 Jan 2019

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Design heuristics for authentic simulation-based learning games

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Abstract—Simulation games are games for learning based on a reference in the real world. We propose a model for authenticity in this context as a result of a compromise among learning, playing and realism. In the health game used to apply this model, students interact with characters in the game through phone messages, mail messages, SMS and video. Perceived authenticity is measured after the game in 196 phone interviews that yield quantitative and qualitative results. We show evidence of relationships between attributes of the game environment and perceived authenticity. This yields a list of parameters that can be adjusted to favour authenticity. We also study three situations of interaction and show when and why they are perceived as authentic, or not. These results lead to recommendations for the design of simulation games that can be perceived as authentic.

Index Terms— Authenticity, Serious Games, credibility, immersion, simulation, role-play, higher education, communication.

1 Introduction

Rigby et al. [1] remind us in a book on video games that authenticity implies a sense of trustworthiness and honesty. Authentic people and places are those that can be trusted, that do not feel made-up. Authenticity is a complex notion with no single use across disciplines. Here we shall define it with a specific goal, that is, to design authentic simulation games. A simulation game immerses learners in a situation for which there is a reference in the real or professional world, but the reference is present only for the purpose of learning. This reference ensures the realism of the activities and arouses motivation. Petraglia [2] argued that authenticity is not an intrinsic property possessed by an object but a judgment, a decision made on the part of the learner from the standpoint of his/her past experiences and sociocultural context. The issue of authenticity was first discussed in the field of educational science about a century ago [2], including in the work of John

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Dewey, who studied the relationship between learning and experience. The search for authenticity goes with the idea that learners should be trained to participate in the world that surrounds them [3] and that learning should be based on the cultural and social context and past experiences [2]. Several authors proposed principles for authentic learning with the goal of attaining the same level of authenticity in contextualised (or situated) learning experiences compared to experiences in the real world (e.g. [2], [3], [4], [5]). Herrington ([5], [6]) proposed a framework with nine conditions for authentic learning. Their principles concern the whole instructional design, while we focus here on a specific environment, the simulation game, and on the learners' perspective.

Today, authenticity and contextualisation are widely advocated in constructivist learning environments [2]. Constructivism is one condition of the theory of authenticity of Newmann et al. [4]. Note that an authentic construction of knowledge is similarly advocated in approaches such as problem-based, project-based, inquiry-based, role-playing/simulation based, etc., approaches. The other two conditions in this theory [4] are disciplined inquiry (i.e. a prior knowledge-base, in-depth understanding and an elaborated form of communication) and real-world relevance (producing or presenting something that is meaningful outside of school). Science education is one field where authenticity is often discussed (e.g. [7], [8], [9]). The objective is to engage learners in an investigation that is, by nature, that of the scientists. In science education, authenticity is associated with the complex nature of scientific problems that should be preserved in learning situations [7]. Even if simulation games have a closer connection to reality than any of the other types of games, most authors (e.g. [3], [5]) agree that authenticity does not

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mean a perfect reproduction of reality. Smith [10] argued in a review of research on simulations in the classroom that the physical fidelity of the simulation environment is less important than the extent to which the simulation promotes 'realistic problem-solving processes' (p. 409), which is referred to as the 'cognitive realism' of the task. High-fidelity simulators do not necessarily lead to better performance in learning (e.g. in [11]). When students spend too much time becoming familiar with too many details, they may fail to meet the main learning goals. A means to create cognitive realism in games is immersion, which makes learners feel that situations offered by the games are real and meaningfull.

Authenticity, though a necessary concern for all games [12] as advocated in very recent literature ([13], [14]), is especially important in fields that are difficult to teach because students do not relate the learning goals to their personal experience or learning project. This is, for instance, the case with abstract learning contents (e.g. statistics for medical students). The issue addressed by this article is twofold; one is to create conditions for authenticity when designing a simulation game, and the other is to measure perceived authenticity when the game is running. In the following section, we propose a model of authenticity in simulation games and then the research questions it allows us to address experimentally.

2 Authenticity Model and Research Questions

We now come to a model of authenticity that will be used both to design authentic games and to analyse learners' perceived authenticity. Busselle et al. [15] offered a theoretical framework to explain circumstances under which perceptions of 'unrealness' affect engagement in narratives (television or online contents) and subse-

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quent perceived realism judgments. They discussed three types of unrealness: fictionality, external realism (a match for external reality) and narrative realism (coherence within a story, consistency). We retain and rename the last two notions and add *learning relevance* (first introduced in [12], but with different names). The latter includes the concept of perceived usefulness identified by Potter [16], which corresponds here to the value of the game for learning. Our claim is that these three dimensions are means to pursue a goal (that may never be fully attained): absolute authenticity.

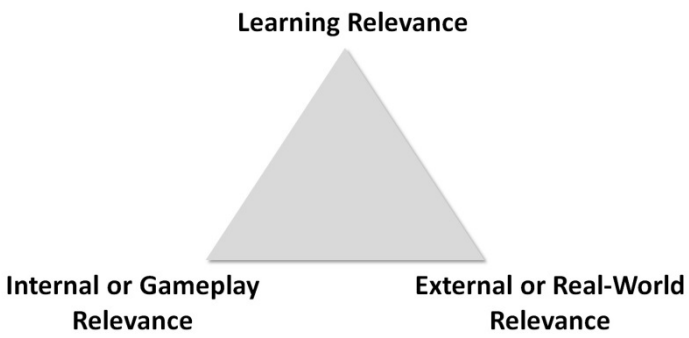

Fig.1 Dimensions of authenticity

Two dimensions refer to the well-known tension between play and learning in learning games. A third dimension is added in the case of simulation games, that of reality. These three dimensions can be matched to the three worlds Casper Harteveld [17] suggested to consider for the design of games. We further define them from the standpoint of authentic simulation games. First, the external reference is implemented in the game based on a model of reality [17]. Focusing on authentic simulation games, the external reference ensures that learners have a feeling of authenticity in the senses that they have the feeling to be prepared to react adequately in real professional situations. In the context of video games [18]

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this relates to 'perceived realism'. Here we use Newmann et al.'s [4] phrase *real-world relevance* to stress that, for students' work to be authentic, it cannot be produced and valued only for school. Second, the game must remain consistent over time and coherent in its gameplay (rules, tasks and feedback). In particular, it should offer a logical sequence of events. Incoherence in the game may cause disengagement [1]. This is also related to studies on immersion in virtual reality that suggest that one is more susceptible to persuasion or abstract lessons when engaged in a coherent narrative [19]. According to Brown et al. [20], the main indicator of immersion is the player's degree of involvement, which translates into engagement at the deepest level. Similarly, we assume that engagement is an indicator of the *gameplay relevance* dimension and therefore of authenticity. Third, *learning relevance* in Fig. 1 is related to appropriation [21] or 'ownership', cited by Petraglia [2] as one of the conditions of authenticity in learning. It is the fact that learners make the proposed problem their own, with the feeling that it is relevant, or meaningfull [17], for their personal learning projects. Then they will look for their own solutions rather than finding strategies to fulfil the teacher's expectations [22]. Since the problem has been conceived such that the target knowledge is the tool that is most adapted for the resolution of the problem [22], learning can take place. Otherwise, the learner may just focus anecdotally on a particular solution to a particular problem for the purpose of the current play, with little ability to transfer the knowledge to other similar problems and to learn. In games, the problems are not always explicitly stated to learners, they are expected to emerge from the interactions. The difficulty is designing a game that creates for learners the best conditions to lead them to identifying and tackling these problems.

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Our final goal is to provide recommendations to design authentic simulation game environments. For this reason, our first research question is: (1) What are the attributes of the game environment that can be parameterised during the design phase to favour perceived authenticity? An authentic game is a game perceived as authentic by learners. Thus, this paper addresses the following questions: (2) What cues (within the game environment) enable students to make judgments of authenticity in a particular game? (3) What situations of interactions are perceived as authentic or not, and why? We conducted a quantitative and qualitative exploration of these questions using the game Laboratorium of Epidemiology©.

3 Game Description

The Laboratorium of Epidemiology© (LOE) immerses learners in a full-scale simulation combined with a game scenario [12], [23]. It has been collaboratively designed and used by researchers, teaching staff (hereafter called tutors) and students as both an educational project and a research project, since 2008. The educational project is to renew a mandatory medical school course in biostatistics, which students are reluctant to take because of its theoretical character. The research project, to which we gave the name 'Laboratorium', is to design and assess a game in the field. The design principles of this design-based research [24] include repeated data collection campaigns that are not unique events in students' or tutors' lives but, rather, an attempt to reduce data collection biases and produce well-documented databases.

LOE is designed to immerse players in a world with its own rules and goals, especially through role-playing in which both students and tutors are involved. There

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are a number of categories of immersion in the literature on games (e.g. [20], [25], [26]). LOE was designed based primarily on fictional immersion [26], which is further defined as diegetic (immersion in a fictional world with a sense of space and time), narrative (encouragement to become acquainted with the developments of the narrative and to follow it to the end) and self-identification (players' roles and relationships with game characters). Students play the role of public health physicians and are placed in an otherwise inaccessible professional situation (because they are at the beginning of their studies) involving the occurrence of a disease in several hospitals. They have to solve a problem that includes interacting with different people and organisations following the compulsory procedure of the French medical system. The sense of time is created by deadlines and the time it takes to people in different organisations to achieve their tasks. The sense of space comes from both the phycisal deployment of the situation (e.g. students having to phone a committee), and the organisation of the interface (e.g. a succession of doors to be opened before getting to meet a patient).

The main goal of LOE is to show to students the value of statistics for physicians, their outcomes and limits, and in particular to prepare them to read critically medical reports based on statistics. In teams of three to four students playing the role of a team of physicians, they must freely organise themselves to design and carry out an epidemiological study and write a scientific article to be presented at a (simulated) congress. Each tutor follows a class of seven or eight teams playing the role of a methodologist who helps each team to realize its objectives. Tutors play also the role of characters of the game (see below), this participation remains unknown from the students to preserve the realism of the situation. At the end of

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the game, the most successful teams are rewarded: they earn the right to present their results in a long communication (ten minutes instead of five for the others) at the congress. About one-third of the articles are selected for a long presentation. It is a long-lasting game that lasts five months, including eight four-hour sessions in class (Table 1) and six two-hour lectures before and during the game.

TABLE.1 Main tasks and IT environment in the eight sessions

	Main tasks	IT environment
1	Bibliographical research; choose the main objective and make a plan	Virtual websites of various organizations providing texts and videos
2	Design an epidemiological survey and send the protocol for validation by the ethical committee	E-mail application, Ethical Research Committee (ERC) website
3	Carry out the survey at one or several hospitals	Virtual hospitals (videos), mobile phone
4,5	Analyse data	Statistical software, spreadsheet application
5,6	Write an article and submit it	Text editor, congress website
7	Prepare an oral presentation	Slide editor, congress website
8	Attend a (simulated) congress	Slideshow, congress amphitheatre

The challenge in the design of the LOE game was the gamification of an epidemiology study in the context of a biostatics course for medical students. Note that all of the nine elements of authentic learning as defined by Herrington et al.'s ([5], [6]) framework are realised in LOE: an authentic context, authentic tasks, access to expert performances, multiple perspectives, collaboration, reflexion, articulation of different domains, coaching and scaffolding and authentic assessment. More specifically, one challenge in LOE was to design authentic interactions with organisa-

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tions according to the three dimensions of Fig. 1 [23]. This system of interactions (Table 2) was inspired by recent work on embedded phenomena [9] and participatory simulations [27]. It is a persistent and distributed simulation, sharing characteristics of pervasive games [28].

TABLE.2 Interactions between students and various organisations

	Action	Feedback	Learning goals
1	Students ask the hospitals for authorisation to interview patients, leaving a short phone message on an answering machine (phone, oral)	The heads of departments validate the students' request (phone, SMS)	To appropriate the goal of my study To be convincing and quick on the phone
2	Students send their protocol to the Research Ethics Committee, REC (e-mail)	The experts of the REC validate the protocol (e-mail)	To address other professionals by e-mail To anticipate data collection and data analysis
3	Students interview patients in some of the medical departments (choose a hospital, then a department, then a patient, then a question)	The patient answers the question (video)	To experience that there are persons behind data, to target relevant information, to control data quality
4	Students request supplementary data from the medical information department (Web form to fill in)	The medical information department sends data with a delay that depends on the sample size (e-mail)	To answer relevant questions concerning epidemiological studies To experience that there is a cost in the data request
5	Students submit their scientific article to the medical congress (website)	The scientific committee sends the referees' comments and the final decision (website)	To learn medical journal-style writing (form and content)

3.1 Interaction with the Hospital by Phone

Students will use their own phones to perform interaction 1 in Table 2. The ubiquity of mobile phones (and email) applications is providing more and more mobile game experiences, but most of all, it blurs the line between the game space and real-world experience [29]. To facilitate the tutors' immersion, we designed a Web

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interface for listening and answering to students' messages so that tutors do not answer in their names but in the names of their role. Tutors may select a Short Message Service (SMS) answer among a list of possible answers, which reminds them of the validation criteria. We use IP convergence to integrate VOIP technology into the Web application: Phone2Web via IMAP to check phone messages and Web2SMS to send SMS.

3.2 Interaction with Patients via Video

LOE includes video clips of actresses and actors portraying 45 patients (interaction 3 in Table 2). A benefit of creating virtual interviews was the ability to script the responses according to real patient data and learning goals. We used real data. The system allows the students to interact with the patient by selecting one of five pre-defined questions (Fig. 2).

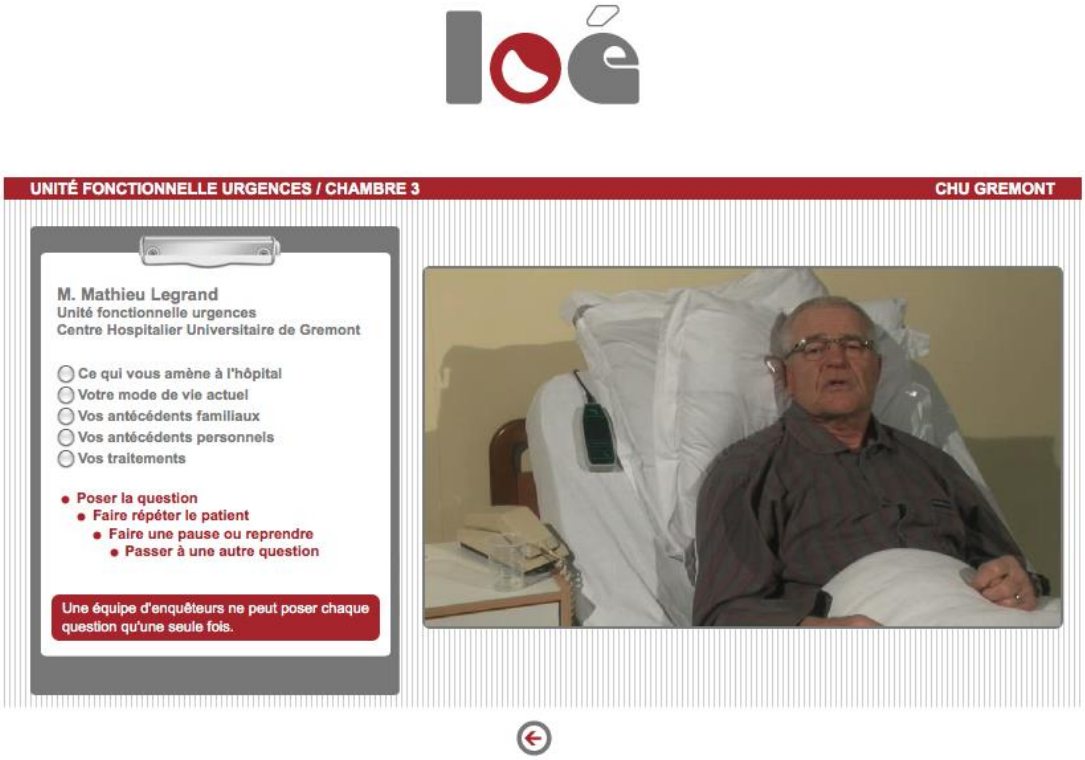

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Fig.2 Screenshot of room 3 with patient video and questionnaire

Each question is associated with a video clip (lasting about one minute). This response can be seen only once by the team of students. On-demand video has been implemented using Adobe© Flash technology. When entering the room with a click on its door (not shown here), a video immediately starts: either the patient is absent (video of a nurse), the patient is not available (video of a physician doing a physical examination) or the patient is there (video of the patient either saying hello or stating that he/she saw the interviewer already). A probabilistic algorithm regulates the presence and absence of patients. With this system, students learn some aspects of patient interviewing: to listen to patients with great attention, to identify accurately symptoms and signs within the patient narrative, to be prepared (know what to look for in advance), to control data quality (e.g. by confronting notes from two interviewers of the same patient), and to manage time (patients are not always available).

3.3 Interaction with Experts Through their Website

Students use their personal e-mail applications to communicate with the ERC (interaction 2 in Table 2), which shows its email address on their website. Students send their protocols as Portable Document Format files (PDF) that should be introduced by a short message. Tutors play the role of the experts. The immersive interface that we use for tutors is a standard Webmail interface with a dedicated signature and e-mail address. It is separated from their usual mailbox to help them play their role. Another interaction with experts is number 5 in Table 2, starting when students submit their article to a congress online. We developed our own

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congress Web platform. The tutors who play the role of the referees connect to the congress website and download students' articles that were allocated to them (randomly so that they do not necessarily know the students). Then they fill out a pre-structured form to report on the article. They have a list of points they should pay attention to to help them in this task. When ready, teams of students find this report online on the congress website using their own accounts.

LOE is an open-source project (on SourceForge.net) whose technology is used to support the role-play between students and tutors, employing various techniques to hide tutors behind characters and to collect data for tutors and for researchers.

4 Measures of Perceived Authenticity

To study the attributes of the game environment that influence students' perceptions of authenticity, the key data source is obviously the students themselves. According to our model, studying perceived authenticity implies considering the three dimensions (Fig. 1). Due to editorial limitations, we present only part of the data analysis that has been carried out in the LOE project (from 2009 to 2013). While we present observations of students during the game elsewhere ([12], [23], [30]), here, we concentrate on a particular data campaign, that is, interviews conducted immediately after each game session.

4.1 Data Collection

Authors studying perceived realism in television or on-line content have suggested that judgment focus should be on the specific moment and content that prompted the judgment rather than on the realism of the whole content or activity category [15]. For this reason, we collected students' judgments immediately after

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each session. Our population is composed of three cohorts (2010, 2011 and 2013) with about 170 students each year studying at the medical school in Grenoble, France, in a compulsory biostatistics course. Each year, about 45 teams of three or four students are distributed over six tutored classes. The aim is to obtain a large variety of students' feedback on authenticity related to the game environment. We asked three questions during recorded phone interviews that occurred within two hours after the end of each session: (Q1) What did you produce today? (Q2) Do you perceive what happened today as intuitively credible with regard to a professional reference? (Q3) Do you think what you did today is useful for your professional training?

Q1 is just a starter to help students remember the experience. The term 'credible' ([7], [30]) in Q2 was chosen to include both the *real-world relevance* and *gameplay relevance* dimensions (Fig. 1) after a series of tests. Credibility means both 'Does it looks like an imagined reality?' (epidemiological studies are new for these students) and 'Do you believe in it when you play it?'. Q3 refers to *learning relevance*, though this was sometimes considered by students in response to Q2. Very little was said by the researcher-interviewer to avoid influencing the students and to see what part of the game environment they would spontaneously talk about. We tried to reach at least one-half of the teams of students after each session. We asked each team to have a volontueer student or we chose one randomly, and we seldom talked twice to the same student over the sessions. The general research objectives had been explained to them at the beginning of the semester. In 2010, we talked to 21 students in session 1, 23 in session 2, 23 in session 3, 21 in session 4, 16 in session 5 and 27 in session 7. Two sessions are not represented (see Table 1), session 6

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is similar to sessions 4 and 5 and session 8 hardly exposed students to the game environment. In the following years, we conducted interviews only after session 3 since it contains most situations of interaction that we wanted to study: 43 students in 2011 and 22 students in 2013. The whole data set consisted of transcripts of these 196 phone interviews of about five minutes each.

4.2 Method of analysis

A unit of meaning (a topic addressed by a student) was coded if it mentioned a part of the game environment (characters, documents, tools, etc) explicitelly. We will see in the next section that these parts were grouped into a number of attributes a priori, and that this list of attributes was validated and completed thanks to the data analysis. The coder indicated whether each attribute was mentioned in a positive judgment of authenticity or in a negative one. Finally, the dimension of authenticity was coded with respect to whether the judgment concerned realism, gameplay or learning (Fig. 1).

5 Game Attributes that Increase Perceived Authenticity

We now answer research question 1 concerning what game attributes support perceived authenticity. We focussed on attributes that can be represented in the game environment. First, we identified a number of them a priori. Next, our data analysis was used to validate these attributes and study in more detail how they support perceived authenticity. Finally, a complete list of attributes is proposed to designers in the form of a table.

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5.1 Game Attributes in LOE

A list of attributes was built on the basis of a bibliographical review [32], a similar work done with a physics simulation [7] and the LOE design experience [12]. Game attributes that could have an impact on learning differ from one author to another. We chose the list of attributes of Wilson et al. [32] because it is comprehensive, exhaustive and based on a recent literature review. In this list, we focus on the attributes that are present in a game based on fictional immersion like LOE (see left column of Table 3). They concern evaluation (resulting in feedback and rewards), challenge (defined by the given mission), control (the degree of freedom given to learners), face-to-face interactions between players, modes and media of communication between players or characters and interactions at the interface. To indicate more precisely the scope of each attribute, we group them into four areas (see left column of Table 4): mission (mission content and resources, data), mise en scene (the graphical representation and structure of the environment), the user's freedom (constraints and level of control of the users) and interactions (characters' personification, behaviours and feedback from characters, mode and media of communication). In LOE, the designers tried to satisfy the three dimensions of authenticity (Fig. 1), but sometimes one must sacrifice one of them to solve a conflict between two dimensions, to make the problems given to students tractable or for practical reasons [12].

5.2 Game attribute in students' judgments

We used the phone interviews from 2010 since they covered all the sessions, that is, 131 students in total. The results are shown in Table 3. The figures indicate the number of units concerning a particular attribute, which is further distributed over

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the three authenticity dimensions (Fig. 1). The figures in brackets are the number of units that were positive judgments of authenticity.

TABLE 3. Students' judgments on authenticity

Attributes	Realism	Gameplay	Learning
Mission content and resources	17 (11)	3 (3)	5 (4)
Original data	32 (29)	6 (3)	5 (5)
Graphical representation	1 (1)		
Structure of the environment	6 (6)	3 (3)	2 (2)
Constraints	14 (6)	2 (2)	
Level of control	5(0)		
Characters' personification	1 (1)		
Behaviour and feedback from characters	62 (44)	6 (0)	8 (7)
Mode and media of communication	19 (8)	5 (0)	
Timing (pace and calendar)	10 (0)	4 (0)	
Students' products (form and content)	35 (14)	2 (0)	5 (1)

Students mentioned explictelly their products as well as aspects of timing, this led us to add two new attributes; both will be explained below. In looking at the three remaining columns, one sees that the distribution is not homogeneous among the three dimensions of authenticity. This is due to the fact that students mostly detailed their answers to Q2 concerning realism ('credibility compared to professional practice'). The last question (Q3) concerned usefulness (related to the *learning relevance*), but most students did not mention a particular attribute of the game environment then. Finally, *gameplay relevance* is a dimension that is best seen in students' acts rather than in students' discourses [12]. However, we used these

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judgments to improve the coherence (*gameplay relevance*) of the game after 2010 (see below). Finally, in looking at the realism column, one can see that the distribution is far from homogeneous. This is an interesting result that shows the relative importance of each attribute in students' eyes. We now discuss each attribute.

Mission (content and data). A realism comment was, 'It looks like it was not made just for us' or 'Documents look serious'. Concerning the data, 'in exercise sessions, [the teacher] manipulates the data for the student to go in a certain direction. Here, it is not the case'; this student said that *real-world relevance* overrides *learning relevance*. The students were not aware that the data are real. However, all said that they seemed real because 'the data are variable, with few repetitions', 'it looks like a physician did the survey because all the different forms of the disease are distinguished', 'there are a lot of details on each patient', 'the statistical test shows what we expected' or 'we got an unexpected result'. The latter shows that, whatever the result, students did not question the authenticity of the data. This and the impact of the figures included in the documents show the importance of figures that are crucial cues of the authenticity of the mission. Students did not question the data, although they should be critical (it is part of the learning goals), which suggests a perception of realism at the expense of learning.

Mise en scene (structure and representation). Very few comments on authenticity were made about the website structure and/or graphical design. They appreciated the quality of the environment, which was never criticised by any of the students but, rather, described as 'serious', 'well done' and 'expensive'.

Degree of freedom (constraints and control). A number of participants mentioned the constraints spontaneously and could even discern the value of the con-

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straints with regard to one of the authenticity dimensions. For example, a student recognised the constraints of the phone call as relevant for learning: 'It forces us to say orally and in a succinct message what we want and in a professional manner'. Many students mentioned the constraints related to the interviews of patients as cues of realism (see the next section). Concerning the control level, students often reported that they were probably helped more than in real life. In contrast, many students said that they had too much freedom during the first sessions.

Interactions with the characters. It was not the personification but, rather, feedback and behaviour that was largely mentioned by students, as well as the modes and channels of communication. Some students regretted that they could not interact with people in person, but most of them were happy to have at least some interactions with people. We will study these aspects in detail in the next section.

Timing concerns the pace of the whole game, the time it takes to get from one step to another and the calendar of this epidemiological study compared to a real one. It takes time to gain access to patients in hospital or to data (it was indicated that they could get 100 more patients per day), and this contributed to the realism. By contrast, for those students who obtained data too quickly, the interaction was not realistic. This is an example where the lack of internal consistency (*gameplay relevance*) led to a perception of inauthenticity.

Students' products were usually in written form and communicated to experts reachable through their website. Students judged the form and/or the content of their product (protocol or article). When asked whether they could submit their articles to a real medical congress (*real-world relevance*), 23 students gave the following answers (words in brackets not present in the original quote): 7 students

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said 'yes' ('we got [statistically] significant results'; 'we got good feedback [from congress reviewers]'), 10 students said 'maybe not' ('our results are not [statistically] significant'; 'our results are the same as in the literature') and 6 students said 'definitely not' ('this is not professional work'; 'there are mistakes'; 'we are not ready'; 'we are beginners'). The comments of the second group suggest that another result might have changed their mind, which is why they are classified as 'maybe not'. This shows a rather good authenticity level concerning the main product in the LOE game, given that the respondents are second-year medical students far from medical research. Note that a teacher confirmed that, each year, one or two studies (of 45) might make a true contribution to research.

In looking at the figures in brackets in Table 3, one can see that some attributes are mostly mentioned in positive (or negative) judgements of authenticity. For instance, the behaviours and feedback from characters were mentioned by 70% to stress a credible aspect of the game, while 63% mentioned the mode and channel of communication to describe an inauthentic aspect of the game.

5.3 A proposition of Game Attributes to Increase Perceived Authenticity

We showed that attributes obtained a priori are present in students' judgement and that two should be added. Therefore, we propose a list of 11 attributes of the game environment and how they can be adjusted to increase the perceived authenticity.

TABLE 4. Proposed attributes of authenticity of a simulation game

Area	Attributes	Authenticity
Mission	Mission contentand resources	Apparent seriousness of the resources, presence of scientific figures and references, reasonable amount of information and complexity

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	Provided data	Data are real and show variability, redundancy, relevant and irrelevant data, professional vocabulary
Mise en scene	Graphical representation	Probably a reasonably looking interface is enough
	Structure of the environment	Relevant for learning and gameplay
User freedom	Constraints	Constraints that force students to tackle issues relevant for learning
	Level of control of the users	Some freedom on the topic and the pace to go through the mission
Interactions	Characters' personification (sex, status, language, appearance, age…)	Just enough to make feel that there is a real person behind the character (and not a machine or a teacher)
	Behaviour and feedback from characters (including assessment)	Professional tone and scope (rather than didactical ones)
	Modes and channels of communication	Like in the real world
Timing	Pace and calendar, probabilistic events	Realistic steps and moments to wait; an event in the gameplay
Students' products	Form and content of students' products	Realistic form (template) and content that can be taken seriously in real life

This list of attributes is useful in designing authentic simulation games, especially those based on fictional immersion.

6 Situations of Interaction Perceived as Authentic

We present now an analysis of three moments of interaction in the LOE game, whether they are perceived as authentic or not, and why. This analysis will allow (1) to show evidence that the model of attributes defined in section 5 covers the situations related to authenticity in the analyzed game, and (2) to show a way to apply the heuristics in the analysis of a simulation game. Then we present an analysis of students' global judgement of moments of interaction. First note that we conducted a design-based research [24] that led us to make several iterations and modifications of the design over the years (2009 to 2013). For example, the phone interaction was modified starting in 2011 according to the results of the interviews

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in 2010. To promote *learning relevance*, the problem is stated more explicitly (the message on the answering machine is more detailed). For *gameplay relevance*, a single call is requested from students (to avoid repeated calls that lead to the disengagement of learners). For the sake of realism, professionals interact in person (by phone) with students who left incorrect messages.

6.1 Asynchronous Phone Interaction for a Request

The interaction by phone (Table 2) targets a character that is only slightly personified (with only a name and a status in the hospital). This character's feedback comes in the form of an SMS (or, in some cases, a phone call from a real person). Interviews from 2010 show that most students did not find this interaction realistic or relevant for learning (e.g. 12 of 23 students explicitly said, 'No, this interaction is not credible'). Few students mentioned the SMS as a factor of disbelief, while the answering machine was cited in most interviews. The interviews revealed that the changes introduced in 2011 were fruitful (e.g. only four of 43 students said, 'No, this is not credible' in 2011). Several students indeed said that the message on the answering machine was clear and useful, that the experience was relatively stressful (just before calling) and, for those who had a real person on the phone, that 'the person was a great help to more accurately describe my study' or 'I was taken seriously, and I was impressed'.

This case study shows that the mode and channel of communication have a significant effect. Students found this phone interaction not credible primarily on the basis of the communication channel, which led to a lack of engagement in this activity (studied elsewhere [12]). This was partly resolved when improving this interaction on the three dimensions of authenticity.

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6.2 Pre-recorded Video Interaction for Interviews

We analysed the 88 interviews carried out after session 3 (in 2010, 2011 and 2013). Globally, the patients were seen as people, and seven students said explicitly that the ability to see and hear patients was a good thing.

In this interaction, there were constraints designed for learning, and we checked whether these constraints were mentioned by the students and how. One constraint was that one cannot question a patient several times on the same topic (Table 2, Fig. 2). It was mentioned by eight students in the interviews. However, in 2010, no student identified the formative nature of this constraint, i.e. its *learning relevance*. Several students talked about the inconvenience occasioned by this constraint (if one missed what had been said, it was lost). Some mentioned this constraint as evidence of lack of realism since a real patient may wish to repeat his answer. In this example, a constraint that was both realistic and relevant for learning was seen as neither one nor the other by the students. In 2011, this constraint was changed, and students can now make a patient repeat an answer as many times as they want, as long as they do not switch to another question. After that, the interviews revealed that students had a positive attitude about the *real-world relevance* and *learning relevance* of this constraint. Another constraint was in patients' way of talking. Twenty-one students commented spontaneously on this aspect: 'It is the same as in real life; we have to sort out what they say and translate it into medical terms'. In this interaction, students had a positive perception of the authenticity of the patients. Finally, the constraint of a limited, pre-defined set of questions was commented on by 11 students. Depending on the student, it was either a sign of lack of realism because one cannot ask another question or a sign of

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realism because these questions corresponded to a typical medical interview of a patient. Students also reacted concerning the mode and channel of communication. The fact that one can see that 'these patients are actors' was mentioned by 12 students. For other studies ([23], [30]), we transcribed and analysed students' verbal interactions during session 3 (Table 1). For this paper, we collected the comments on the patients. Students had immediate reactions to what patients said, usually an interjection (e.g. 'a tumble!'; 'he's deaf!'). After viewing the video, they sometimes made inappropriate comments (e.g. 'I hate these old people unable to answer a single question'). Nevertheless, they might do the same after interviewing a real patient. We observed several examples of personification of the patients: students showed feelings for the patient's condition ('Honestly, I am worried about him'; 'Did you see his blood pressure? We'll have to take care of him.'); students talked about a person rather than about a system ('The patient is not there; the nurse said that he has gone for some test'). Also, students reacted to probabilistic events (presence/absence of patients): 'See whether the patient is back from the test' or 'Be careful; maybe the patient in room 4 will go away soon'. This provides several indications that some students had the expected attitude toward patients in the sense that they behaved as though in a real-life situation.

To conclude, constraints that were embedded in the design of this interaction functioned for only a few students. It seems necessary to have an integration phase after this part of the game to ensure that all students noticed how these constraints could help them learn. Concerning the mode and channel of communication, the video was welcomed by students because they could 'see and hear people'; it is important to have good actors and gameplay coherence, although these do not

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seem to be sources of disengagement.

6.3 Asynchronous Interaction with an Expert for Validation

First, experts validated the protocol (email interaction), and then experts reviewed the articles (through the congress website). We analysed 50 interviews from 2010 and looked more specifically at how students perceived this feedback from characters. Twelve of 23 students (session 3) found the first interaction credible and seven did not, while 20 of 27 students found the second interaction credible and six did not (session 7). Factors that made these interactions credible were the form of the answer (email message), the fact that it was anonymous and detailed, the credible tone of the report, its seriousness, the delay in the answer and the fact that it is fairly critical. Factors that made these interactions not credible were as follows: 'not enough to help us improve our work', 'too simple', 'the reviewer hardly read our article' or 'it's too schoolish'. Not all of the tutors did a good job of playing the role of an expert, some having difficulty playing a role other than that of a teacher. Indeed, some students said that they saw the didactical intention behind the feedback of the expert, which made it less realistic: *learning relevance* came at the expense of *real-world relevance*.

We obtained high rates of perceived authenticity for this type of interaction in the form of an asynchronous exchange of written messages, including an evaluation of students' products. Important factors that favoured perceived authenticity concern the timing (pace, delay…), the form and content of the expert feedback as well as the ability of the tutor to shift from a teacher role to a role given by the game (here an expert). Note that students received a grade after the end of the game based on the evaluation of the protocol, the article and the oral presentation

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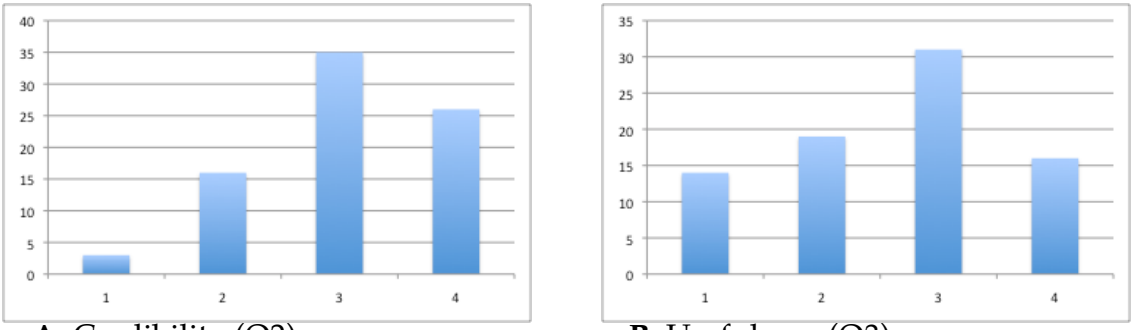
at the congress. In this sense, we can speak of an authentic assessment ([4], [5], [14]).

6.4 Global analysis of situations of interaction

We analysed the answers of 88 students concerning the global credibility (see Q2 in section 4) and usefulness (see Q3) of session 3, which involves the three types of situations of interaction analysed above. We could classify 80 answers in four categories: not at all credible/useful (1=no), not credible/useful globally but one thing is credible/useful (2=no, but), credible/useful globally but one thing is not credible/useful (3=yes, but) and absolutely credible/useful (4=yes). The average is 3.04 for Q2 and 2.61 for Q3.



A. Credibility (Q2) **B.** Usefulness (Q3)

Fig. 3. Students' judments on authenticity (from no=1 to yes=4)

Concerning the issue of credibility (Fig. 3A), 24% students (19/80) found this session not credible. The reasons they gave concerned the interaction with an expert by email (4), with the patients through videos (9) and with the hospital by phone (8). Several students complained about not having face-to-face interactions. Concerning the issue of usefulness (Fig. 3B), 41% (33/80) of the students were not convinced. The reasons concerned mostly the whole game. Several of them

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thought that it was useful only for physicians who were going to participate in medical research (not them) or that, when they would need it in several years, they would have forgotten everything. Others said, 'We have to study an issue that has been studied before', 'We spent too much time trying to understand what we had to do' and, 'It would be faster to have a lecture'. The reasons for finding it useful were also broad, but some were specific to what happened in session 3. They found it interesting to learn about the procedure to gain access to patients, how to interview patients and how to write and submit a protocol.

Although almost half of the students did not find the first three sessions of LOE useful for their training, they found it credible. It is necessary to work on the usefulness of such a game that demands a lot of work from students. For LOE, this concerns their conception of what a physician should be. Obviously, the teacher has a role in briefing, lectures and debriefing sessions. This was taken care of in LOE after 2011.

7 Conclusion

We present a set of heuristic rules intented to promote authenticity in simulation games, in the form of eleven attributes. The first concerns the mission (1). The level of difficulty when entering the game is critical; if too high, students take refuge in their role of students rather than engaging in a mission that seems too complex or too vague. Resources and providers of information should be presented with some apparent scientificity; the parameters that appear to play a role are the amount of information provided and the presence of scientific figures and of references. (2) Regarding the data that students use for analysis, they should include some varia-

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bility, redundancy, relevant and irrelevant data, like real data do in the real world, and unlike the school world where everything is clearly designed for a purpose. Attributes related to the degree of freedom of the players are problematic constraints and user control. (3) The constraints are determined by the variables of the problem that the designer created for learning so that its resolution requires the mobilisation of the target knowledge. These constraints embedded in the game should be accompanied by an integration phase where the tutor returns to relevant experiences lived in the game and gives them a status for learning. (4) The level of control is defined by the students' choice of tasks of the specific problem to be solved and of their pace through the game. In looking at the moments of interaction with characters, first, the personification (5) can be parameterised (sex, status, language, appearance, age, etc.) according to the learning goals, but with just enough information to give the feeling of interacting with a person and not a machine or a tutor. (6) Our results show that the character's feedback and behaviour is the main attribute that can be manipulated by the designer in order to favour perceived authenticity. On this point, our results are in line with a review of the literature in simulation-based medical education that shows that providing feedback is the most important feature for learning [33]. Furthermore, we show that (7) the mode of communication and the channel of communication also have a significant effect. (8) Timing is another significant attribute implemented by mapping the real order and pace of actions onto the game and by creating events with some degree of uncertainty and unpredictability [13]. Another attribute concerns (9) students' products: form (with a provided template, for instance) and content (with a clear indication that it should have some *real-world relevance*). This includes

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authentic assessment [14], which may be performed by characters of the game (e.g. experts) with real-world criteria. Finally, our analyses show that the mise en scene, i.e. the graphical representation (10) and the structure of the environment (11), has no impact as long as a reasonable-looking interface is offered; the game worked as an ambient game, and the screen-mouse interaction remained in the background.

While most studies have a limited timescale, our results are based on a longitudinal study undertaken from 2009 to 2013. This is important when focussing on learners' perception; it allowed determination of whether their perceptions of the designed authenticity matched expectations. Moreover, it avoided bias of the 'novelty effect' since students know that the game has been played by others for several years. Note that our results support the conjecture that personality profiles and cognitive styles play a role since the same attribute sometimes led to opposite judgments on authenticity from different students; this should be investigated in future work.

This work thus provides evidence on how authenticity can be used as a principle for game design (e.g. [13]). Our proposal is that designing an authentic simulation game results from a parameterisation of the above attributes, looking for a compromise between three dimensions: real-world relevance, gameplay relevance and learning relevance. In other words, perceived relevance with respect to a real-life reference, perceived coherence and consistency of the proposed situations and game rules and perceived relevance with respect to learning goals. Furthermore, we showed how this model can be used as a tool to measure learners' perceived authenticity. Our study concretises the concept of authentic gamification [14], which led to rather good perceived authenticity.

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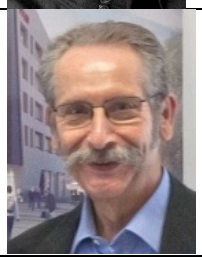	**Nicolas Balacheff** received a PhD in mathematics education. He is now senior scientist emeritus at the French National Centre for Scientific Research (CNRS). Nicolas was the co-founder in 1980 of the journal Recherches en Didactique des Mathématiques. He served as President of the International group for the Psychology of Mathematics Education (1988-1990). In the recent years, he served as director of the computer-science and discrete mathematics Laboratory Leibniz (2000-2006). He was the founder and first scientific director of Kaleidoscope, European network of excellence on Technology Enhanced Learning (2004-2007).

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