EMERGO: A methodology and toolkit for developing serious games in higher education

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Societal changes demand educators to apply new pedagogical approaches. Many educational stakeholders feel that serious games could play a key role in fulfilling this demand, and they lick their chops when looking at the booming industry of leisure games. However, current toolkits for developing leisure games show severe shortcomings when applied to serious games. Developing effective serious games in an efficient way requires a specific approach and tool set. This article describes the EMERGO methodology and generic toolkit for developing and delivering scenario-based serious games that are aimed at the acquisition of complex cognitive skills in higher education. Preliminary evaluation results with case developers using the EMERGO methodology and toolkit and with learners using EMERGO cases are presented.

KEYWORDS: *EMERGO; higher education; methodology; multimedia practicals; scenarios; serious games; toolkit*

Continuous demand is placed on educators to update pedagogical approaches and apply them in more cost efficient ways. Rapid changes in today's labor market require suitable approaches to lifelong education. New generations of learners need new pedagogical approaches to stay motivated (Prensky, 2001). We see a growing demand for new ways of learning that are often based on constructivist principles. These demands are caused by societal trends such as lifelong learning, the diminishing gap between working and learning, and possibilities of new learning technologies. Examples of such new ways of learning include collaborative learning, in which discussion and negotiation play an important role (Dillenbourg & Schneider, 1995), and problem-based learning, in which knowledge is constructed by solving real-world problems (Savery & Duffy, 1995). Motivation can be considered to be the key aspect

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of effective learning (Garris, Ahlers, & Driskell, 2002; Ryan & Deci, 2000). For many educational stakeholders, serious games seem the answer to such demands (Nadolski, Van der Hijden, Tattersall, & Slootmaker, 2006). Some of these new ways of learning have already been translated and applied to approaches and models for game-based learning (e.g., Kiili, 2005; Squire, 2006).

However, to fulfill these demands, we first need to overcome the severe costs of developing serious games. Serious game development demands a specific methodology and tool set for its design, development and delivery. Such a methodology and tool set not only support the design and development of serious games but also provide guidelines on how such games could be effectively distributed and used. Although many methodologies and tools for leisure games development already exist, their suitability for serious games can be questioned (Aldrich, 2005). The use of these existing methodologies and their toolkits might even be detrimental for developing serious games in higher education, because they pay only scant attention to education and learning. In serious games, real-life scenarios and the discovery of domain-related, rule-based content for cognitive development are placed center stage, as opposed to leisure games, in which motor development in realistic and often very immersive environments is the most important activity.

EMERGO offers a tailored methodology and generic toolkit for the efficient development and delivery of serious games (also called multimedia cases) for acquiring complex cognitive skills (also called competences) in higher education. EMERGO cases are delivered via the Internet and foster active and cooperative learning in a realistic, practice-based setting. This is achieved by using gaming elements, simulation elements, and pedagogical elements and by including system-based, teacher, and peer support (Aldrich, 2005). This approach is in line with the multimodal and multimedia reality of the next generation of learners (Prensky, 2001). Through EMERGO cases, learners are engaged in rich and challenging learning environments in which they encounter real-life problem situations and are constantly confronted with the consequences of their actions. This way, learning experiences become highly personalized, and learners will stay motivated.

The EMERGO methodology and toolkit as such do not guarantee the development of effective, attractive, and efficient learning materials. This would presume the presence of expertise in designing and developing serious games and high-quality content. A key challenge for serious game designers is to find an optimal combination of delightful play and achieving specified learning outcomes.

Serious games should be used to study their learning effectiveness within higher education settings. This will allow current limitations in the uptake of games in higher education to be addressed, specifically through the generation of empirical data on their effects and a greater understanding of their most effective use (de Freitas, 2006).

Although EMERGO is a work in progress, its methodology and toolkit build on extensive experience at the Open University of the Netherlands with the development of single-user, stand-alone serious games (e.g., Gerrichhauzen et al., 1998; Hommes et al., 2000; Huysse et al., 1998; Wöretshofer et al., 2000) and on accompanying research into such games (e.g., Hummel, Paas, & Koper, 2006; Nadolski, Kirschner,

& Van Merriënboer, 2006). EMERGO games are distributed on the Internet, will be more flexible with respect to pedagogical approaches and learners, and will be more user friendly for all stakeholders. Preliminary evaluation results on the use of the EMERGO methodology and toolkit and its resulting cases confirm these claims.

This article has an instructional design perspective and focuses on the use of the methodology and toolkit by case developers and the use of its resulting cases by students. The actual effects of the games and the development of the toolkit itself are not addressed here. In the second section, we further define scenario-based serious games and then describe the phases of the methodology and tools used to realize the actual development and implementation of the games. In the third section, we present preliminary evaluation results from game developers who used the EMERGO methodology and tools and students who studied EMERGO cases. The conclusion contains suggestions for future improvements and research.

EMERGO methodology and tools

The EMERGO methodology guides the development of scenario-based serious games. It takes ADDIE, a well-known phasing approach for instructional materials (Plomp, Feteris, Pieters, & Tomic, 1992) as starting point, further transforming and extending it toward the domain of serious games.

We define scenario-based serious games as *simulated* task environments, which have been modeled on real-life situations that often include a sequence of learning activities that involve complex decision making, problem-solving strategies, intelligent reasoning, and other complex cognitive skills. Such games are often based on professional or academic role adoption and modeled on expert behavior. Students are left in charge to deal with complex problems according to professional or scientific standards. Real-life situations display ambiguity and conflicting information and offer a large degree of freedom. Often, complex real-life problems (also referred to as "cases") are likely to involve several participants (i.e., multiuser cases). Because some actor roles could be covered by the computer, single-user cases are also possible. Situated learning (Brown, Collins, & Duguid, 1989) emphasizes that learning environments need to offer realistic situations in which learning through meaningful practice takes place, the premise being that the acquisition of complex cognitive skills is context dependent and occurs most effectively in a relevant context (Anderson, 1993; Brown et al., 1989; Kolb, 1984).

ADDIE is an acronym for "analysis, design, development, implementation, and evaluation" (see Figure 1). From now on, these phases will be further described in the context of EMERGO.

Although all phases can be conducted in this order, it is recommended to use iterations. Assumptions and expectations can be tested during development, and gradually, agreement and common ground within the whole project team will arise.

The EMERGO methodology prevents overspending and minimizes risks for failure. Case parts are developed and tested in cycles, which results in more intense

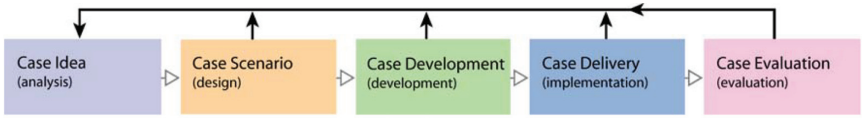

FIGURE 1: Methodology for case development: from case idea to case evaluation
NOTE: Open triangles indicate a suggested order, but phases can be conducted iteratively (black arrows).

and frequent—but not necessarily more time-consuming—communication and checks among various stakeholders compared with the classic waterfall approach. The EMERGO toolkit is used during the phases of development and implementation. Both methodology and toolkit are intended to be used mainly by teachers. Teachers can be assisted by educational technologists and other experts, such as graphic designers and game designers, when proceeding from case idea toward case delivery. The exact deployment of the methodology and toolkit depends on many circumstances, such as the complexity of the case, the content of the case, and the standard working procedures (e.g., quality assurance) of the organization. The methodology and toolkit are as much as possible neutral to such circumstances.

Analysis

Case developers first need to consider various issues related to the intended case. By discussing them, the project team gains more insight, common ground, and awareness: Why is the case needed, for whom is it meant, what are the (learning) objectives, what will be in it, and how will it be structured? A realistic picture of possibilities and impossibilities must emerge before actually starting case design and development. By answering an appropriate subset of the questions in Table 1, the team provides a *global description* of the intended case as input document for the design phase.

Design

The design phase needs to result in a *detailed scenario* document via the intermediate steps of *framework scenario* and *ingredients scenario*, each step providing more detail and completeness.

Framework scenario. This step describes the global activities students carry out during the game. A standard format for noting activities is followed: "Where the student will [description of the activity]." This enables to identify a first series of activities without getting overwhelmed by details (the first advantage). We can already distinguish compulsory and noncompulsory activities, ordered and nonordered activities, and expected and unexpected activities. The scenario is a blueprint with issues to be further worked on (the second advantage), resembling a construction drawing for a building. The team does not need to spend too much time on details

TABLE 1: Questions for analysis

Subject	*Questions*
Case embedding	For which courses, curricula and institutions will it be used?
	Is it a stand-alone item or used with other instructional materials?
	What study load and time interval are expected?
	How many credit points earn students by successfully completing it?
Case content	What is the main complex cognitive skill?
	Do other complex cognitive (sub)skills need to be acquired?
	What subject matter domain(s) are involved?
	What prior knowledge and skills are expected for enrolled students?
	What is central to the case (e.g., patient, equipment, process)?
	What are physical locations in the case? (Try to map them to virtual spaces.)
	What case characters are relevant?
	Do students need to proceed via a stepwise procedure?
	What kind of activities do students need to perform for acquiring the main complex cognitive skill?
	Is there a strict order for the compulsory tasks?
	Are there compulsory tasks and noncompulsory tasks, and what determines this?
	Is redundant information provided, or is everything strictly needed?
	How realistic and authentic is the case?
	If students can redo a case, will this be the same case or a variant?
	Can students undo former decisions?
	Are different learning routes and tasks for different students offered?
	What kind of cooperation is needed by students?
	Do students have different case characters?
	Do students have active roles?
	Do teachers have active roles?
	What aspects induce and sustain interest and motivation?
	What unforeseen circumstances are incorporated?
	Is competition incorporated? How do students get rewarded for excellent performance or behavior?
Students' progress	How do students discover not yet having acquired the main complex cognitive skill?
	How can students monitor their progress?
	How is it checked if students have acquired the main complex cognitive skill?
	Is summative assessment included, and are its results used in formative assessment?
	Which students' progress figures are to be used by teachers during run time?
Contact with peers	Should contact between students be encouraged?
	Should students see if peers are online, when they have been on line?
	Can students compare their progress with peers?
Using media	Will existing material be used, is new material needed?
	What media genres are used (e.g., interviews, docudramas, movies, animations)?
	What media assets are needed, and what are their costs?
Case delivery	Is the number of students within one run restricted?
	When can students enroll for a run?
	Is it possible to change the case after starting a run?
(Embedded) support	How will technical support be provided?
	How will support be provided for acquiring the main complex cognitive skill?
Costs	How many students will enroll each year?
	What are the development costs per student?
	What is the expected teacher/student ratio during exploitation?
Intellectual property rights	Is it allowed for others to use the case?
	Are materials from other parties incorporated, and what are their intellectual property rights arrangements?

yet (the third advantage). It allows giving equal attention to all elements at several stages of design and development. The framework scenario can be flexibly adjusted during following steps.

Ingredients scenario. The ingredients scenario is the second, more detailed step of the design phase. For each activity, we identify how students are to perform: What does the student do, with whom, with what tools and resources, and with what support (teacher, fellow student, or embedded)? Does task performance result in a product, and if so, how will this be evaluated? Is a sufficient result needed before students can carry on? Which interactions with other participants and the program are foreseen during and after carrying out activities? All (possible) interactions for each activity are exhaustively described, but not yet in terms of required tools and resources.

Detailed scenario. The detailed scenario is the final step of the design phase and describes each activity exhaustively in terms of required tools and resources for their actual performance. If students can interview a person, all interview questions need to be identified. If students need to read resources, all resources need to be identified. At this point, it also becomes clear if case materials are already available or still need to be developed. Furthermore, all tools are identified. The EMERGO toolkit contains several components for developing such tools and can be extended. So, for the most part, no additional tool development is needed. Using flowcharting and scheduling software for this step is highly recommended.

Development

During this phase, the EMERGO toolkit will be used for data entry, with the detailed scenario providing guidance. The toolkit is accompanied by an interactive user guide. All data entry components of the toolkit include templates to guide data entry. Ideally, data entry does not need any specific expertise, but it rarely can do completely without. Intensive and cyclic testing during data entry is needed and often identifies issues that can be resolved only by either domain experts or experts in more complex scripting. Design and development teams will therefore require considerable overlap and need to agree on working procedures. A content management system is indispensable for efficient version management of all digital case assets.

During development, three different roles are distinguished:

1. Case owner (responsible for setting access rights for components)
2. Component author (responsible for data entry of a specific part of the case)
3. Case tester (needs to be able to switch between the various case characters)

A number of case characters will need to be defined, depending on the authentic learning environment the case represents. Clearly, the case character “student” will always be available, and the case character “teacher” is very unlikely to be missing. However, students might play other characters (e.g., president, minute taker, debater). If so, the case tester should be able to test each of them.

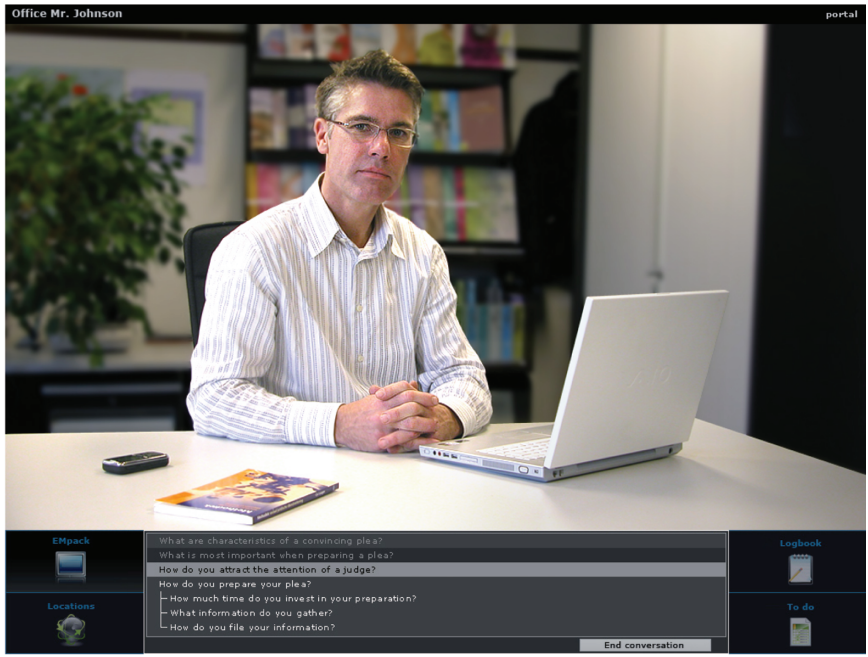

FIGURE 2: Screen capture of the student environment
NOTE: Components are graphically represented. Here, a student can ask questions of a person in his office.

Description of the EMERGO toolkit. In this subsection, we provide the reader with an impression of how students interact with the game environment as well as a first idea of the EMERGO toolkit's possibilities. EMERGO toolkit components for data entry and delivery are described.

In the study environment, students can conduct conversations, visit locations, use equipment or tools, participate in discussions, and so on. Figure 2 shows a possible screen of the student environment. The student can maneuver between locations (using the "Locations" button). Students can activate the EMpack, a backpack filled with various tools they can use during task performance (using the "EMpack" button). Students can always take notes, which are automatically classified in a logbook (using the "Logbook" button). Students can choose tasks in the "to-do list," but within constraints defined by the case developers.

For learning to actually take place, students need to digest and store their impressions and attach personal meaning to them. Therefore, students are supported in note taking in various ways:

1. Taking notes at locations: This can be during a conversation, when reading a document, or using the notebook in their environment.

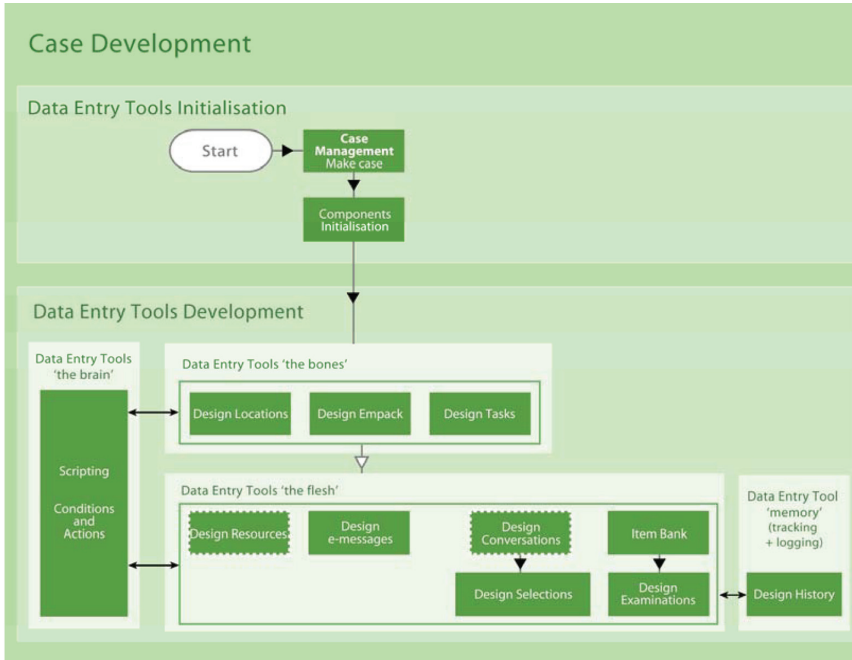

FIGURE 3: Data entry components for case development
NOTE: Arrows with big black triangles indicate a compulsory order, and the arrow with the open triangle indicates a suggested order. If components are in the same box, it is impossible to indicate a suggested order. Bidirectional arrows indicate relationships between components. The scripting component is at the center of all data entry. It defines the case flow using conditions and actions.

2. Arranging and processing notes taken: The logbook automatically classifies all notes from the notebook. Students can summarize, make overviews, and draft reports using their logbooks.
3. Final reports: Drawing up a report can be a product of a task made using the clipboard and logbook. Reports can be uploaded via eMessages.
4. Constitute eMessages: A report can be attached to an eMessage.

As shown in Figure 3 and Table 2, components for data entry can be used for both initialization and development. Table 2 summarizes various data entry components and their functionality, as graphically presented in Figure 3. Almost every component can be used (instantiated) several times in the student environment. For example, "design resources" enables making a "video archive," a "file cabinet," or a "resource collection."

Testing data entry. Testing involves switching between case characters. There are three ways of testing:

TABLE 2: Data entry components and their function

Component	*Function*
Initialization	
Case management: make case	Defines new cases. Existing cases can be used for modding.
Component initialization	Defines all components and their access rights for data entry.
Development	
Design locations	Defines locations and possibly conditions and actions.
Design EMpack	Defines tools on the EMpack and possibly conditions and actions.
Design tasks	Defines tasks in the "to-do list" and possibly conditions and actions.
Scripting	Defines the case flow by conditions and actions that can specified for the complete case, one or more other components, or specific data entry for one or more components. Conditions and actions often relate to student actions but also to other actors actions.
Design resources	Defines resources and their hierarchies.
Design eMessages	Defines various types of eMessages.
Design conversations	Define conversations between students and virtual characters.
Design selections	Defines selection options for students when performing a task.
Item bank	Defines multiple choice items for examinations.
Design examinations	Defines examinations.
Design history	Defines to be logged student choices and retrievable by students.

- Start and use results from the previous session (default).
- Start and use results from another (not the previous) session (using demo runs).
- Start and do not use results from another session.

It is possible to test components in isolation or in connection.

Implementation

During implementation (or case delivery), the game will be accessed by certain students and teachers. Figure 4 shows data entry components in the toolkit for delivery, whereas Table 3 summarizes these components and their functionality. Delivery assumes the following:

- A student can choose the case in his or her study environment (student portal).
- A teacher can choose the case in his or her work environment (teacher portal).
- Data entry for the case has been checked and is acceptable.
- Case run management has been used to prepare the run of the case to be launched.

If so, the game can be "published." Certain students and teachers can choose the case via the EMERGO Web site using their authorization data.

Evaluation

Evaluation will assess whether the case fulfills the initial demands defined during analysis: Is the actual use in line with its expected use? A clear evaluation focus before launching the case should be made explicit in an evaluation plan. In principle,

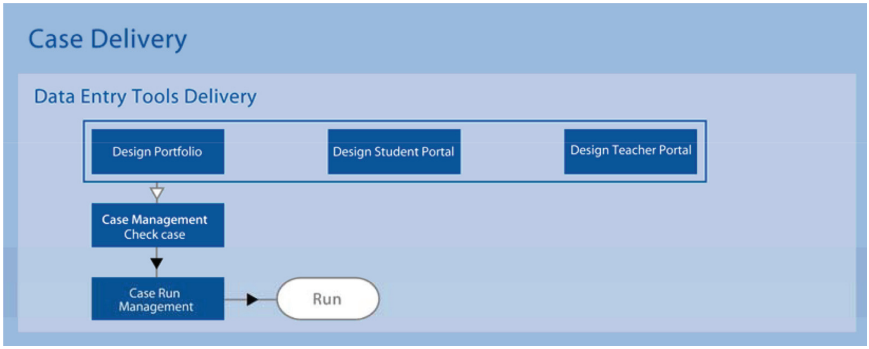

FIGURE 4: Data entry components for case delivery
NOTE: Arrows with black triangles indicate a compulsory order, and the arrow with the open triangle indicates a suggested order. If components are in the same box, it is impossible to indicate a suggested order.

TABLE 3: Data entry components and their function

Component	*Function*
Design portfolio	Defines which student products are added to their portfolio.
Design student portal	Defines which cases can be chosen, what case progress data can be monitored, progress comparisons, etc.
Design teacher portal	Defines which cases can be chosen, what case progress data can be monitored for which students, etc.
Case management: check case	Checks whether data entry is syntactically correct.
Case run management	Defines case runs. Each run has a start time, enrolled students, and enrolled teachers and could have an end time.

in the evaluation phase, answers to questions in the analysis phase can now be checked (see Table 4).

Evaluation results

This section describes preliminary evaluation results for (a) developers using the EMERGO methodology and toolkit and (b) students using cases during their study.

Using the EMERGO methodology and toolkit

We wanted to investigate whether case developers were capable of using the methodology and toolkit independently and to identify improvements needed during a small, rather qualitative evaluative pilot study. Case developers (n = 5) used the

TABLE 4: Questions for evaluation

Subject	*Questions*
Case embedding	What courses, curricula, and institutions did use the case?
	Is the case exploited as a stand-alone item or with other instructional materials?
	What study load and time interval are measured?
Case content	Did students acquire the main complex cognitive skill?
	Did students have the assumed prior knowledge and skills?
	Did students perform tasks as expected?
	Did students consult resources as expected?
	Did students cooperate as expected?
	Did students use peer support?
	Did teachers perform as expected?
	Did students enjoy the case and where they immersed?
	What unforeseen circumstances did students encounter during the case?
	What rewards did students receive during case performance?
Students' progress	How did students discover if they had acquired the main complex cognitive skill?
	How and when did students monitor their progress?
	What where teachers' actions on students' progress?
Contact with peers	Did students get in touch with peers?
	Did students compare their progress with peers?
(Embedded) support	How often did students ask for technical support, and was this sufficient?
	How often did students ask for support to acquire the main complex cognitive skill, and was this sufficient?
Costs	How many students enrolled the case?
	What teacher/student ratio was measured during exploitation?

EMERGO methodology and toolkit for five cases in the domain of environmental policy. All case developers were familiar with developing distance education but were not experienced case developers. They did not have prior experience with EMERGO. Each case developer recorded time spent. The estimated study time for all cases together is 60 hours, whereas it took about 1,500 hours to develop them (i.e., a production ratio of 1:25). The five cases differed in complexity, but no data were collected to compare the production ratio for each of them. Overall, these cases can be considered to be large and relatively complex in nature.

Process and instruments. This evaluation consisted of an electronic questionnaire and a face-to-face focused interview. The questionnaire included five questions (each with about a dozen items) that made an inventory of the extent to which the methodology and components from the toolkit were used as well as their appreciation. Most items had predefined alternatives but also left room for open answers. Four respondents returned the questionnaire. The results from the questionnaire were used to design the focused interview, which was held within a week after collecting the questionnaires. The aim of the interview was to identify improvements for both methodology and toolkit, and the interview was conducted with four case developers and led by the evaluator.

TABLE 5: Suitability and simplicity for independently using EMERGO toolkit components (n = 4 case developers)

	Used?	*Independent?*		*Simple?*			
Component	*Yes*	*Yes*	*No*	*1 (completely disagree)*	*2*	*3*	*4 (completely agree)*
Design locations	4	4				2	2
Design EMpack	2	2					2
Design tasks	3	3				2	1
Scripting	3	2	1	2	1		
Design resources	4	4				2	2
Design eMessages	4	4				3	1
Design conversations	4	4			2	2	
Case run management	2	2				1	1

Results. Respondents unanimously indicate that the EMERGO methodology and toolkit supported them in a flexible way but that they could use more concrete guidelines and examples. This was especially needed for a smooth transition from detailed scenario to data entry. Case developers indicated that they expected that a multidisciplinary team would be needed for more complex case development and that their expertise after using the methodology and toolkit had improved.

Respondents extensively used the EMERGO toolkit but did not all use the same components. Table 5 summarizes respondents' scores on suitability and simplicity for independently using toolkit components as they were needed for producing the five cases. Their scores showed that only the scripting component induced problems for independent use. The scripting and design conversation components were most difficult to use. Most components from the toolkit already were considered very user friendly, but the scripting and design conversation components need further improvement in this respect, especially for more complex cases. As of this writing, we are incorporating context-dependent help functions and examples when working with the toolkit to address this need.

Studying EMERGO cases

We wanted to investigate in a qualitative pilot study with actual students studying the cases whether

1. the Web interface was working adequately
2. the user interface was considered to be user friendly
3. how the cases were appreciated by the students

A small group of students from the Open University of the Netherlands (n = 8) used three EMERGO cases (the first three out of the five mentioned above) when taking their course in environmental policy for regular credit points. The estimated study time of these three cases was 22 hours; cases showed increasing complexity and decreasing support.

Process and instruments. This evaluation consisted of four questionnaires that all included questions with predefined alternatives and a possibility for an open answer. The evaluation consisted of three parts dealing with (a) technical aspects, (b) user interface aspects, and (c) didactical content aspects. The first questionnaire contained questions only for the first two categories, whereas the other questionnaires contained similar questions for all aspects to gather case-specific info for the third category. In total, 35 questions were provided to respondents. One respondent returned the first two questionnaires only, because the cases did not function on respondent's Mac computer. Four respondents returned all questionnaires. Nonresponse was due mainly to private matters and practical reasons, because the evaluation period was partly during the holiday season. Questback (https://questback.com) was used for the work flow during the evaluation. Students had about 3 weeks to finish the cases. A reminder was sent 1 week before the deadline.

Results. The Web interface appeared not error prone and did meet most requirements. However, a performance improvement is needed for a more smooth learning experience, especially when loading streaming video fragments. This would also benefit the user interface, which despite the performance problems already met all expectations. More cross-platform compatibility is also needed.

All students were satisfied with the user interface. They encountered only small problems, mainly resulting from choices made during the detailed scenario. For example, one student also wanted to consult some task-specific information during task performance, not only before task performance, as it was provided for the current version of the cases. This could easily be adjusted with the existing toolkit components. All students were also satisfied with the content of the cases. This was mentioned in relation to the structure of cases, their alignment with prior knowledge and skills, and their realism. As stated by one of the students: "It is true to life." In other words, all students appeared motivated when interacting with the cases.

Conclusion

There are limited preliminary evaluation results to report so far. However, these already clearly indicate that the EMERGO methodology and toolkit will support serious game developers in delivering more efficient scenario-based serious games. A production ratio of 1:25 is indeed very efficient when producing computer-based learning programs, compared with reported production ratios ranging from 1:100 to 1:600 (see, e.g., Alessi & Trollip, 2001) and also when compared with our previous experiences for comparable cases such as "Preparing a Plea" (Wöretshofer et al., 2000) and "Out of Order" (Gerrichhauzen et al., 1998). However, because all cases used in this study are quite complex, their production needed quite a lot of different types of expertise.

Students studying the cases were very satisfied and strongly motivated when interacting with them. It therefore seems that more efficient development was not achieved at the expense of less didactical quality.

Because the actual learning results were not measured during this evaluative pilot study, it still remains unclear whether the cases were also effective. Indeed, more research is needed to see whether such serious games are beneficial for learning and whether the EMERGO methodology and toolkit also support the delivery of more effective scenario-based serious games.

Although the EMERGO methodology targets the development of scenario-based serious games aimed for the acquisition of complex cognitive skills in higher education, this methodology can also be used for serious games aimed at more simple skills and beyond the area of higher education. Our methodology makes serious games easier to produce with less specific expertise within the project team. However, a broad range of expertise will still be needed to develop serious games. Multidisciplinary teams need to represent expertise from both information and communication technology, semiotics, narratology, cybernetics, ludology, educational psychology, and instructional design. We have stressed the instructional design point of view in this article, leaving other expertise areas untouched that also play an important role. The broad application area of the EMERGO methodology and toolkit could further boost serious game development. More research into the development and implementation of these EMERGO products in other domains and fields of education is needed to further justify this claim.

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