EMERGO: methodology and toolkit for efficient development of serious games in higher education

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Abstract

Societal changes demand education to apply new pedagogical approaches. Many educational stakeholders feel that serious games could play a key role in fulfilling this demand, and smack their chops when looking at the booming industry for leisure games. However, current toolkits for developing leisure games show severe shortcomings for the development of efficient and effective serious games. Furthermore, developing serious games asks for a specific approach which differs from the approach used in developing leisure games. EMERGO provides a methodology and generic toolkit for developing and delivering serious games aimed at the acquisition of complex cognitive skills in higher education. This article describes the EMERGO methodology and toolkit as well as preliminary evaluation results with case developers using EMERGO.

Introduction

There is continuous demand for education to update their pedagogical approaches and apply them in cost-efficient ways. Rapid changes in today's labour market require suitable approaches to lifelong education. New generations of learners are needing new pedagogical approaches to stay motivated (Prensky, 2001). Motivation can be considered to be the key aspect of effective learning (Ryan & Deci, 2000; Garris et al., 2002). For many educational stakeholders, serious games seem the answer to such demands (Nadolski et al., 2006b). However, in order to fulfil these demands we first need to overcome the severe costs in developing serious games. Serious games development demands a specific methodology for its design, development and delivery. Such a methodology does not only support the design and development of serious games, but also provides guidelines on how such games could be effectively distributed and used. Although many methodologies for leisure games development already exist, their suitability for serious games development 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.
EMERGO offers a more specific methodology and generic toolkit for efficient development and delivery of multimedia cases for acquiring complex cognitive skills in higher education. EMERGO cases are delivered via the Internet and will foster active and cooperative learning in a realistic, practice-based setting. This can be achieved by using gaming elements, simulation elements and pedagogical elements, and by including both system-based-, teacher- and peer support (Aldrich, 2005). This approach is inline with the multimodal and multimedial reality of the next generation of learners (Prensky, 2001). Through EMERGO cases, learners are engaged

in both a rich and challenging learning environment where they encounter realistic problem situations, and constantly are being confronted with the consequences of their acts. This way, learning experiences become personalized and learners stay motivated.

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

Serious games could be used to study their learning effectiveness within higher education settings. In this way, two current limitations of the uptake of games in higher education can be addressed, namely a lack of empirical data on their current effects and a lack of understanding of how games could be used most effectively (de Freitas, 2006).

Although EMERGO still is work-in-progress, its methodology and toolkit have been build upon 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 upon accompanying research into such games (Hummel et al., 2006; Nadolski et al., 2006a). EMERGO games will be distributed by the Internet, will be more flexible with respect to pedagogical approaches as well as to learners, and will be more user-friendly for all stakeholders. Currently, first evaluation results on using the EMERGO methodology and toolkit confirm these claims, and a field study with actual learners is planned from June onwards.
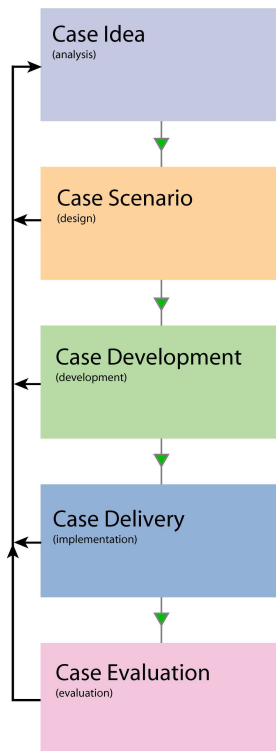
EMERGO methodology

The EMERGO methodology is tuned to serious games for acquiring complex cognitive skills (referred to as cases) and takes ADDIE, a well-known phasing approach for instructional materials (Plomp, Feteris, Pieters, & Tomic, 1992) as a starting point. It also adopts Unified Processing, an approach for software development (Kruchten, 2004). Both are transformed and extended towards the domain of serious games.

ADDIE is an abbreviation of *A*nalysis, *D*esign, *D*evelopment, *I*mplementation and *E*valuation (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. In other words, use a Unified Process approach with cycles instead of the classical waterfall approach. Design assumptions and expectations can be tested during development, and gradually a uniform picture can arise that is supported by the whole project team.

Being based upon ADDIE and Unified Process, the EMERGO methodology prevents overspending and minimizes risks of failures. Case parts will be developed and tested in cycles, which results in more intense and frequent – but not necessarily more time consuming – communication between various stakeholders.

An important precondition for enabling shorter cycles is the ability to carry them out quick and easy. The EMERGO toolkit caters for this need.

Figure 1. Methodology for case development: from Case Idea to Case Evaluation. Green arrows indicate an advised order but phases can be conducted iteratively (black arrows)[1].

The five EMERGO phases and the toolkit are now described in some more detail.

Phase 1: Analysis

At the start, case developers need to consider various issues related to the intended case. By discussing them, the project team gains more insight, and more awareness for the case will arise: why is it needed, for whom is it meant, what will be in it, how will it be structured? A realistic picture of possibilities and impossibilities emerges 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.
After providing – provisional – answers to these questions, the project team finishes the analysis phase by providing this global description as input document for the design phase.

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[1] See EMERGO Website for this and other figures (http://www.emergo.cc)

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 is 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 (for example: 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, non-compulsory 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 behaviour?
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 on line, 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, docudrama, movie, 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 enrol 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 enrol each year?
	What are the development costs per student?
	What is the expected teacher/student ratio during exploitation?
IPR	Is it allowed for others to use the case?
	Are materials from other parties incorporated and what are their Intellectual Property Rights(IPR) arrangements?

Phase 2: Design

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

Framework scenario
This step describes the global activities students carry out during the case. A standard format for noting activities is proposed "Where the student will...<description of the activity>". This enables to identify a first series of activities without getting overwhelmed by details (first advantage). In this series, one can already distinguish between compulsory and non-compulsory activities, activities that need to be performed in a certain order or not, activities unexpectedly popping up or being in the students' 'to do-list'. The approach quickly provides a blue print for issues to be further worked upon (second advantage). The framework scenario resembles a construction drawing for a building. The team does not need to spend too much time on detailing out certain elements at the beginning (third advantage). It enables giving similar attention to all elements at several stages during design and development. The framework scenario can flexibly be adjusted during following steps.

Ingredients scenario
The framework scenario is the second, more detailed step of the design phase. For each activity it is identified how students are to perform: what does the student do, with whom, with what tools and resources, and with which 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? What are foreseen interactions with other participants and the program during and after carrying out an activity? The (possible) interactions for each activity are exhaustively described, but not yet in terms of required tools and resources.

Detailed scenario
This final step of the design phase describes each activity exhaustively in terms of its required tools and resources to enable the 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, mostly no additional tool development is needed. Using Flowcharting and Scheduling software for this step is heavily recommended.

Phase 3: Development

During this phase, the EMERGO-toolkit is used for data entry with the detailed scenario providing guidance. Ideally, data entry does not need any specific case expertise, but this seldom occurs. Intensive and cyclic testing during data entry is needed and often identifies issues that can only be quickly resolved by case experts. Therefore, the design and development teams will need considerable overlap. Furthermore, data entry and testing are interdependent and might require specific expertise. Thus, it is important to agree on a specific working procedure. A content management system is indispensable for efficient version management of all digital case assets.

During development, three different roles are distinghuised:
1. Case owner (responsible for setting access rights for components)
2. Component author (is 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. Evidently, 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 (for example: president, minute's secretary, debater). If so, the case tester should be able to test each of them.

Figure 2 shows a screen from the student environment. The student can manoeuvre between locations. Students can activate the Empack that incorporates tools students can use during task performance. Students can always take notes that are automatically classified in a so-called Logbook. Students can choose tasks in the 'to do list', but within constraints as defined by the case developers.
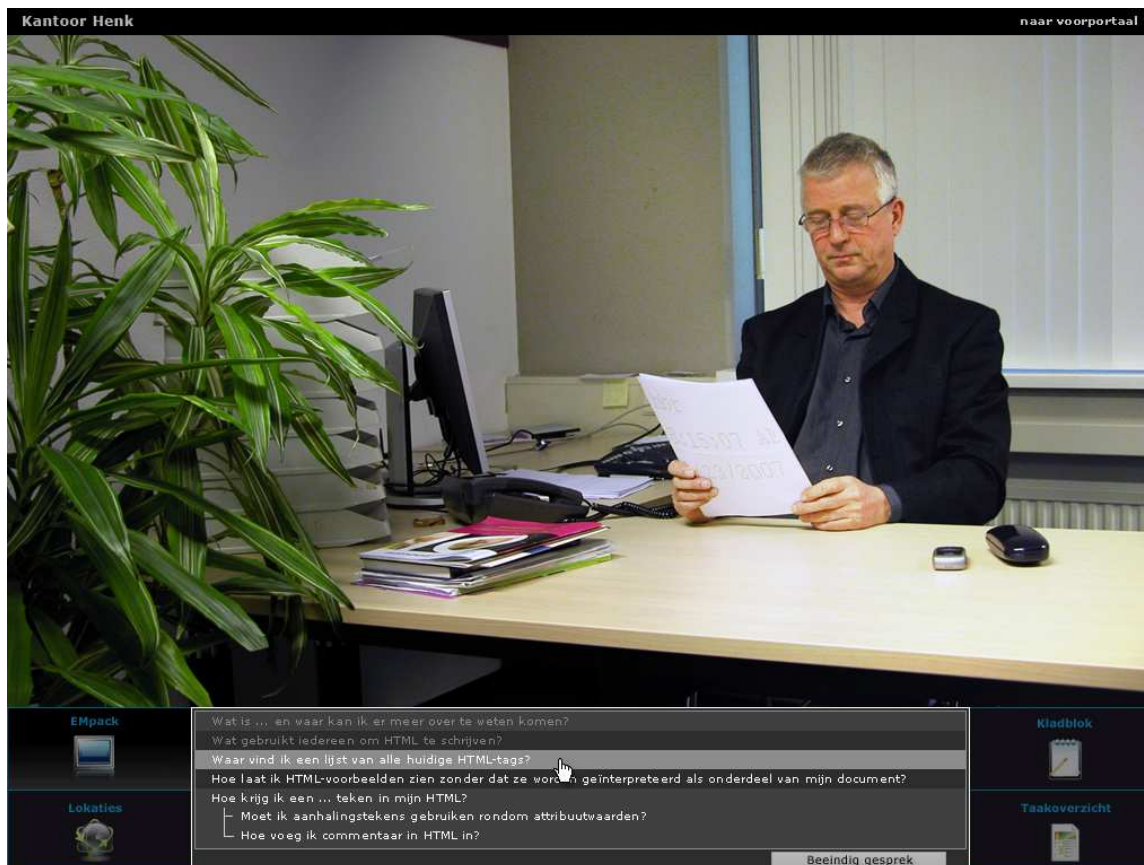

Figure 2. Screen dump of the student environment. Components are graphically represented. Here, a student can ask questions to a person in his office.

Global description of the EMERGO toolkit

In this section we will provide an impression of how students interact with the student environment as well as a first idea of the EMERGO toolkit possibilities.

Successively, EMERGO toolkit components for the data entry environment are described.

In the study environment, students can conduct conversations, visit locations, use equipment or tools, can participate in discussions et cetera. For learning to take place, students need to record their impressions and attach meaning to them. Therefore, students can take notes in various ways:

1. Take notes at locations. This can be during a conversation, when reading a document, using the Notebook in their environment.
2. Arranging and processing notes taken. The Logbook automatically classifies all notes from the Notebook. Students can summarize, can make overviews and draft reports using their Logbook.
3. Final reports. Drawing up a report can be a product of a task made via using Clipboard and Logbook. Reports can be uploaded via e-messages.
4. Constitute e-messages. A report can be attached to an e-message.

As appears from Figure 3 and Table 2, components for data entry can be used for both initialisation and development.
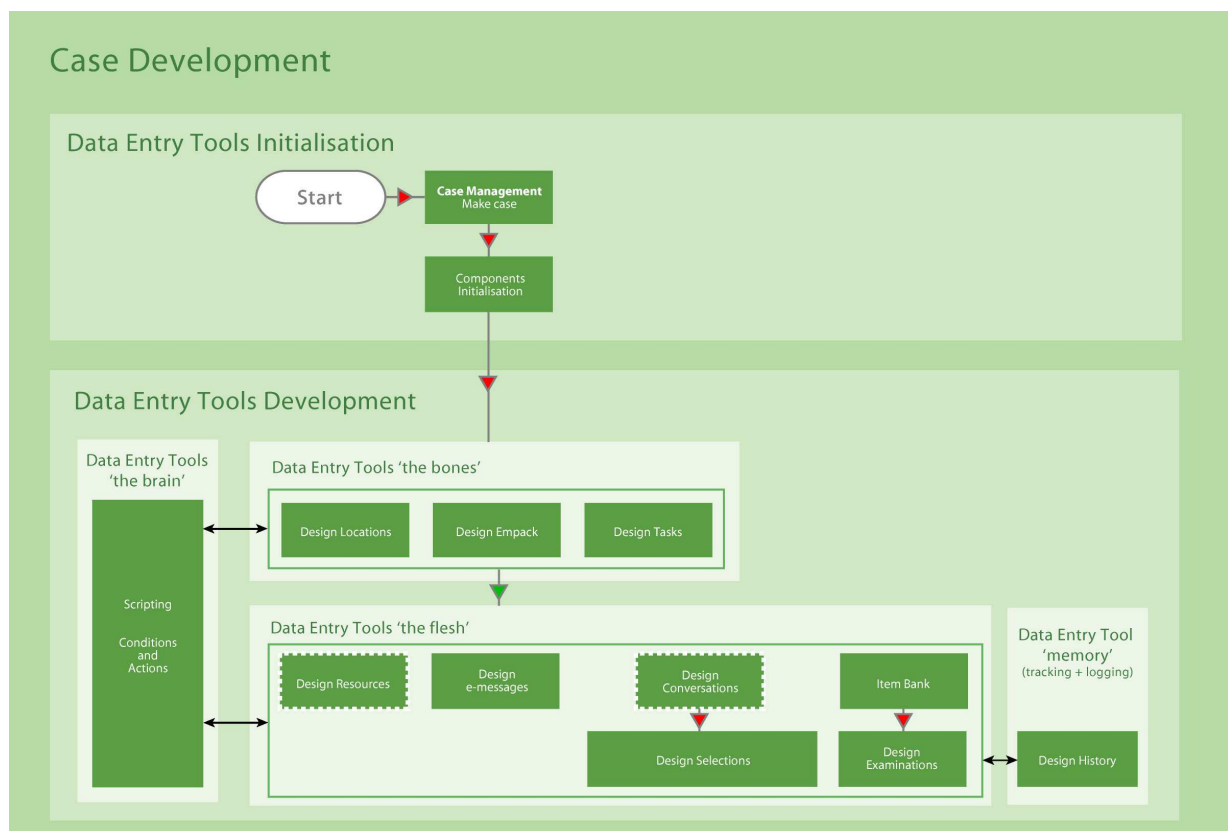
Figure 3. Data entry components for case development. Red arrows indicate a compulsory order, green arrows indicate an advised order. If components are in the same box, it is impossible to indicate an advised order. Bidirectional arrows indicate relationships between components. Note that the component Scripting is at the centre of all data entry. It defines the flow within a case, using conditions and actions.

Table 2 summarizes various data entry components and their functionality. 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', a 'resource collection'.

Table 2. *Data entry components and their function. Orange components relate to initialisation, non-colored components are used for development*.

Component	Function
Case Management: Make case	Defines new cases. Existing cases can be used for modding.
Components Initialisation	Defines all components and their access rights for data entry.
Design Locations	Defines locations between which students can manoeuvre 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 conditions and actions. These can be on the level of the complete case, one or more other components, or specific data entry for one or more components. The component Scripting defines the case flow. Conditions and actions mostly relate to specific actions of the student, but can also relate to other actors actions.
Design Resources	Defines resources and their hierarchies.
Design e-messages	Defines three types of e-messages: (1) predefined e-messages with prestructured subjects and recipients, (2) predefined e-messages asking for assistance with predefined recipients but free subjects, and (3) predefined, to be received e-messages.
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.

Testing data entry
Testing involves switching between case characters. There are three ways of testing:
1. start and proceed with results from the previous session (default)
2. start and proceed with results from another session (not the previous) (using demo-runs)
3. start and do not use results from another session

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

Phase 4: Implementation

During implementation, the case is accessed by certain students and teachers. Figure 4 shows data entry components for case delivery, whereas Table 3 summarizes these components and their functionality.

Case delivery assumes:
- a student can choose the case in his study environment (student portal)
- a teacher can choose the case in his work environment (teacher portal)
- data entry for the case has been checked and is OK
- case run management has been used to prepare the run for the case to be launched

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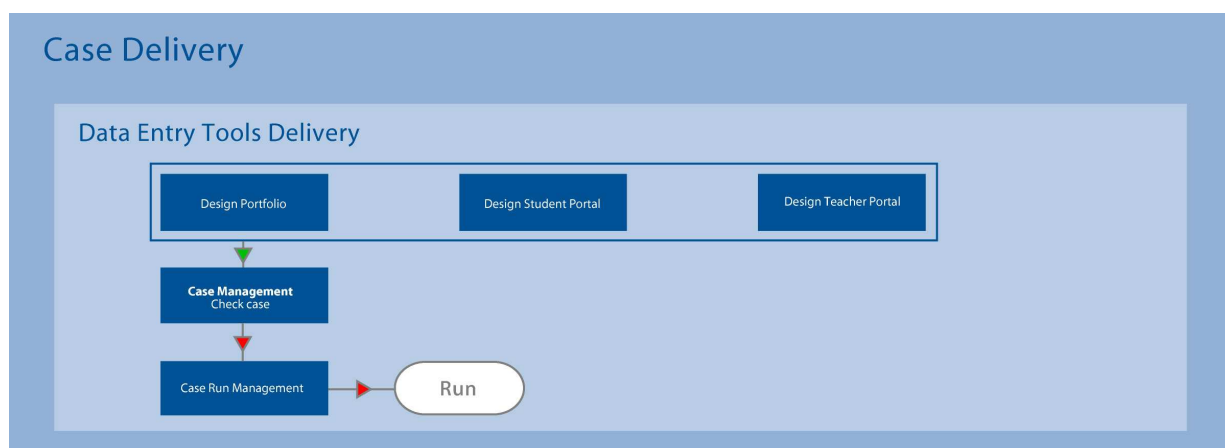

Figure 4. Data entry components for case delivery. Red arrows indicate a compulsory order, green arrows indicate an advised order. If components are in the same box, it is impossible to indicate an advised order.

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, et cetera.
Design Teacher Portal	Defines which cases can be chosen, what case progress data can be monitored for which students, et cetera.
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, enrolled teachers and could have an end time.

Phase 5: Evaluation

Evaluation will assess whether the case fulfils 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, in the evaluation phase, answers to questions in the analysis phase can now be checked (see Table 4).

Table 4. *Questions for evaluation.*

Subject	Questions
Case embedding	What courses, curricula and institutions did use the case?
	Is the case exploited as stand-alone item or with other instructional materials?
	What study load and time interval is 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 in order 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?

Concluding remarks

There are limited evaluation results so far. However, preliminary observations clearly show that the EMERGO methodology and toolkit support serious game developers in delivering more efficient and effective serious games. Although the EMERGO methodology targets the development of serious games aimed for the acquisition of complex cognitive skills in higher education, this methodology can also be used for serious games aiming at more simple skills and beyond the area of higher education. Our methodology makes that serious games are easier to produce and need less specific expertise within the project team. However, still a broad range of expertise will be needed for developing serious games. Multi-disciplinary 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. However, this leaves untouched other expertise areas playing an equivalent important role in arriving at balanced serious games.
The broad application area of the EMERGO methodology and toolkit could further boost serious games development. More research in applying these EMERGO products is needed to further justify this claim.

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