

## 80Days: Adaptive Digital Storytelling for Digital Educational Games

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**Abstract.** The overall aim of the European research project 80Days situated in the field of Technology-enhanced Learning is to combine adaptive learning, Storytelling and gaming technology in order to build intelligent, adaptive and exciting learning environments in the form of Storytelling-based digital educational games (DEGs). This paper presents the major results of the Serious Gaming group at TU Darmstadt achieved in the first development cycle of 80Days: Based on a short introduction in section 1 providing a brief overview of the 80Days approach and key challenges being addressed, section 2 introduces methods and concepts of an adaptive digital storytelling framework and indicates how this contributes to intelligent personalisation and adaptation in DEGs. Section 3 describes practical results in terms of a first technical platform of 80Days integrating an adaptive learning engine, story engine and game engine plus a content repository and StoryTec as authoring environment to create such Story-based DEGs. Section 4 summarizes the current status and main results of the 80Days approach achieved so far including first evaluation feedback, and points out further research and development activities.

**Keywords:** Technology-enhanced Learning, Digital Educational Games, Digital Storytelling, Personalization, Adaptation, Authoring Tools

## 1 Introduction

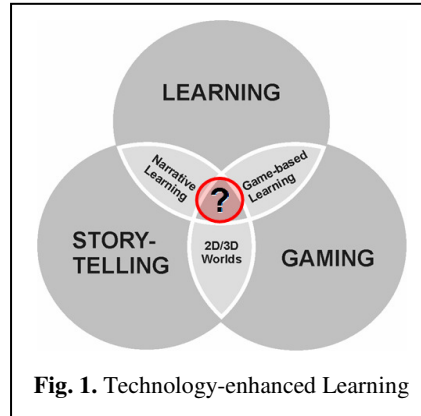
80Days<sup>1</sup> is a pathbreaking research initiative to explore new frontiers in Digital Educational Games (DEGs), which combine effective learning with fun and pleasure. The conceptual and technological basis of the highly interdisciplinary 80Days approach enforcing cooperative research among cognitive scientists, psychologists, computer scientists, game technology provider, designers or evaluation experts are built by the results achieved within ELEKTRA<sup>2</sup> [9] and INSCAPE<sup>3</sup> [6, 7] situated in

<sup>1</sup> 80Days – Around an Inspiring Virtual Learning World in Eighty Days. EU, FP7, IST, STREP, Challenge 4.1.2 Technology-enhanced Learning. [www.eightydays.eu](http://www.eightydays.eu)

<sup>2</sup> ELEKTRA – Enhanced Learning Experience and Knowledge TRAnsfer. EU, FP6, IST, [www.elektra-project.org](http://www.elektra-project.org)

<sup>3</sup> INSCAPE – Interactive Storytelling for Creative People. FP6, IST, IP, [www.inscapers.com](http://www.inscapers.com)

the fields of Technology-enhanced, game-based Learning respectively Intelligent Content and Semantics and authoring tools for the creation of interactive multimedia stories. Hereby, the Serious Gaming group at TU Darmstadt (TUD; being established late 2008, arisen from the former Digital Storytelling group at the Computer Graphics Center (ZGDV e.V.) in Darmstadt) brings in its comprehensive know-how in the area of Interactive Digital Storytelling and Storytelling based Edutainment applications [8] as well as its technical achievements out of INSCAPE, namely ICML as XML-based format to describe interactive stories and first demonstrator versions of a Story Engine and a Story Editor [5] to create, structure, experience and control ICML-encoded stories in Storytelling platforms such as INSCAPE. These concepts and technologies are further cultivated within 80Days and –combined with learning and gaming concepts– being adapted to the needs of Story-based DEGs (see Figure 1).



**Fig. 1.** Technology-enhanced Learning

The main questions tackled within the first project period of 80Days have been “*What makes a good, Story-based learning game?*” on a fundamental level and, more concrete “*How to build such an exciting game?*” as well as “*How does a story continue at a certain moment during play?*”. To answer these questions, the consortium investigated research in adaptive, interactive digital storytelling as well as learning and psychology including competence development.

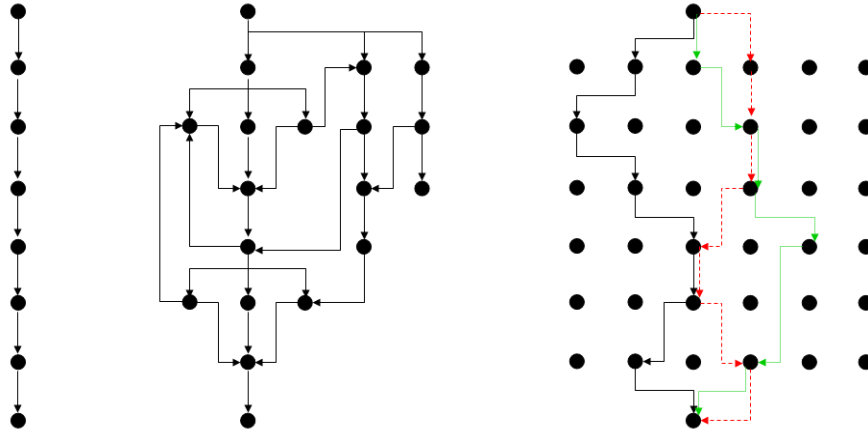
From a Storytelling perspective, the major challenges we addressed so far concern a) integration issues, both on a conceptual and technical level, b) the Narrative Paradox describing the conflict between author and player control [12], c) the question what happens during run-time when some conflicts occur among the different approaches and underlying methodologies respectively among the corresponding run-time components (Game Engine, Story Engine and Adaptive Learning Engine) and how the game continues? The following sections of this paper concentrate on those adaptive storytelling aspects for DEGs; first conceptual approaches to merge Storytelling and learning aspects and related State-of-the Art research work are described by Kickmeier-Rust, Göbel and Albert in [11], detailed information about methodologies of the Learning engine is provided by Albert and Peirce et. al. in [1] and [15].

## 2 Adaptive Digital Storytelling Framework

During the first project year of 80Days, an adaptive storytelling framework has been conceptualized addressing the RTD issues mentioned above. Central aspects include the analysis and use of appropriate story forms, structural story models (serving as the threads of stories) and the conceptualization of Narrative Game-based Learning objects (NGLOBs) as atomic story units to compose such Story-based DEGs.

## 2.1 Story Forms – Sequencing in DEG

With respect to macro adaptation and the question how a story continues at a specific moment during play, figure 2 presents the main classes of story forms for games and the pros and cons of its usage for sequencing and macro adaptation in DEGs.



**Fig. 2.** Story Forms: Linear (left), branching, non-linear (center), modular, re-use (right)

The simplest form represents the linear approach: The advantages are that the author has full control of the story and it is quite easy to implement that approach from a game developers perspective. Contrary, the major drawback is the lack of flexibility and possibilities for personalisation and adaptation in the sense of macro adaptivity and sequencing. Branching is a little more complex than the pure linear approach and more expensive in terms of content production, however, there is still full authorial control and a lack of flexibility for macro adaptation.

The non-linear approach is more flexible and provides some space for macro adaptation and sequencing of story units due to the variety of transitions per story unit. Nevertheless, there is a limited possibility to combine and re-use story units in different scenarios, story lines and contexts, for instance different user groups, game lengths or game modes in 80Days.

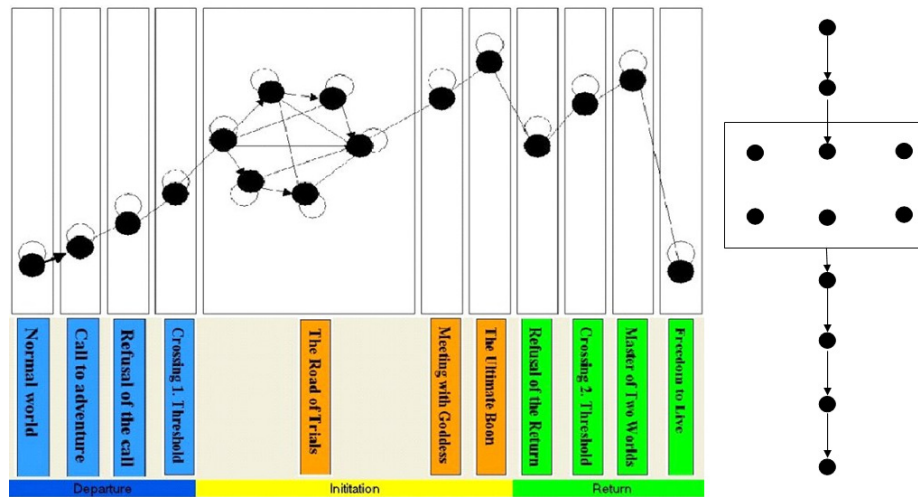
Within the modular approach, the set of story units might be understood as “a sea” of story modules, which might be (in principle) freely connected and combined with each other. This approach builds the basis for emergent narrative Storytelling systems [4, 13] and offers best opportunities for macro adaptation and an almost endless set of possible storylines/paths or sequences of story modules. On the other side authorial control is very limited –contrary, the player gets more or less full control over the scenario– and it becomes quite difficult to “guarantee” a suspenseful story.

In sum, it is definitely not possible to determine which story form is most appropriate for adaptive, Story based DEGs. Contrary, from our perspective, the challenge is to combine the different forms and find some good balance among linear and modular concepts to provide enough flexibility for macro adaptation and sequencing on the one hand and simultaneously to “guarantee” some suspenseful

story based on well-proven and elaborated story structures such as story models used in literature, theatre, TV/film or Story-driven adventure games.

## 2.2 Hero's Journey as Thread

From a top-down perspective, that combination of linear and modular concepts might result in some guided, but still open and flexible story structure such as the Hero's Journey [2, 16] well proven in the field of learning games, especially learn adventures. We identified the Hero's Journey (see figure 3) as the most appropriate existing story model matching the requirements of 80Days to create highly flexible and adaptive, yet suspenseful and informative DEGs following the RTD paradigms of 80Days.



**Fig. 3.** Hero's Journey story model (left) – linear and modular story units (right).

In demonstrator 1 of the 80Days approach being prepared as “early demonstrator” after project month 15, the first part of the Hero's Journey (the departure) and a good portion of the middle part (the initiation), have been covered: A cinematic intro has been produced to cover the story start and first steps of the Hero's Journey, a tutorial (introducing geography as subject and explaining the gameplay) might be understood as first threshold.

Further, different micro missions (~story units or quests/ level in a typical game) refer to the dramaturgic function of the road of trials, which represents the modular part of the story model. This means, (in theory) the players can decide the order of micro missions on their own, whereby, (in practice) not all sequences (=learning paths) do make sense. For instance, based on CbKST (Competence-based Knowledge Space Theory) and underlying skill structures [3], it might be better to visit a micro mission 1 first and to learn something about subject A, before mission 2 with a subject B (where it is useful or even necessary to have some background knowledge on skill A). Therefore, the skill structure and useful transitions among micro missions

are used within the authoring tool to define reasonable transitions among micro missions and its corresponding associated skills.

The rest of the story model, especially the climax of the story, where the transfer of the moral of the story ("*Save the earth!*" in the DEG on geography in demonstrator 1 of the 80Days approach) should take place and the third part of the story, the return to the ordinary world, will be tackled within the next project period for the preparation of a second demonstrator version.

### 2.3 Narrative Game-based Learning Objects

From a bottom-up perspective, the question is what makes an atomic story unit combining storytelling, learning and gaming methodologies and how to combine those units in a reasonable sequence.

For that, in a first step we extended our existing model for story objects and conceptualised narrative, game-based learning objects and annotated the story objects of ICML with a triple  $F_D \times F_L \times F_G$  of dramaturgic, learning and gaming functions: A dramaturgy function  $F_D$  has been introduced in order to indicate which dramaturgic steps (of an underlying story model such as the Hero's Journey) are fulfilled (by which degree) by a NGLOB; the related skills are covered by a learning function  $F_L$  and the game modes (referring to different user and player groups) by a gameplay function  $F_G$ . Further, weight factors  $w_D$ ,  $w_L$  and  $w_G$  have been defined to indicate the degree of appropriateness of particular NGLOBs to fulfil a specific dramaturgic function (a concrete step of the Hero's Journey, e.g. to transport the moral of a story), learning function (e.g. to provide map skills in the subject of geography via specific methodic-didactic concepts and interaction templates) or gameplay function (e.g. to provide as much as possible information for studious gamers or to make a learning situation as exciting as possible to match the needs and expectations of experienced gamers familiar with action games and a high amount of interactivity).

These concepts have been fully implemented in the ICML format and have been taken into account within the development of the first releases of the Story Engine and Story Editor.

### 2.4 Story Pacing

Concerning intelligent personalization, adaptation and the re-use of content for different user scenarios and contexts, we have elaborated a set of game modes, which represent different speed versions of the game as well as story pacing mechanisms.

Within a login screen at game start, the users are asked to provide some information about their age, gender, game experience and sensation seeking tendency. Based on that assessed criteria an estimation of the users' preference to different game modes is undertaken and the user is assigned to one of the user groups related to the game modes "relaxed version", "driven version" and "fast version". The different game modes are characterized by different speed versions of the game: For instance, within the relaxed version we provide explorative flying without any time pressure; within the driven version there is some time pressure and a virtual character called

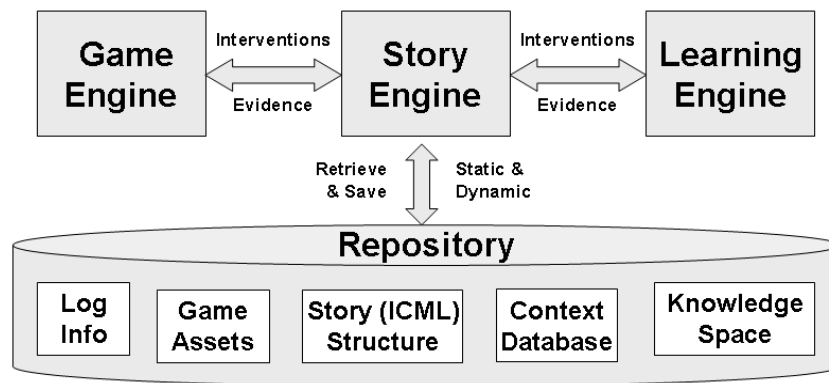
“Feon” motivates the player to hurry up at certain moments; the fast version provides a distinct time limit, exciting background music, etc.

From an authoring perspective, the challenging task is to set the story units (i.e. learning and gameplay situations and NGLOBs) in relation to the game modes and to define how a flexible, adaptive NGLOB should be characterized (constitution and behavior during gameplay) for the different game modes respectively player groups.

From a run-time perspective, the story engine first checks which game mode should be applied and then starts to apply all NGLOBs related to those game modes.

### 3 80Days Technical Platform

The implementation of the framework is based on the results and considerations of theoretical research as described in section 2 as well as in [11] and [5]. Figure 4 provides an overview of the most relevant software modules of the framework:



**Fig. 4.** High-Level Architecture of the 80Days Run-Time System.

A repository of different objects and information builds the basis of the functions of the three major engines involved in the 80Days framework – the Game Engine (GE), the Story Engine (SE) and the adaptive Learning Engine (LE). These objects are provided in different forms, for example as database tables or as files in the file system. Elements of the repository are the assets used in the game, e.g. UI files or 3D objects. Other central parts are the story, encoded in the ICML format, as well as the Context Database, which provides static information about story and gameplay and which manages dynamic information about the development of the story over time during different playing sessions.

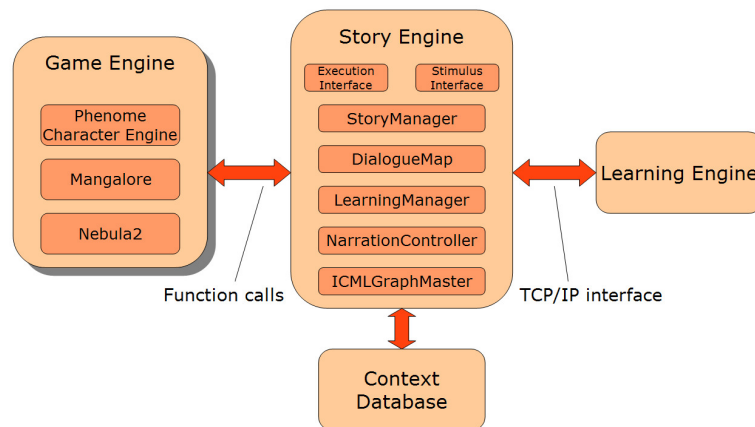
#### 3.1 Run-Time Environment

The main engine the user interacts with is the GE, developed by Testaluna s.r.l. based on the open source Nebula 2 engine and the Managalore framework. The GE handles gameplay mechanics such as steering a UFO, displays the results of interaction and

abstracts the information about the gameplay into discrete events called game evidence (as described in [10] in the context of the ELEKTRA project).

Game evidence is divulged to both the Story Engine as well as the Learning Engine. The latter is a further development of the Adaptive Learning Engine introduced into the ELEKTRA project by the Knowledge and Data Engineering Group at Trinity College Dublin. For detailed information, see [1] and [15]. The tasks of the Learning Engine are interpreting game evidence, assessing the impact of the evidence on the skill representation of the user and returning so-called adaptive interventions which aim at supporting and motivating the user, for example in the form of dialogues.

The Story Engine is responsible for managing the flow of the story, which can either be on a high level (handling only macro-adaptivity, i.e. the sequencing of large story units) or a fine-grained level (e.g. by managing individual speech acts) for more control. Controlled by the story as described in the corresponding ICML file, the Story Engine reacts to game evidence by evaluating the executable story graph and committing the results to the Game Engine, resulting for example in a change of scenes.



**Fig. 5.** Story Engine as Control Unit

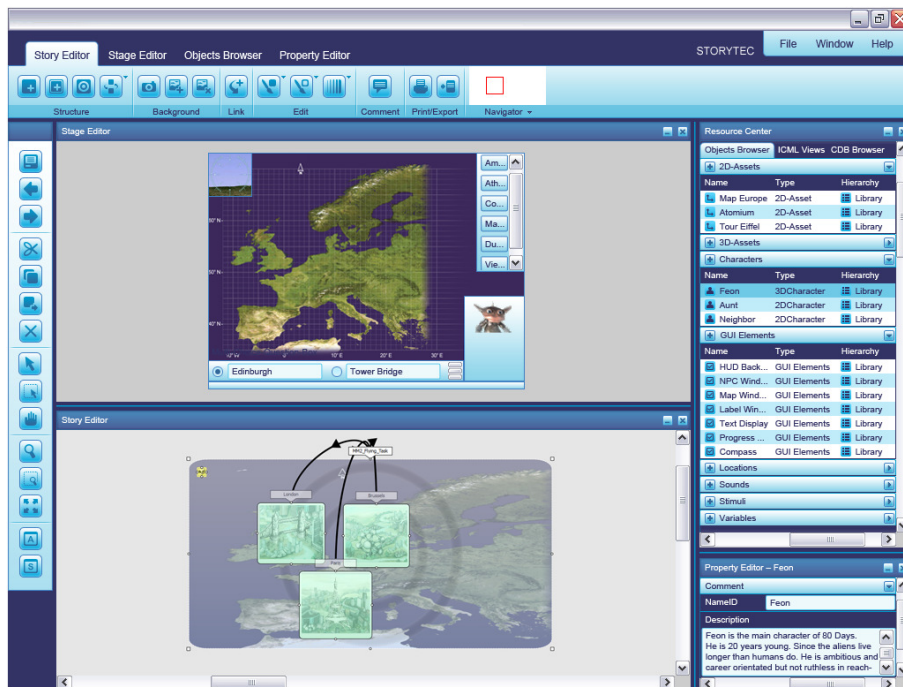
Figure 5 shows a more detailed overview of the interrelation between the Game, Story and Learning Engines. Since the Game and Story Engine are compiled into the same executable and the Story Engine communication components are realized as Managalore-derived classes, the two engines communicate via function calls. The communication between LE and SE is handled via a network protocol since the LE is supplied as a Java application which can run (as “service”) on remote computers.

### 3.2 Authoring Environment StoryTec

With respect to the overall aim of cost-effective production of learning games, TUD set a RTD focus on the conceptualisation and development not only of a Story Editor, but a comprehensive Rapid Prototyping authoring environment entitled “StoryTec” to compose 80Days like learning games.

Hereby, similar to the previous INSCAPE project, the principal aim is to enable authors, especially non-programmers, to create individual stories and to bring in interactive elements without programming skills: Different editors are provided enabling non-programmers to compose interactive scenarios or to define rules and conditions which are considered within the unfolding process during run-time in order to determine how a story/educational game continues at a specific moment.

Compared to the previous approach of ELEKTRA, StoryTec improves the maintenance and the direct control of the author. While the framework is more restricted than other solutions with full programming languages, the threshold for non-programmers is intended to be much lower, at the same time providing the user (=author, e.g. a geography teacher) a design space to create and explore/test ideas in.



**Fig. 6.** Authoring Environment “StoryTec”

The graphical user interface (see figure 6) has been designed by TUD in cooperation with htac e.V. as institute for applied science and technology transfer, with direct contact to industry in the field of serious games and DEGs. Based on the different identified potential author groups (game designer, pedagogues and content providers, teachers or technicians/game programmers), the GUI design guidelines are following a mixture between underlying methods and concepts of MS Office products (assuming that e.g. teachers are familiar with that kind of tools) and Adobe’s Creative Suite (providing designers a familiar look and feel).

A comprehensive description of StoryTec and its support for authors (with less or no programming skills) to create interactive, Story-based DEGs is provided in [14].



## 4 Conclusion

TUD's work on adaptive digital storytelling contributes to the two primary goals in 80Days: Both to intelligent personalization and adaptation, as well as to cost reduction on the authoring side.

On the theoretical side, the main results achieved so far include an adaptive storytelling framework providing a) NGLOBs as atomic story units to compose Story-based DEGs, b) a structural model combining linear and modular story forms (a modified version of the Hero's Journey in the case of 80Days) serving as "thread" and c) story pacing mechanisms to personalise and control Story-based DEGs during play taking into account context, player skills and behaviour, game modes etc. in order to decide how a story continues (→ sequencing, macro adaptation).

On the practical side, a major portion of the theoretical concepts have been integrated into the early demonstrator version of the 80Days approach: The Story Engine provides interfaces to a Learning Engine and Game Engine; StoryTec as authoring environment enables authors to create and compose "80Days-like" DEGs.

First evaluation studies for the early demonstrator and the DEG on geography confirm the relevance of 80Days' research activities on intelligent personalisation and adaptation as well as efficient authoring and underline the need to make the DEGs more flexible, pleasurable and adaptive considering the overall context and serving the needs and characteristics of users and their skills and background.

Further RTD activities at TUD will be investigated into the conceptual and technological enhancement of intelligent personalisation and adaptation (optimisation of the Story Engine and underlying mechanisms to control Story-based DEGs) as well as authoring (efficient production; re-use of NGLOBs in different scenarios and contexts plus authoring support for non-programmers to create interactive scenarios). Further, an emphasis will be set on evaluation studies, both to get indicators about the user experience during play (soft factors like motivation, fun, suspense) and usability of the authoring environment StoryTec.

## Acknowledgements

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