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Hangzhou Normal University, Hangzhou, China
E-mail: zhigengpan@gmail.com

Adrian David Cheok
Keio University, Kanagawa, Japan
E-mail: adriancheok@kmd.keio.ac.jp

Wolfgang Müller
University of Education, Weingarten, Germany
E-mail: mueller@md-phw.de

Guest Editors

Ido Iurgel
Rhine-Waal University of Applied Sciences, Kamp-Lintfort, Germany
E-mail: ido.iurgel@hochschule-rhein-waal.de

Paolo Petta
Austrian Research Institute for Artificial Intelligence (OFAI), Vienna, Austria
E-mail: paolo.petta@ofai.at

Bodo Urban
Fraunhofer Institut for Computer Graphics Research IGD, Rostock, Germany
E-mail: bodo.urban@igd-r.fraunhofer.de

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Preface

This special issue of the *Journal of Transactions on Edutainment* comprises two parts. The first part consists of original research papers on interactive digital storytelling in the applied context of edutainment: We wish to thank all reviewers for their availability and their important contributions to paper selection and their suggestions for further improvement of accepted submissions. The second part contains a selection of best papers of the conference eLBa 2011, which were expanded and revised for publication in this journal.

Papers on Interactive Digital Storytelling

"In other words, by now almost nothing that happens benefits storytelling; almost everything benefits information", (Walter Benjamin, Illuminations, 1969). Dispelling such pessimism, the digital age has reinvigorated the powerful foundational bond of learning and storytelling under genuinely novel guises, three of which are addressed in this special issue: Fun, interactivity, and social computing can be seen to testify to the relevance of Benjamin's further considerations: "Actually, it is half the art of storytelling to keep a story free from explanation as one reproduces it... The most extraordinary things, marvelous things, are related with the greatest accuracy, but the psychological connection of events is not forced on the reader. It is left up to him to interpret things the way he understands them, and thus the narrative achieves an amplitude that information lacks." (ibid.) We have organized the research results collected in this part of the volume into the three categories of "Theory," "Technology," and "Case Studies."

The first two papers address fundamental questions of the theory of IDS. Henrik Schoenau-Fog et al. focus on the paradox of authorship that lies at the heart of many approaches to IDS: If an author has prepared a story for a system, then apparently there cannot be any interaction that would influence the storyline in any substantial way, because the resulting new narrative would then contradict the author's intentions and without an author to define the story, for all the extraordinary freedom to interact the resulting system may offer, it will not contain any relevant narration. The challenge of reconciling the requirements of authorship and freedom of interaction motivates much of the research and development in IDS. The authors introduce the reader to this problem and present a method that retains the freedom of navigation while maintaining the possibility to construct various coherent narratives. The authors illustrate their approach with the help of their application, First Person Victim.

Hartmut Koenitz et al. deal with a different very important theoretical issue that is currently hampering constructive exchange about and shared understanding of IDS: Successful theories, ideas, and functional systems are emerging that prove that there are solutions to the paradox of authorship; but there is no established conceptual vocabulary to discuss with clarity and precision the common traits and the differences of the various efforts. The authors argue that this is due in good part to the diversity of backgrounds of the researchers working in this very interdisciplinary field. Koenitz et al. then introduce a unified theoretical framework of the domain, pointing out in particular how tying up to definitions from traditional narrative theory would overly constrain future development. For this reason, a main concern in the development of their framework has been the support for fluidity.

The next two contributions focus on questions of appropriate choice of technology for specific problems of IDS. Theoretical advances and conceptual intuitions often drive the development of innovative technologies that implement or enable these ideas; but the opposite influence exists as well, where recent technological advances are creatively exploited in new ways to improve existing approaches and to produce novel IDS systems. With such a focus on technological advance, Li Zhang reports on improved detection of affective meaning in text-based interactions. The author demonstrates how to employ Bayesian and neural networks for the estimation of mood and derivation of emotional indicators, and presents the IDS testbed used for evaluation.

Kim Dung Dang et al. address another demanding technological challenge: As IDS systems offer increased freedom to interact, with related ranges of outcomes and paths, authorial control and verification of the vast number of variations and possibilities quickly becomes a prohibitively complex task. In the context of programming, the challenge translates to the question on how reliable debugging of an IDS system can be made possible. The presented approach exploits recent improvements of linear logic algorithms to enable automated analysis of resource allocation for all stories that can be generated in a given scenario.

The majority of the papers on IDS in this issue address case studies: Given the complexity of the influencing factors, the diversity of the aspects, and the novelty of many ideas, the royal road most often taken leads through experimentation, prototype building, and early user involvement.

Nicoletta Di Blas and Paolo Paolini report on a six-year large-scale experience with employing digital storytelling in Italian schools. Students of all classes used a dedicated authoring tool for fictional and non-fictional storytelling in a classroom context. The encouraging results regarding curricular as well as broader benefits are backed up by surveys and interviews. Cat Kutay focuses on the cultural experience of the Aboriginal and Torres Strait Islander peoples in Australia. The work addresses ways of empowering these peoples to share and collect culturally relevant stories. For this, multimedia authoring tools appropriate to their narrative style have to be devised and created, and special attention has to be paid for enabling collective narratives from different and possibly conflicting perspectives. Katherine Howland, Judith Good, and Benedict du Boulay have developed a suite of tools that support the storytelling aspects of game creation by 11–15-year-old children. The authors report in particular on the participatory design process towardsthese tools that have undergone initial evaluation with promising results. Helen Varley Jamieson and Vicki Smith report on the use of UpStage, an online platform for real-time interactive performances that also exemplifies distributed collaborative storytelling. The authors provide several examples to illustrate the tool and their ideas, and discuss the new kinds of relationships that emerge between the performers and the remote audience.

Selected Papers from eLBa 2011

Established in 2008, eLearning Baltics (eLBa) has quickly become a well-established international conference for eLearning, instruction and knowledge management. Editions of eLBa comprise a set of pre-conference workshops, the international scientific conference eLBa Science, the business congress and user forum eLBa Business, and an accompanying exhibition for eLearning products and services: the eLBa Exhibition.

The event brings together researchers, practitioners and scientists, people using eLearning products and services as well as people producing them. eLBa Science addresses diverse topics and perspectives, technologies and theories, implementations, and evaluations of eLearning from the fields of computer science, pedagogy, psychology, and design. The topics include technology-enhanced learning, pedagogical issues for eLearning and virtual training, as well as game-based learning and edutainment.

This issue comprises revised and extended versions of selected papers from eLBa Science 2011.

The first three papers address technologies and applications of eLearning. In “Comprehensive Blended Learning Concept for Teaching Micro Controller Technology,” Seiler and Sell present a toolkit for education in mechatronics and computer science that supports Internet-assisted distance learning, home labs, as well as face-to-face education in classes. The second paper by Krüger and Dierks-O’Brien, “Cooperative and Self-Directed Learning with the Learning Scenario VideoLearn – Engineering Education Using Lecture Recordings,” describes the development of the VideoLearn method based on “design-based research,” the method itself, and results from a case study of its application. Finally, Rebholz and Zimmermann discuss concepts for intelligent assessment in “Applying Computer-Aided Intelligent Assessment in the Context of Mathematical Induction.” They introduce the Web-based exercise tool ComIn-M and describe the basic principles of intelligent assessment in the context of mathematical induction.

The next three papers focus on case studies and mobile applications. The paper by Walton, “Access Space and Digital Outreach Trainers Case Study,” addresses the differences between tacit learning and explicit learning through exploration of the relationship between a Local Authority (Barnsley Metropolitan Borough Council) and a third sector body (Access Space Network) whose joint intent is to optimize digital inclusion in an area of economic deprivation. Walton examines how the effectiveness of the “Digital Outreach Trainers” can be improved through socialization and the use of technology. In “Human Computation in Mobile Cooperative Learning: A Museum Tour Case Study,” Flores and Maciuszek present an application scenario merging mobile and cooperative learning by taking advantage of human processing capabilities. The last paper in this section, "Learning to Read by Touching Nametags with NFC Phones" by Riekki et al., presents a pilot study about how near-field communication—mobile devices in conjunction with RFID tags—can be used to support children in developing their reading abilities; the new approach was evaluated with a kindergarten group of 24 children.

The last two papers focus on game-based learning and social media. The paper "Learning, Reasoning and Modeling in Social Gaming" by Söbke et al. contributes a study identifying processes of collaborative knowledge construction in social games, exemplified by an analysis of comments in the FarmVille Wiki. The authors show that players of FarmVille develop and apply learning methods similar to scientific reasoning.

In "Social Media Communication—Social Media as Object and Method for Learning", Riedel et al. present the results of a pilot project on the development of generic and interdisciplinary competencies employing a scenario for self-controlled and collaborative learning in schools and universities.

January 2012

Ido Iurgel
Wolfgang Müller
Paolo Petta
Bodo Urban

Transactions on Edutainment

This journal subline serves as a forum for stimulating and disseminating innovative research ideas, theories, emerging technologies, empirical investigations, state-of-the-art methods, and tools in all different genres of edutainment, such as game-based learning and serious games, interactive storytelling, virtual learning environments, VR-based education, and related fields. It covers aspects from educational and game theories, human-computer interaction, computer graphics, artificial intelligence, and systems design.

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Authoring for Engagement in Plot-Based Interactive Dramatic Experiences for Learning

Henrik Schoenau-Fog, Luis Emilio Bruni, Faysal Fuad Khalil, and Jawid Faizi

Department of Architecture, Design and Media Technology,
Section of Medialogy, Aalborg University, Copenhagen,
A.C. Meyers Vænge 15, 2450 Copenhagen, Denmark
{hsf,leb,fkha06,jafa06}@create.aau.dk

Abstract. When developing interactive storytelling applications, most authors have to choose between providing the interacting subjects with either a predetermined and plot-based narrative structure or a loose arrangement of events, which maintains the freedom of interactivity while sacrificing the author's control over communicating a theme. To address this problem, this paper contributes a method for organizing narrative events in a free-roaming virtual environment. The Interactive Dramatic Experience Model (IDEM) retains the freedom of navigation while maintaining the possibility to construct various coherent narratives that enable the theme to be communicated. This may be of particular relevance when using digital, interactive, and representational technologies in the mediation of ethically relevant and socially responsible themes. In order to explore the use of the IDEM, we have developed and evaluated the "First Person Victim" application. This interactive experiential storytelling scenario is intended as a tool for teaching about the negative consequences of war.

Keywords: Edutainment, Authoring, Interactive Storytelling, Drama, The Flying Wedge, Engagement, Emergent and Embedded Narrative.

1 Introduction

In certain circumstances the author/designer of an interactive storytelling application may intend to allow maximum freedom of interpretation into unforeseeable new narratives. However, this is not the case for interactive storytelling scenarios that are concerned with communicating ethically relevant and socially responsible themes. This is particularly evident in applications intended for learning, where the challenges are to maximize the interacting subject's freedom of navigation while maintaining a threshold of narrative closure and reception of the main theme intended by the author of the application.

In this paper we will describe our attempt to develop an interactive experiential storytelling scenario, which supports the participant's engagement during the experience and also incentivizes post-experience follow-up discussions. By enabling

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each participant to experience an individual version of a narrative concerned with a particular didactic or normative topic, we give them the chance to discuss the theme from different points of view. For example, in a classroom setting the intention would be to provide students with individual, customized experiences which would then foster and support in-class discussions e.g. [1]. It is thus important that the application can trigger a variety of story-constructions among students, while maintaining the freedom of navigation, the coherence of the causality between events, and effectiveness in the communication of the theme.

In order to design and author an experience that offers the potential for multiple individual story generations, it is also necessary to address the challenges of the combinatorial explosion [2] by founding the experience on a limited amount of encounters and events. It is thus essential for the author to organize events in a way that gives the interacting subject the sensation of confronting indefinite possible outcomes in a free-roaming virtual environment, which in reality are based on a limited amount of events.

This problem leads to a range of questions, which are subsequently addressed in this paper: How can such an experience be planned by an author? How can events and encounters be organized and structured? How can a sense of coherent causality be maintained? How can one ensure that the theme is effectively communicated? And, finally, how can engagement be sustained in such experiences?

At this point it is relevant to qualify the terms “author” and “authoring” as used in this context. Customarily, in the field of digital interactive applications, the roles of designer and author are conflated. Authoring therefore includes mainly the general tasks of a designer, without paying particular attention to the thesis or the substance of the content being mediated. Whereas this may be the case in purely entertainment applications, it may sometimes be problematic in the context of edutainment and serious games that deal with didactic or normative content. In these cases, the authoring part of the equation should be more concerned with assuming responsibility for the content.

2 Drama and Narrative Structures

In order to address the questions mentioned earlier, we begin by stressing the importance of dramaturgy. When working with edutainment by using interactive storytelling as a tool for teaching, dramaturgy may be used as a central element in the creative process. Drama has been used as a tool for human intellectual and emotional development since the times of the ancient Greek philosophers, for whom the cathartic effects of tragedy, for example, played an important role in the moral and ethical development of society in order to encourage justice [3]. Additionally, dramaturgy has also been considered as a prerequisite in the authoring and design of modern interactive storytelling applications [4].

Through this project we will thus attempt to use dramaturgy and interactive storytelling in order to create an interactive dramatic experience intended as a tool for mediating serious issues in classroom settings.

However, an author's construction of dramatic tension, which is determined by the causal relationship between the chains of events, may conflict with the navigational freedom of an interacting subject. In general, this relationship between authorship and interactivity is seen as being inversely proportional, and the problem of having a free-roaming interactive world and an author-controlled narrative at the same time is often termed as the "Narrative Paradox" [5,6,7,8].

Various plot-based linear and interactive narrative structures have been used for inspiration by various scholars as attempts to overcome the challenge of the narrative paradox. In the following subsections, some common structures will be described in order to assess their potentiality for creating interactive and dramatic experiences.

2.1 Linear Structures

Linear narrative structures imply the predetermination of a sequence of events by the author, where she is fully in charge of not only choosing the theme to be conveyed but also the sequential order of its deliverance. Hence, a reader in this case obviously has a fairly passive role, without being able to act and affect the story.

Fig. 1 illustrates three common ways of describing this linearity and the important milestones in the development of the plot. In Fig. 1a, the Aristotelian model of linear stories is shown, indicating where the storyline comprises four major periods: exposition, ascending storyline, climax, and dissolution [9]. Fig. 1b shows Freytag's dramatic triangle or pyramid, where the dramatic tension rises from the introduction to climax and falls to catastrophe [10]. Finally, Fig. 1c demonstrates Laurel's well-known plot structure model, which consists of several segments [11]. The slope of each segment and its degree show the amount of event tension: (a) represents the exposition, (b) the central action of the story, (c) where characters take major and convincing actions to obtain their goal, (d) represents a period of heightened activity and commitment where many probability lines are eliminated, (e) is the climax where one of the probability lines becomes necessity, (f) is the falling action representing the consequences of climax, and finally (g) represents the resolution [11].

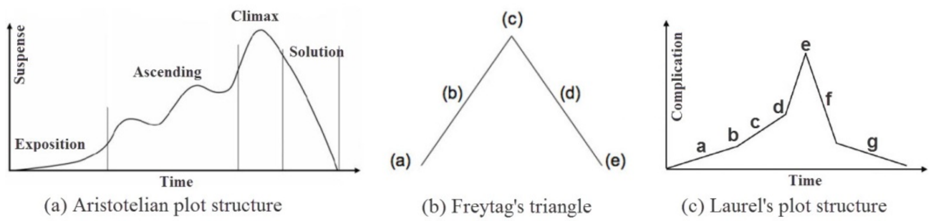

Fig. 1. Linear narrative structures

An interactive drama may benefit from using rising suspension, tension, or complication to engage interacting subjects in the story. However, the problem of how to combine a linear structure with freedom of interaction still remains.

2.2 Non-linear Structures

The storyline of the plot takes a different shape when interactivity is involved. Interactivity implies freedom for the interacting subject and differential readings of the narrative, which may interfere with the theme or topic intended to be communicated by the author, since there is often little or no control over how the interacting subject might encounter events in such narratives, as can be seen in the following few examples.

Fig. 2a illustrates the tree branching structure as described by Ryan [12]. When a specific branch or node is taken, there is no possibility of returning back to the decision node, and one of the problems that an author then faces is rapid growth after a few steps, which may lead to a combinatorial explosion [2].

Fig. 2b shows the open plot structure [13], which can look like a road map consisting of decision points that may carry the user to another point of decision – your decisions take you wherever you want to get. It is considered the most expressive format for the reader and the less expressive for the author [13]. In addition, the dramatic arc is almost abandoned for the interests of exploration, modification, and investment [13].

Fig. 2c demonstrates the network plot structure in which, according to Ryan [12], the recipient's movement will neither be free to navigate nor limited to a single course. The structure allows circuits, so the duration of visiting of each node cannot be controlled by the system. Furthermore, narrative continuity can only be possible from a single node to the next, or between sequences of nodes with single connections. For instance, the user may go through a node where it is narrated that a specific character is dead, and then subsequently move to another node where the same character might still be alive.

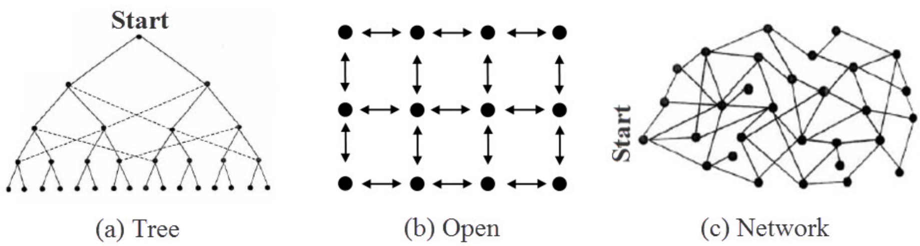

Fig. 2. Non-linear structures: (a) Branching: no way back; (b) Open: no dramatic arc; (c) Network: circuits allowed

These are just a few structures of the many that have been used or postulated by theorists and designers. What they have in common is that they highlight the challenges faced by authors when organizing events in ways intended to provide a dramatic experience.

2.3 Emergent Narratives

In the field of interactive storytelling, various attempts have been made by researchers to overcome the previously mentioned challenges of the narrative paradox and the combinatorial explosion.

Contemporary researchers in the field consider the "emergent narrative" notion – where the narrative can be generated as a result of interaction between characters – as one possible solution for the challenge of solving the narrative paradox [14,15,16]. Emergent narratives are often implemented by the use of AI, rule-based interactions, and intelligent agents.

These attempts to design systems that are highly non-linear focus on the developing of so-called character-based storytelling, where the story emerges from the roles played by the virtual actors, coupled with the dynamic interactions between these roles. Using AI techniques, the characters are assigned with different plans of action, and the actions they take correspond to possible behaviors, for example the expression of personality traits and moods. The user's intervention causes alterations to the plot and interferes with the character's actions. Based on this scenario, the user must be able to determine what a likely next move could be or how dramatic the ongoing event is. An eventual goal for the user would be, for example, to change the ending of a familiar storyline towards either a happier or a more humorous conclusion e.g. [17].

Another well-known example of an emergent narrative is "Façade", which includes theatrical drama, while the structure of events follows the Aristotelian dramaturgic arc of tension, exposition, ascension, climax, and denouement/resolution [18]. Comparable to this approach is the interactive storytelling platform "Scenejo". This application enables playful simulations of dialogue between animated 3D virtual agents and the user, by employing the chat-bot technology for a text-based interaction [19].

A final example which is relevant to the present context of didactic or normative content (in edutainment) is "Fear Not!" [20], which addresses the theme of bullying through role-playing with 3D characters.

These examples of emergent narrative experiences focus on allowing the interacting subject to intervene and communicate with characters in order to change the course of the generated stories. In this project we focus on a different issue, i.e. utilizing embedded events [21] in virtual environments to give the interacting subject the sensation of participating in the construction of a plot-based emergent narrative, while maintaining dramatic tension and engagement and, most importantly, assuring the effective reception of the intended content.

3 The Interactive Dramatic Experience Model

Our exploration of integrating navigational interactivity with a plot-based narrative is driven by the goal of mediating an interactive dramatic experience that encourages the interacting subject's individual story construction while sustaining engagement. The idea is that this can be achieved with a limited number of embedded events which, if organized in a certain way, can produce the *sensation* of participating in the construction of an emergent narrative, addressing this way the challenges posed by the narrative paradox and the combinatorial explosion.

The proposed "Interactive Dramatic Experience Model" (IDEM) intends to provide authors with a method that can be employed to plan and lay out the organization of events in a manner that will guarantee the communication of a theme while at the same time allow the interacting subjects to experience navigational freedom in a virtual environment.

Our approach in developing the IDEM is inspired by investigations concerning authoring for emergent narratives, as in for example [15] and by taking the concept of the "Flying Wedge", introduced in Laurel's seminal work [11], as a very plausible starting point.

3.1 The Flying Wedge

The Flying Wedge concept is based on a theatrical point of view, whereby a completed plot in a play represents the whole action, and the potential of a play is formulated from a set of possibilities available to the author or playwright. As the play progresses, the number of possibilities of potential events decreases radically. These possibilities are influenced by the play's enactment. The performed enactments eliminate some of the possibilities and make some others more probable.

As the course of events becomes more defined, the resulting decrease in possible outcomes "[creates] engagement and varying degrees of suspense in the audience" [11, p. 69]. These events lead to a final moment, or peak, at the play's climax. At this point all the competing lines of probability are discarded except for one line, which then becomes the outcome. In this instant the whole action of the play is completed, and finally the probability becomes the necessity. This process is illustrated in Fig. 3 and can be described as the dramatic potential, which is formulated by possibility, probability, and necessity over time.

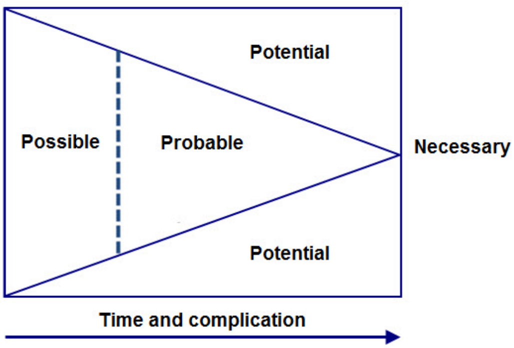

Fig. 3. The flying wedge – a plot's progression from possibility, to probability, to necessary events [11, p.70]

The actions in human-computer interaction can also be described as having a beginning, middle, and an end. The beginning is made up of incidents that are parts of the whole experience. Therefore playing a digital game from the beginning to the end can be considered as a whole action. Human-computer activities are furthermore similar to drama in the process of formulating potential through progression from possibility, to probability, to necessity. For example, choosing a certain character at the beginning of a digital game initiates the process of delimiting the potential. Thus, the shape of the potential over time in digital games and interactive storytelling could be compared with the structure laid out by the flying wedge. We have therefore used this structure in a literal fashion to lay out the foundation for the IDEM.

3.2 The Structure of the IDEM

In our conceptualization of the IDEM, in Fig. 4, a few additions have been made to the original model introduced by Laurel [11]. First, a definite number of scenes (or stages) are organized linearly from A-F (in the example of Fig. 4). Each of these scenes consists of a column of equivalent "elements", or "units" (represented as circles), which are possible manifestations for each of these scenes or stages of the narrative.

Additionally, a drama manager is included in order to organize and trigger specific events depending on the executed actions and navigational choices made by the interacting subjects. Any implementation of the drama manager should thus be concerned with selecting the available narrative elements in each scene. An author can therefore plan for and organize any number of narrative elements within each of the scenes or stages of the IDEM.

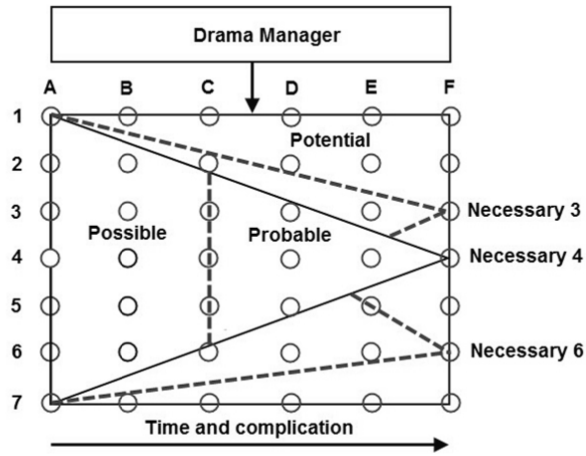

Fig. 4. The IDEM. A drama manager is added to the flying wedge, as well as the narrative elements represented by the circles.

The dashed vertical line represents the inciting incident, where the events begin to rise in tension in order to reach the highest level at the climax; it is also the threshold that separates the many possible events from the fewer probable events.

The moment the interacting subject experiences one of the narrative elements or events of the first scene (column A in Fig. 4), a rough notion of the whole action emerges and the subject starts to have expectations of what is about to come. The subject might then interpret the narrative elements encountered in the environment as the consequential effects of past encounters, which may stimulate curiosity and inspire her to go on to discover potential causes, thereby supporting engagement.

The gradual sharpening of the wedge is depicted in Fig. 5 by illustrating the progression from upper-left to bottom-right. This sharpening determines the amount of narrative elements available for the interacting subject (represented by the gray dots). Moreover, the subject's chosen and executed actions (represented by the black dots) determine which events are going to be available in the next step.

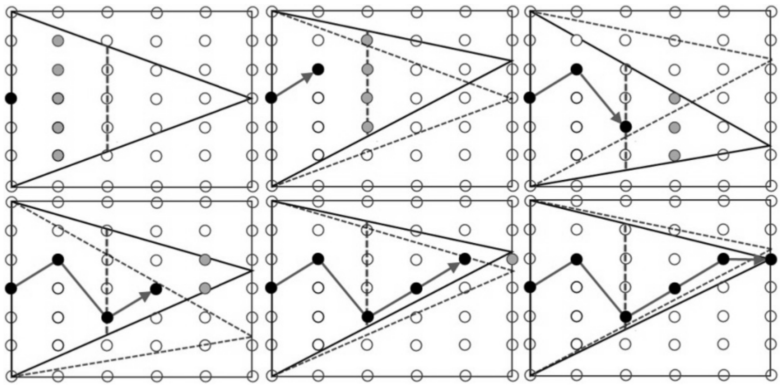

Fig. 5. The progress of an eventual story development, illustrated from upper-left to bottom-right

As the story unfolds, the actions performed by the subject lead to a limitation of the number of possible events available further on in the experience. The drama manager uses the executed action to eliminate some events and make others more probable to be encountered later. In other words, the executed actions constrain further what may follow. Carrying out some actions make more sense than others in terms of cause and effect. Therefore, more probable lines and their degrees of suspense may increase the subject's engagement.

At the final stage – the necessity – all the competing probable lines or probable narrative events are eliminated except one. At this point the interacting subject has a single event (necessity) remaining to be involved in, which represents the peak, or the end (climax), of the story.

The IDEM makes it possible for the interacting subject to experience various storylines, beginning from a variety of starting points and leading to several story endings influenced by the subject's freedom of interaction, hence generating many possible experiences and story paths that are different from one another. Furthermore, the experience provided by the IDEM is intended to be divested of any kind of game characteristic that might lead to the loss of dramatic tension in the overall experience (interrupt dramaturgy).

4 Case: The First Person Victim

The IDEM presents opportunities to create interactive applications in different edutainment contexts. In this paper, the model's application is illustrated through the case study of our prototype – "First Person Victim" (FPV) – which is an interactive experiential storytelling scenario intended as a tool for learning about the consequences of war. This theme was chosen as a showcase for educational purposes, with the aim of contrasting with games and other experiences which may motivate the interacting subject to carry out violent and aggressive behaviors (e.g. shooting, killing, and demolishing) [22]).

The theme of the FPV places the subject in the role of an unarmed civilian in a town, which is under attack by a foreign military power. During the experience, which lasts from 5 to 20 minutes, it is possible for the interacting subject to navigate freely in the virtual environment and thereby trigger various narrative elements. In the current prototype it is not possible to interact directly with other characters but only to witness tragic and dramatic events unfolding in the war zone.

The environment has been designed and implemented using the game engine Unity [23], which can be utilized to create a 3D First Person Shooter (FPS)-style environment and other types of experiences.

4.1 Applying the Drama Manager

A dynamic drama manager in the IDEM has been implemented to control six scenes in the FPV experience (columns A-F in Fig. 6). Each scene consists of seven alternative narrative elements (rows 1-7 in Fig. 6). The experience thus comprises a total amount of 42 micro elements/events, which can be triggered by the interacting subject (although only seven will be experienced in a single passage). Each scene represents an area in the virtual environment. For example, scene A is an apartment, scene B is a street section, and scene C is nearby a tunnel. The spatial design of the virtual environment is not directly related to the IDEM, although layout of the space may support increasing necessity, tension and engagement.

The 42 micro elements may consist of events (e.g. an exploding fuel station), encounters (e.g. with a woman who is looking for her family), or interactive objects that allow the interacting subject to obtain particular information (e.g. a cellular phone conveying information on where to go). Each event is thus in the form of audio, visual, and audiovisual elements.

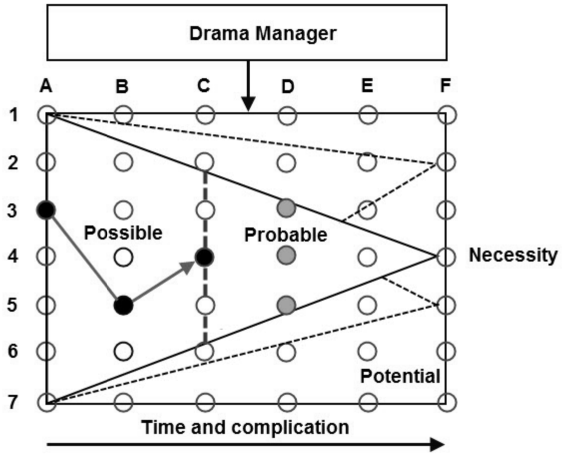

Fig. 6. The IDEM as used in the FPV. A storyline (the arrow) is determined by the flying wedge and the drama manager's selection of available events, and is generated based on the interacting subject's navigation and choices.

The subject is, for example, able to trigger an "audio object" such as a radio to get some information, or to receive phone calls (Fig. 7a). It is also possible for the subject to receive visual mobile text messages and to interact with a TV and watch visual footage of the beginning of war at the same time as the first rocket is hitting the neighborhood (Fig. 7c). Furthermore, encounters with other characters are represented by audiovisual elements and consist of enactments of real actors projected onto a 2D plane in the virtual environment (Fig. 7b). The narrative elements in the IDEM can thus easily be expanded to many other kinds of expressive means, depending on the intention of the author.

Fig. 7. Examples of narrative elements in the form of (a) audio; (b) audiovisual; and (c) visual elements

Additional elements are macro-events, which are constantly active during the entire experience, independently from the interacting subject's actions. These events can, for example, be explosions, rocket attacks, air raids with helicopters, etc.

The narrative elements are triggered based on the factors of time, space, and proximity between the interacting subject and the objects. The subject may, for example, receive a phone call after a specific amount of time spent in the same location if the subject is not performing any actions. However, most of the events are triggered based on a specific distance from each event (the distance is unknown to the interacting subject). Fig. 8a depicts a situation where the subject has moved close enough to be able to listen to one of the characters in the experience, who is offering to help the subject to cross the border in order to get to a safer place. Fig. 8b shows another event in which the subject discovers a rocket-launcher, which is the origin of the rockets fired into the town, and thereby realizes the cause and effect relationship in the story. Finally, Fig. 8c depicts yet another situation where the interacting subject has decided to leave the town and rockets are destroying a nearby residential area.

Fig. 8. (a) Meeting a character; (b) Military vehicle firing rockets; (c) City being bombed

The drama manager furthermore organizes and selects the events for each node. Each single event in scene A (see column A in Fig. 6) is connected to five possible events in scene B. Each single event in scene B again has connections to four possible events in scene C. This process continues further until a single event is available: this single event represents the climax in scene F – in our case the end of the tragic story.

The availability of node choices is thus generated by the drama manager as follows: if the interacting subject triggers in an event in node A3, for example, the next available events will be only in column B (however, not all possible events in column B), and if the subject then triggers the event B5, the next available events will be only a range of events in column C. The direction of interaction or the plot generation will be therefore always progress in order from column A to F based on the interacting subject's former actions.

In order to illustrate this with an example from the FPV, let us assume that the subject triggers the event A3 in the apartment in Scene A that turns on the TV. This then enables the subject to watch the news and understand that the city is under attack. At least five of the next available events in scene B will then be causally related to the perceived information. Therefore, the following possible events might be that a neighbor knocks the door and tells the subject to hurry to leave the building (B3), or that a helicopter drops paper sheets with a message urging civilians to leave the city (B5).

The function of the drama manager is thus to allow certain events to be active for triggering by the interacting subject, while the remaining events will be deactivated. The author will therefore be in charge of deciding and implementing which of the events will be active at the various scenes, by taking into consideration the causal relationships between the events, so that every available event must make at least some sense with the previously triggered ones.

4.2 Maintaining Tension

In order to visualize the level of tension in the FPV, Fig. 9 shows the merging of Laurel's structural plot model for linear stories (see section 2.1, Fig. 1c) and the functionality of the flying wedge. Some segments in the original model have been discarded, namely 'f' (falling action after the climax) and 'g' (resolution). The reason for this is that we have chosen to follow the tragedy genre in the FPV, thereby ending the narrative at the most tragic incident which consequently is also the climax (see further explanation in [22]). In other words, the storyline comprises only segments (a, b, c, d, e), with (e) representing the climax or the necessity, in which case the concept will match with the functionality of the flying wedge that ends the story at the same level of climax or necessity. The single spheres that connect each of the single scenes from A to F represent the navigational choices made by the interacting subject, while the line between the nodes represents the generated storyline.

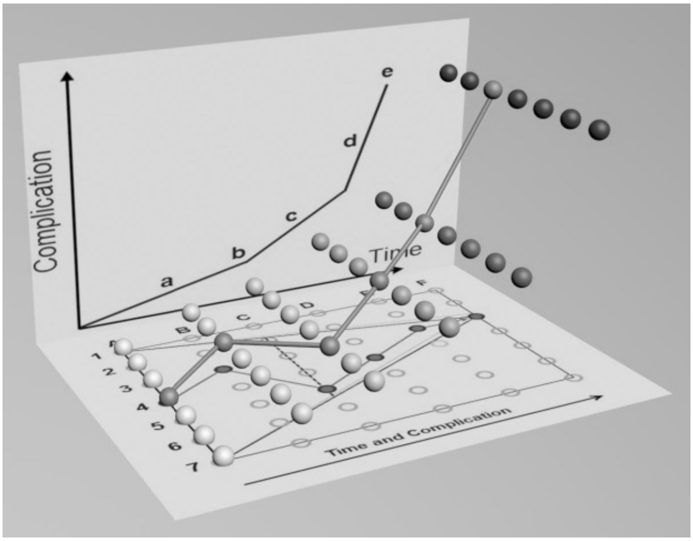

Fig. 9. The IDEM concept illustrates the storyline path generation, which maintains the dramatic arc of tension (further explanation in the text)

The figure also illustrates the gradual increase of event tension that is implemented with inspiration from Laurel's work [11], represented here by the gradient of the spheres from lighter to darker, the darkest being the highest level of tension among the events. For instance, witnessing an event where someone is being kidnapped (e.g. event B4) is lower in tension than the same person being shot (e.g. event F3).

The light gray color in the first row represents the tension of events as being very low. The events in the second row are a bit higher in tension, as the interacting subject witnesses or becomes involved in events that are tenser compared to the previously executed events. The third row of events, with a gradual darkening in color, involves more dramatic situations, wherein, for example, a man is trapped in a car which then explodes. When the interacting subject reaches the highest row of events (the dark gray spheres) the subject may witness even more dramatic occurrences, for example the torture of a friend or a relative (in the story) being shot. The level of tension of events included in the IDEM should thus be planned by the author to increase gradually, if the experience is to have an effective dramaturgical development.

4.3 Plot Structure

The overall plot structure of the IDEM can be described as progressive, as it is moving ahead in one direction (Fig. 10). The availability of node choices is handled by the drama manager, as described in section 4.1, and the direction of interaction or plot generation will therefore progress from column A to F.

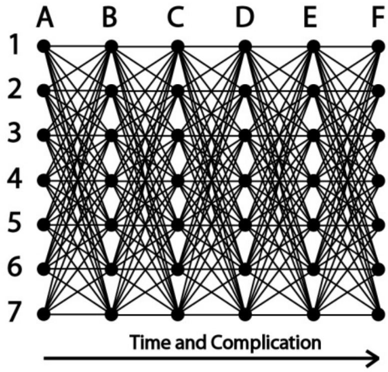

Fig. 10. The progressive plot structure of the IDEM. Each node in each column is connected to all nodes in the next column.

If we compare this structure with the branching tree structure mentioned in section 2.2, we notice that the outward branching becomes inversed with the aid of the flying wedge. The gradual sharpening of the wedge thus guarantees an inverse branching functionality, solving the problem of an eventual combinatorial explosion of story endings.

Another characteristic that may distinguish the IDEM from other non-linear plot structures is that it is intended to maintain the dramatic arc. However, the author will still be responsible for developing narrative elements to the predetermined nodes. The narrative elements in the rows of events should thus preferably have a gradual increase in tension and causal relationships between the rows, hence maintaining the drama and narrative coherence.

Finally, the pattern of nodes is not statically scripted – it is generated dynamically by the drama manager, depending on the interacting subject's input. This feature is thus an alternative to the static fold-back structure often used in games. The subject's choice and navigation furthermore determines the availability of the amount of nodes, and in addition specifies which nodes will be triggered next based on former actions. As such, the storyline is generated from the reciprocal interaction between the subject and the system.

4.4 Sustaining Engagement

In order to supplement the drive of the drama, we additionally prompt the interacting subject's desire to continue the experience by using the Player Engagement Process framework [24] as inspiration to design for sustained engagement. We therefore, for example, encourage subject-defined intrinsic objectives. One way of doing this is by presenting conspicuous events, which obviously must have a triggering cause, but such cause remains implicit or not utterly revealed, triggering curiosity in the interacting subject to explore further and seek more information in her surroundings. For example, the subject might witness the explicit effect of exploding rockets, but she may be unaware of the implicit cause of the rockets, which then may trigger a desire to discover the location of the rocket launchers.

Moreover, a few events include extrinsic application-defined objectives (e.g. a character tells the subject to get to a van that can help the subject to escape out of the town). This way we might enhance the subject's desire to continue, the level of engagement, and the feeling of free navigational interaction.

The FPV application and the events of the IDEM furthermore support activities that might encourage interacting subjects to continue. Besides activities related to experiencing the story and characters, the subjects might also want to keep experiencing the FPV due to:

- Exploration of the environment (e.g. supporting curiosity by making the locations interesting)
- Experimentation with different story possibilities (e.g. trying the application again)
- Solving problems (e.g. attempting to help a woman in a burning building)
- Sensing the environment (e.g. through impressive effects of explosions and soundscapes)

Finally, we intend to make interacting subjects strive to accomplish progression in the experience (e.g. by advancing through the environment) and closure (e.g. to experience the climax of the experience and a sense of intelligibility).

In summary, we thus aim to motivate, engage, and move the subject forward through the dramatic experience, not only through the story, but also through the drive supported by the desire to continue.

5 Evaluation and Findings

We have evaluated the application of the IDEM and the FPV prototype in a range of tests, which are mainly focused on evaluating engagement, the interacting subject's intentions during the experience, and learning outcomes [24,25,26]. These evaluations demonstrate that around 40% of the respondents experienced sustained engagement in the initial 15-20 minutes of the experience, and also wanted to try again, despite the tragic content. However, the main reasons for not wanting to continue in the prototype were reported to be technical problems and level design issues, which thus leaves room for improvement.

In the current study the evaluation will focus on investigating the IDEM by evaluating variations in story generation, the navigational freedom of the interacting subjects, the level of tension, and finally understanding of the theme.

In order to investigate whether the IDEM has the potential for creating a diverse set of story generation outcomes based on a limited amount of events, an initial pilot test was conducted among university students (n=30, unique participants). Test participants were asked to try the FPV application, and each participant's storyline path resembling the triggered events was recorded by the application. The resulting data can be mapped as a graph, which is depicted in Fig. 11.

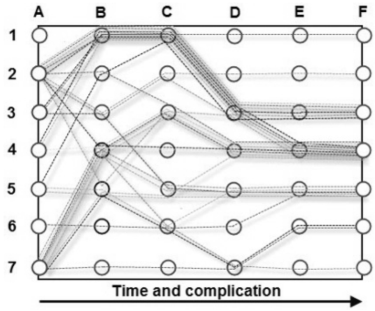

Fig. 11. Different storyline paths generated by the interacting subjects (n=30), with some overlapping lines

The figure illustrates that some narrative events were triggered more frequently than others, resulting in overlapping story paths generated by the test subjects (shown as multiple lines in Fig. 11). Although some narrative events were encountered more than others, the graph illustrates that different participants in the test encountered diverse sequences of events and individual storyline paths. The results consequently suggest that the structure of the IDEM can support multiple story generations based on a limited amount of events.

This finding is furthermore supported by recordings of in-class self-reflections and discussions conducted after the experience in [26]. During these discussions test participants realized that they constructed different stories based on the various encounters and that they had very different experiences which made them want to try again. This variety of experiences may furthermore support repeated interactions and in-class discussions, as also suggested by [1].

Since the events encountered by participants were embedded in different locations in the virtual environment, the variations in the graph in Fig. 11 also illustrate the possibilities for freedom of navigation in the FPV. A series of qualitative interviews with university students, focus group participants (n=3), and single respondents (n=11) also supports this result. The respondents stated in general that the environment felt like an open world, where it is possible to navigate freely, exemplified here by one respondent's statement: "The map seemed very big, and I wanted to explore. I felt that I was on a path and I didn't reach it to see where it ended". These results indicate that the environment of the FPV prototype indeed supports freedom of navigational interaction.

We have not yet evaluated systematically the change in the level of tension among subjects. However, in a run time evaluation, which is described in [25] university students and staff (n=22) reported that they experienced a range of feelings related to tension, such as agitation, nervousness, excitement and anxiety, tension, shock, dizziness, fear, worry, frustration (when unable to help others), powerlessness, anger, misery, disgust, desolation, and emptiness. Future studies are needed in order to explore variations in the level of tension in more detail.

An important parameter to the present study assesses to what degree the communication of the theme has been efficient, and, if so, whether the interacting subjects become acquainted with the theme of the FPV. During all the tests conducted, respondents reported that they understand that the theme is related to being a victim of war or being in a war-zone. In an evaluation among students in three schools (n=40, age: 13-18) [26], findings furthermore indicate that those students who were engaged in the experience more frequently experienced theme-related feelings and acquired knowledge concerned with the theme than non-engaged students. These results thus suggest that communication of the theme by employing the IDEM structure has been successful.

6 Discussion and Conclusion

One of the main tenets of the present work is that what is commonly referred to as the "theme", "topic", "substance", "thesis", or "content" is of central importance in some fields of interactive media. This is the case with edutainment, for if one wants to use digital, interactive, and narrative-based technology for pedagogical, educational, and didactic purposes, there must be a more or less explicit or implicit normative goal in the whole endeavor. From the "edu"-cational point of view, this normativity must be expressed in terms of the intended content and the desired learning outcome. On the other hand, from the enter-"tainment" point of view, the normative goal has to do with encouraging participation with high levels of engagement, fun, joy, playability, and the possibility of an individualized experience.

Edutainment is certainly not the sole field of application in which the intelligibility of particular mediated content is central to the goal of the system. However, some developments in interactive narrative, storytelling, and drama have focused on the generation of engagement by attempting to empower the interacting subject in the composition of the narrative, emphasizing the feeling of narrative closure and not the intelligibility of a particular thesis. The idea with the IDEM is thus to focus on conveying a theme as an interactive dramatic narrative *experience* rather than attempting to devise an application that *tells a story* based on user input.

In any case, two recurrent issues in interactive and non-linear narratives are the "narrative paradox" and the "combinatorial explosion", which pose interesting design challenges when mediating particular contents that need to be conveyed in a trustworthy manner. We set out to address these issues by suggesting the IDEM described herein.

Findings from the evaluation indicate that this model, exemplified by the current implementation of the FPV, provides interacting subjects with an interactive dramatic experience, which entails and presupposes the communication of didactic or normative content, while simultaneously maintaining freedom in navigational interactivity. Another characteristic of the IDEM is that it provides an alternative to the outward branching tree plot structure, described in section 2.2, by introducing an inverse branching structure based on Laurel's seminal idea of the flying wedge [11]. This feature ensures that an author will not risk a rapid increase in nodes, which may lead to a combinatorial explosion. Furthermore, when comparing the IDEM plot structure in Fig. 10 with the network plot structure in Fig. 2c, it is apparent that the IDEM does not allow circuits: A visited node can be triggered only once, while the current available possible events will have a causal relation to previously triggered events.

The model is furthermore intended to serve as a departing point for authors and designers given the task of embedding particular normative content in an interactive application. In this sense it might be of interest for people who are working in edutainment, in sustainable applications of digital interactive technology, in persuasive technology, or authors who have a particular stake in the "message" being mediated. It can also help in making a sharper distinction between design choices and authoring intensions. In applications that have a manifested agenda (other than mere leisure, as e.g. in edutainment), authoring involves assuming responsibility for the content.

We know that the same objectives and normative goals can be achieved in many different ways. In our model, once the authors have laid down their agenda and narrative goals, they can start structuring and planning the narrative using the logic and organization of the IDEM. Authors can then decide on the number of scenes and alternative manifestations of each scene (the narrative elements in the columns). For example – as in our FVP application – an author can start by describing events in the last scene, and then work backwards towards the first scene, while ensuring that there is always an option to encounter events which have a causal relation to earlier encountered events. After organizing these events in the IDEM matrix, the next step is a custom implementation of the drama manager (of which there can be many different realizations according to the particular dramaturgical needs). Authors can moreover use the IDEM for orchestrating engagement triggers, which may create the desire to continue participating in the experience as well as to plan for varying levels of tension. This feature contrasts with the open plot structure, described in section 2.2, by providing a discernible arc of tension.

Finally, after the actual authoring and organization of events, the design part comes into play. Here, many different aesthetic choices and combinations of media elements and resources can be used in the development of the different narrative elements in the IDEM matrix.

The IDEM is thus thought to combine the engaging and motivating aspects of a feeling of participating in an emergent narrative with the reliable reception of the content, so as to ensure the normative didactic goal of the system. Our motivation for the emphasis on "normativity" comes from our interest in the use of digital, interactive, and representational technologies in the mediation of ethically relevant and socially responsible themes. This can be seen as part of a larger concern on the more general sustainability of these powerful emerging interactive representational technologies and the cultural and cognitive ecology of the content mediated through them [27]. This is how we arrive at themes concerning issues such as war, ecology, discrimination, social exclusion, violence, poverty, sustainability in general, and particularly the theme that we chose to exemplify our model, i.e. the consequences of war for civilians and refugees, as presented here with the FPV.

The implementation of interaction possibilities in the FPV experience is, admittedly, fairly restricted and simple in its current prototype state, as the interacting subjects are only able to interact through their navigation in the environment. However, the IDEM concept can easily accommodate AI-controlled 3D characters, as well as other types of interactivity and affordances.

We thus do not claim to have solved the narrative paradox, but merely suggest that using the IDEM in the authoring process may be a contribution in the right direction, particularly in the context of conveying serious themes. The use of such plot-based interactive storytelling scenarios for learning may therefore point to new directions and approaches for teaching and learning through edutainment and purposive interactive dramatic experiences.

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First Steps towards a Unified Theory for Interactive Digital Narrative

Hartmut Koenitz[1], Mads Haahr[2], Gabriele Ferri[3], and Tonguc Ibrahim Sezen[4]

[1] University of Georgia, Department of Telecommunications, 120 Hooper Street
Athens, Georgia 30602-3018, USA
hkoenitz@uga.edu
[2] School of Computer Science and Statistics, Trinity College, Dublin 2, Ireland
Mads.Haahr@cs.tcd.ie
[3] Università di Bologna, Dipartimento di Discipline della Comunicazione, v.A. Gardino 23, Bologna, Italy
gabriele.ferri@gmail.com
[4] Istanbul University, Faculty of Communications, Kaptani Derya Ibrahim Pasa Sk. 34452
Beyazit - Istanbul, Turkey
tongucs@hotmail.com

Abstract. As the domain of Interactive Digital Narrative matures, it becomes increasingly important for researchers to understand the conceptual differences and underlying theories in the different approaches. This paper presents new theoretical perspectives on the fragmented theory and practice within the domain and proposes first steps towards a unified theoretical framework for the domain. The paper is informed by the discussions between theorists and practitioners at two workshops held by the authors.

Keywords: Interactive Digital Storytelling Theory and Practice, Interactive Digital Narrative, Shared Vocabulary, Unified Theory, Story, Narratology, Digital Media.

1 Introduction

The umbrella term Interactive Digital Narrative (IDN, [1]) describes a diverse field, which can be traced back to Weizenbaum's computer program Eliza (1966) that first displayed the expressive potential of digital media.

Ever since, the field - feeding from many traditions - has grown to encompass a wide variety of practices including interactive drama (e.g. Façade [2]), hyperfiction literature (e.g. Afternoon [3]), interactive fiction (IF) (e.g. Zork [4]) and other variants such as interactive cinema (e.g. A City in Transition: New Orleans 1983-86 [5]), narrative games (e.g. The Last Express [6]), location-based installations [7, 8] and mobile media [9].

Researchers from fields as far apart as computer science, literary studies, communications and media studies engage in this vast topic. They encounter artifacts made by artists trained in traditional art practices, and commercial products with their

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own production practices evolved in time; but while the majority of researchers are concerned with theory, they also often double as practitioners themselves. The result is a field not only rich in expressive forms, but also in theoretical perspectives.

The downside of this diversity is in its potential for misunderstanding between researchers. While often the same terminology is used, a particular term or an associated concept can have very different meanings within a specific tradition. This has problematic consequences for scholarly discussion and for communication with parties outside of academia who sometimes create their own vocabulary to describe their products. We feel that the field of IDN is now sufficiently mature that a unified theoretical framework and a common vocabulary will be necessary for further advancement. This has been the motivation for two workshops organized by the authors at the ICIDS 2009 [10] and ICIDS 2010 [11] conferences.

This paper presents our findings from the workshops in the form of a synthesis of the main issues discussed and by outlining strategies for further work in this area.

In our research, we follow the intuition that definitions of narrative used in describing established media forms are insufficient for the analysis of emerging forms of narrative expression we see developing in digital media. Instead we contend that applying such definitions reduces our ability as researchers to grasp the full extent and severity of the new works while at the same time limiting our capacity to create bold experiments that push the boundaries of narrative forms. In this understanding we are guided by developments in contemporary narratology, which cast narrative as a flexible cognitive structure not tied to any particular form [12, 13]. Additionally, our aim is to establish a theoretical framework that is non-static and that can react to developments in the practice of digital media. Consequently, we present our current position, explicitly unfinished, open to discussion and further refinement.

2 Traditions and Positions

Two positions discussed in our workshops can be broadly identified as “IDN as a technical problem to solve” on the side of researchers based in computer science vs. “IDN as a process for discovering new expressive forms” on the humanities side. However, this binary view is preliminary and should only serve as an opening towards a more fine-grained discussion of the underlying perspectives and positions.

A first step towards a better understanding of the plethora of theoretical and conceptual perspectives in IDN is to look at the traditions in which several key academics have been trained and with which they align themselves. The following list provides an overview of some key theorists and practitioners in the field and the respective academic fields they originate in or explicitly refer to in the work on IDN:

Murray: Victorian Literature
Laurel: neo-Aristotelian dramatic theory
Mateas: Computer Science/Artifical Intelligence
Ryan: French Narratology/Contemporary Narratology
Montfort: French Poststructuralism
Davenport: Cinema Verité
Jennings/Harrel: African/diasporic oral traditions

Hayles: English Literature, postmodern literary criticism
Wardrip-Fruin: New Media & Computer Science
Rieser: Electronic Art

A second list describes some particular perspectives on IDN these researchers offer in the academic discourse:

Murray: An emerging expressive form within the specific affordances of digital media [14]
Mateas/Laurel: An interactive version of linear Aristotelian drama [15, 16]
Ryan: A design problem in combining the opposing areas of narrative and interactivity [12]
Montfort: The outcome can be described in terms of story/discourse, but we lack a description of the system [17]
Davenport: An extension of the documentary tradition in giving the interactor agency and allowing her to discover the truth [18]
Jennings/Harrel: An extension of the African cyclical narrative tradition and ritual interventions by the audience, which invites many readings and also allows cultural biased computing [19, 20, 21]
Hayles: Works with an important literary aspect that takes advantage of capabilities and contexts provided by the stand-alone or networked computer [22]
Wardrip-Fruin: The potential of expressive processing within the realm of fiction [23]
Rieser: The encoding of mood, emotion and their syntax takes precedence over plot and traditional forms of narrative technique. [24]

Out of these traditions and conceptual leanings, researchers have developed particular uses of terms such as “story” and “narrative.” For example, Michael Mateas describes story as a product of dramatic action, and defines interactive drama as a specific form, “opposed to interactive narrative” [15]. From this perspective he positions interactive drama as attempting to produce the complete and well-formed plot of the ancient Greek predecessors in every single experience: “once the end occurs, any particular run-through has the force of dramatic necessity” [15].

In contrast, Nick Montfort foregrounds a broad perspective on narratology to describe the relation between Interactive Fiction (IF) and story: “An IF work is always related to story and narrative, since these terms are used together in narratology, even if a particular work does not have a ‘story’ in this ordinary sense” [17]. Additionally, Montfort identifies the puzzle/riddle as the central mechanism, which he links to French Poststructuralist concepts like Jean Baudrillard’s idea that nothing “could be more seductive than the secret” [25] and "Roland Barthes" comparison of the reading of literature to the erotic pleasure of a revealing striptease [26].

Formalist Theories and Structuralist Semiotics have also been used as frameworks for IDN (see also [27]), such as Grasbron and Braun’s GEIST system [28], Szilas’ IDTension [29] or Fairclogh’s OPIATE [30]. Those theoretical traditions share a background in modern Narrative Semiotics [31, 32] dating back to Greimas [33, 34, 35 and to Propp [36]. Several differences exist inside that tradition, but they all imply a special use of the notion of ‘narration’ that differs from its common meaning.

It refers to a complex set of layers and components (varying, from theorist to theorist, from interactantial networks to sequences of events, structures of values, modalities, figurativity, narrating voices, etc.) that results from a special logical organization. For instance, Greimas' seminal works on Narrative Semiotics revolved around the concept of a canonical narrative schema [33, 34], a widely sedimented – at least in Western cultures – sequence assumed to be a kind of narrative primitive. Its formulation varied during the past decades from the original four phases (Manipulation, Competence, Performance and Sanction) to a more modern version composed by only three (Manipulation, Action, Sanction). Those steps were traversed by interdefined actantial positions like Destinant and Destinee, Subject, anti-Subject and Object.

These types of schemata are currently criticized by other schools of contemporary semiotics. The canonical narrative schema – due to its roots in Saint Augustine's theological readings of human actions and Aristotle's dramaturgical theories of action [37] – aims for a straightforward narration, a stable skeleton of roles. A distribution of actantial positions that, in many real-world situations, is far too stable to satisfyingly describe meaning-making processes that are often composed by temporary mistakes and tentative interpretations.

Marie-Laure Ryan's training is in French Semiotics and Narratology and her initial work reflected this, but her recent position understands narrativity as taking a variety of shapes, some of which are media-specific and some other media-independent. She describes the combination of interactivity and narrative as problematic in regards to the creation of meaning: "interactivity is not a feature that facilitates the construction of narrative meaning" [12].

While French Narratology clearly provides insights into Western narrations that, based on ancient Greek and Latin influences, privilege linear structure and causal connections, they show several limitations when confronted with other types of narratives. For instance, many African tales are usually cyclical instead of linear and they make use of a different type of cause-effect relation. This – instead of Greimas' Aristotelian and Augustinian approach – is the model preferred by Pamela Jennings and Fox Harrell. Jennings explicitly rejects Laurel's Aristotelian model:

> Aristotle's Poetics is an inadequate narrative model for the creation of computer interactive art, contrary to the thesis laid down by Brenda Laurel's Computers as Theatre. [19]

From Jennings' perspective, Aristotle's Poetics is problematic because it "encourages linearity and truncation of thought" [19] and as such is inadequate as a model for interactive narrative in digital media. Jennings sees digital media as an opportunity to express cyclic narratives, which do not have the "neat beginnings, middles, and ends required by Aristotelian drama" [19]. Instead she suggests African oral storytelling as a theoretical model with numerous crises and peaks and more than one climax. Jennings points out how this tradition also accommodates interaction both with the audience in the form of call and response and in terms of the narrator's reaction to the environment.

Fox Harrell additionally opposes Ryan's view of interactivity as problematic for the generation of meaning with his understanding of "Computational narrative" as an expressive form, which “produces new meanings that are constrained by the system's author [and] can be dynamically restructured” [20].

The role of narration in digital games was and maybe still is to a degree a conflict point. The now relatively silent narratology vs. ludology debate [38, 39, 40] centered on the argument for a formal analysis of digital games, which rejected narrative as an adequate descriptive and analytical concept. Recently, the ludology position has become more flexible [41] and now again poses narrative as one way to describe digital games. For example, Jesper Juul defines digital games a “half-real”; where the rules and formal aspects of games constitute the real part and define what the player could and could not do. The other half, fictional part helps the player to understand the rules and interpret them in a fictional context [42].

Katherine Hayles’ work on electronic literature represents yet another position toward IDNs. The defining factor is that the work in question holds some literary aspect and takes advantage of computation [21]. This approach covers different types and respects differences between different theoretical approaches. We can see this wide perspective in the two electronic literature collections released by the Electronic Literature Organization in 2006 [43] and 2011 [44], which include a variety of artifacts starting from IF and hypermedia pieces to game modes and even Mateas and Stern’s interactive drama *Façade* [2].

With his background in media arts, Martin Rieser questions the notions of interactivity in digital media and rejects the Aristotelian model of drama as sole criteria for complexities of IDNs. He says: “The active participation of audience is not new nor is it disruptive of narrative diegesis; it is merely incompatible with certain narrative conventions, which have become unduly emphasized by historical accident” [23]. According to Rieser, in digital media the encoding of mood, emotion and their syntax takes precedence over plot and traditional forms of narrative techniques; therefore, instead of a manipulator of plot, the author becomes an architect. In this context, he supports a reevaluation of classic narratological concepts.

This short and by no means comprehensive overview is testimony to the wide differences and some inherent issues with contemporary approaches to IDN. An explicitly diachronic perspective adds another needed dimension to synchronic surveillance of the field. One example for this perspective is the development of the notion of plot from Aristotle to Brenda Laurel and Michael Mateas. Laurel [13, 45] augments Aristotle’s original understanding of plot as complete action, which cannot have anything added or removed. For her, plot in digital media is an interactive, changeable “session on a computer” which creates a “whole action.” Michael Mateas further enhances this notion when he describes plot as a structure that creates the formal constraints for the interactor and informs and guides actions [14].

The re-definition of a term such as plot over a period of time has introduced fuzziness, which is problematic in academic discussions. In other words: Is it Aristotle’s plot, Laurel’s modification or Mateas’ definition we are discussing?

3 Possible Directions

The overview of traditions and positions presented in the previous section highlights two of the pressing problems that IDN research is facing today. First, many of the competing concepts require extensive knowledge of the respective traditions from which they are derived in order to be fully appreciated and understood. Secondly, and to make matters worse, understanding a term in the context used by a specific researcher often necessitates an investigation in the etymological development of the particular term.

In our workshops we have approached these problems from two general vistas. In the first workshop, we were led by the question “Do we need a new narratology for IDN?” Consequently, we have offered and discussed several theoretical approaches that aim to avoid the pitfalls of existing approaches. In the second workshop, we turned our attention towards the problem of differences in terminology and fuzziness in meaning under the heading “Towards a shared vocabulary for IDN.”

What follows is a presentation of particular topics that emerged from the workshops (Pragmaticist Semiotics, Medium-Centric Mapping, and Emotion in Games) as well as an evolving integrative IDN-specific theoretical framework. These diverse directions represent our ongoing research effort centering on the common topic of theoretical investigation of IDN that we intend to converge into a common framework, a unified theory of IDN.

3.1 Pragmaticist Semiotics

The study and the development of IDNs will benefit from a more adequate descriptive methodology, since effective designs derive also from the ability to read other systems and to comprehend their workings. In its most general terms, Semiotics aims at qualitative descriptions of how meaningful experiences emerge from the interaction of subjects with their environment, in its cultural, intersubjective and physical aspects. In the past years, the interest in semiotic analyses of interactive systems has increased with the widening acceptance of digital media as expressive forms.

A critique of Formalist and Structuralist methodologies – expecting a too rigid distribution of actantial roles – was sketched earlier, while discussing some specialized meanings of ‘Narrative’ [26]. A different theoretical view may yield more general results and minimize confusion. We refer to the semiotic part of a philosophy called American Pragmatism or Pragmaticism – as C.S. Peirce, one of its founders, chose to name his own version in the late 19th Century. Pragmaticist Semiotics was highly innovative for its time but did not leave many traces in current IDN and game studies. Yet, Peirce’s work on expectations and tendencies might lead to a different framework for describing interactive narratives that is flexible enough to keep together several of the previously mentioned points of view.

To examine the pragmaticist contributions to the analysis of IDNs, it is necessary to introduce two core concepts from Peirce’s original semiotic theory. A majority of his work revolved around the notion of sign, whose description varied several times during his life, until a late definition found in an unpublished article from 1907 [46]. According to those pages, every possible object, thought or action may be a sign when it stands for a second sign for an interpreter. A simple example: the word "dog" stands for the thought of an animal for those who read it and, therefore, is a sign. But what is, asks Peirce, the meaning of a sign? In its mature semiotics, Peirce reflects on the notion of *interpretant* – the second sign produced by the interpreter based on the first sign: he defines the pragmatic meaning of a sign as the subject's disposition to act in a certain way, to think certain things or to produce certain other signs. Peirce calls this flexible tendency *habit*.

This brief account has only scratched the surface of Peirce's philosophy – spanning across thousands of unpublished, unedited, sometimes self-contradicting pages – but his notion of habit has several unexpected and very concrete applications. If we assume that the meaning of a sign is the tendency to act, the habit it produces for a subject, we could say that the meaning of a red traffic light is the tendency for drivers to stop their cars and also the tendency for pedestrians to cross the road. But – as car accidents sadly remind us – these are just tendencies and not rigid rules.

But what has this to do with describing IDN experiences? If we go back to the seemingly incompatible narrative models that were introduced in the first part of this paper and if we re-examine them from a Peircean perspective, it is possible to think about contextual expectations in terms of habits. Western readers, for instance, often expect that a narration will develop in a certain way, that events tend to proceed linearly and that cause-effect relations always apply. This rethinking is an unexpected contribution to descriptive framework for IDNs, allowing us to reconcile the differences between supposedly universal narrative models and the specific traits of digital storytelling. While it would be absurd to affirm that Peirce foresaw interactive narratives, it is much safer to argue that he well understood the flexibility of human expectations. Instead of fragmenting the field between seemingly incompatible point of views – such as Aristotelian plots vs. circular motions – Peirce allows us to think of them as different habits, different contextual tendencies to expect and perceive narrations and experiences in certain ways. Therefore, different genres and cultural variations may be explained as different habits for which different descriptive schemata are needed.

Given the malleability of digital narratives, it is reasonable to call for descriptive models based on contextual tendencies, on users' expectations. The use of Peircean habits to analyze IDNs seems a promising research direction to achieve such flexibility, but also other similar approaches – detailed in the following sections – are aiming at the same objective.

3.2 A Medium-Centric Mapping of IDNs

Similar to pragmaticist semiotics, a medium-centric approach based on medium theory also offers a flexible perspective towards IDNs. Defined by Meyrowitz [47] but based on the works of Innis [48], McLuhan [49], Ong [50] and others; medium theory looks at each medium as a unique environment with a unique set of communicative skills. This theory helps us to understand narrative features of each medium and "texts" composed on these media; as seen in the discovery of hexametrics in Homeric texts [50]. From a narratological point of view, Ryan argues that there are three main views on the effects of a medium on the narrative content.

First, according to Barthes and Bremond, narrative was independent from the medium. Second, Eco represented a radical relativist view; where form and content could not be separated. Ryan herself suggested a third way, in which only some of narrative aspects are shaped by the medium [12].

Which features of digital media shape the narrative aspects of digital artifacts? According to whom do we define the principles of digital media? Negroponte with his emphasis on bits [51], Bolter and Grusin's remediation [52], Murray's four properties and three aesthetic characteristics of digital media [14] or Manovich's database logic? [53] All these and alternative general approaches can be seen as the features of digital media as a "meta-medium"; an umbrella term used by Nitsche to describe computers [54], which can be expanded to cover all digital media. The notion of digital meta-medium gives us a general understanding not only of IDNs but also of every digital artifact. However, each artifact also has its own features defined by its software and hardware construction. Therefore, every software and hardware combination is describable in general terms of the digital meta-medium but each one of them also acts as a unique medium with specific expressive and communicative features.

Montfort and Bogost [55] offer a model, which can help us to understand this notion. They argue that digital media has been analyzed through five levels which are connected to contexts of culture. The reception-operation level focuses on the user's reception and media effects. The interface level covers the whole discipline of human computer interaction. The form/function level deals with the core of the program, which also includes the formal structures of IDNs; like rules, the structure of the virtual world and the abilities of computer-controlled characters. This is the level where most of the narratological analysis of digital artifacts takes place. The code level focuses on how programs are written and is the interest area of the emerging discipline of software studies. Finally, the platform level describes the abstraction plane beneath the code. The platform creates the basis on which all the other levels are constructed. It not only refers to hardware but also to software platforms designed to run on different types of hardware.

Based on these levels, medium-centric approach towards IDNs focuses on unique technological aspects of each artifact defining their narrative possibilities. This means that we also need to focus on the "narrative goals" of each artifact through technological lenses: What kind of narrative experience is modeled in a system? One of the main distinctions in the larger IDN field is on which level (or levels) of narration is interaction placed? Mateas and Stern argue that interactive drama has its user interaction on the level of characters [56]; meaning their goal is to have an interactive chain of events based on character action and dramatic intensity. Yet other IDNs have their interaction on other levels. In such examples the chain of events remain the same while the information the interactor receives change, thus her mental image of the fabula. With an understanding of where the interaction is or what kind of experience the interactive process is modeled after (or uniquely designed for), we can ask what the working principles of the computational process behind this model are and compare them.

The medium-centric approach looks at IDNs from different levels with no hierarchical order but with high interconnectedness. How does an artifact work? What is the narrative concept behind it? How are both connected? These questions – which need to be formulated in an analytic way - can be asked for a game engine, which can be used to create a series of different games [57], of for a unique artifact like *Façade* [2], which is designed as a unique way of procedural expression according to their creators' theoretical and artistic goals. Earlier work on process and narrative relationship offers a basis for such analysis. Focusing mainly on the form/function level, Miguel Sicart analyses moral choices in digital games. To him, some games create real moral dilemmas while some only look moral [58]. His work exemplifies the relationship between computational process, fiction (on which the process is supposed to be modeled after), and the meaning the game creates. Wardrip-Fruin's analysis on form/function and code levels of several IDNs display the importance of identifying the actual operational logics in each particular work to analyze expressive aspects, which even their creators had not recognized [22]. Montfort and Bogost's comparative analysis [55] of *Adventure* for PDP-10 [59] and *Adventure* for Atari 2600 [60] show how different combinations of platform, code, form and interface work together and affect the design, interaction and narrative structure of digital artifacts.

While looking into an artifact through the lenses of medium-centric analysis offer a great deal of understanding of this artifact, a wider application can help us to understand the current state of IDNs. In 2008 Australia Council for the Arts published "a map" of the "new writing universe" for content creators which covered hundreds of developing and emerging new writing forms; digital, analog, interactive and non-interactive. [61] Even a (for publication reasons) simplified and slightly modified version of this "map" (see Fig. 1) shows us how complex the IDN writing scene has become with the advance of transmedia production as described by Jenkins [62] and use of ubiquitous web technologies for new forms of storytelling as analyzed by Alexander and Levine. [63]

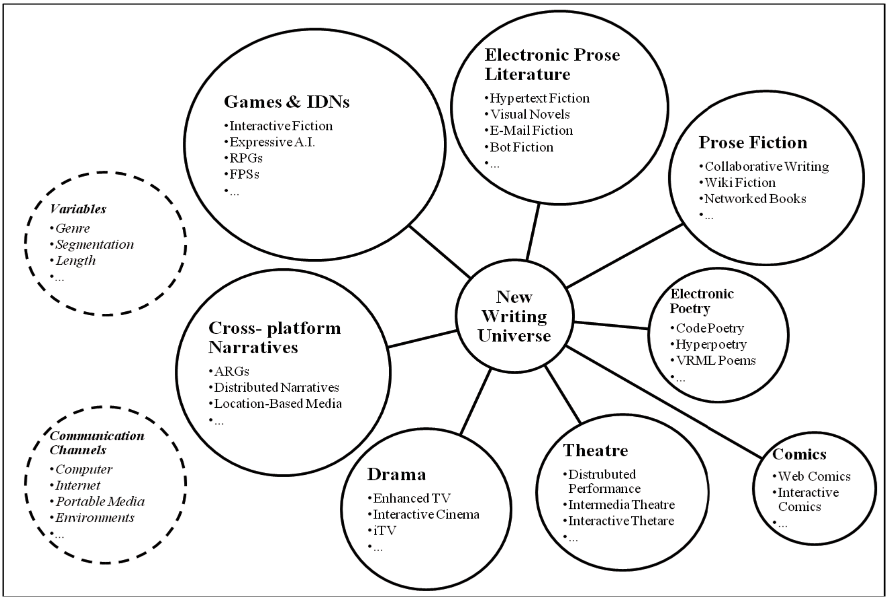

Fig. 1. The New Writing Universe based on Dena and Gleeson [61]

Faced with such an expansion of the field, which deepens the problem of a shared vocabulary and theory, we suggest a mapping of IDNs, which will include unique artifacts, mainstream products, and emerging new forms. We realize the difficulties of creating a strict taxonomy while defining every software-hardware combination as a medium with unique narrative features. Therefore we suggest a much more flexible model, a folksonomy, which creates links and clusters of similar structures and approaches. Based on our evolving analytical method, this folksonomy should be multi-layered, with layers focusing on both Montfort and Bogost's levels and narrative methods, as well as procedural source models. Our goal is to use this matrix to identify shared and unique techniques, approaches, aesthetics and their relations. With our mapping we hope to improve the mutual understanding between different areas of IDN research and production and provide a basis for out project of a unified theory.

3.3 Emotion in Games as IDN

Computer and video games constitute the way in which most people are familiar with IDN. The most recent generation of First-Person Shooters (FPS), such as *Bioshock 2* [65] and *Gears of War 2* [62], feature strong characterization as well as great dramatic tension, yet they still rely on the cut-scene (an inherently non-interactive construct) as a means to advance the plot. It is a difficult balancing act between what is perhaps the biggest challenge in relation to storytelling in games: the conflict between the strong player control required for a good interactive experience and the strong author control traditionally required for good drama. While there are some attempts in research to address this problem (notably *Façade* [2] and *IDTension* [28]) it is not a challenge that the game industry has been eager to take on. Other research-driven initiatives use emotion modeling to drive the behavior of game characters sometimes in an isolated game world (such as ActAffAct [66]) or in response to explicit knowledge about player emotional states (such as Affective Reasonner [67]). The primary aim of such approaches is to improve the behavioral fidelity of game characters, and while it may have the ultimate aim of improving the players' emotional engagement, the results in that respect are still very tentative at best.

An important requirement for games to mature as a storytelling medium is related to the emotional palette available to game designers. It has often been observed that a disproportionate number of the games that use stories deal with themes favored by adolescent males to such an extent that the games have little appeal to other demographic groups. Games abound that involve saving the world (or, at least, the day) with big guns, and most of these (if not all) are designed to engage a part of the emotional spectrum that is connected to high levels of adrenaline. A particularly sophisticated example is *Left for Dead 2* [68], which attempts to control the intensity of the emotion experienced by the player by dynamically adapting game elements, for example adding waves of opponents, not at fixed points in the progression, but in response to the player's situation (location, skill, health levels, etc). Such dynamic pacing does not fundamentally alter the emotional palette available to game designers, but it varies the story progression for each playthrough and thereby dramatically improves replayability. Other recent examples from major studios, such as *Heavy Rain* [69] and *LA Noire* [70], also show that the industry is aware of these shortcomings and are working to expand the expressivity of the medium.

A number of classic games exist that made significant progress towards increasing the emotional spectrum. While it was only a moderate commercial success, *ICO* [71] is highly respected in the game industry for its ability to make players feel *sadness*, *loss*, *solitude* and even *despair*. The methods used in *ICO* are complex and a full account is beyond the scope of the present paper, but an important technique (also used by other games, but nearly perfected in *ICO*) is to create an emotional attachment to a companion character and then placing that character in jeopardy. Another example of a sophisticated emotion created by a game is the opening scene in *Half-Life 2* [72], in which the player-controlled protagonist arrives at the occupied City 17. This short sequence evokes the feeling of *being oppressed* through a purely interactive sequence in which the protagonist is coerced into picking up garbage by a guard and receives electric shock if he resists.

In cinema, work exists that examines the emotional experience that films create for the viewer [73] and that defines an emotion system in relation to film structure [74]. Some work has explored player emotions in specific contexts, such as violence in games (notably [75, 76]), but little work has been done on analyzing the full range of emotions that are, and can be, created by games and the means in which they can be triggered. A comprehensive theory of IDN would benefit from addressing this aspect in a methodical fashion.

3.4 Specific Theory of IDN

The previously mentioned approaches can be integrated by means of a theoretical framework specific to IDN, which takes interactive digital narrative as dissimilar to established narrative forms and thus opens a space for new perspectives on narrative. This evolving framework (for an earlier version see [77]) describes IDN as comprised of *system* (the digital artifact), *process* (the user interacting with the system and the system's reactions), and *product* (a particular instantiated narrative). Inspired by Roy Ascott's theory of cybernetic art [78], this model improves upon Wiener's mechanistic concept [79] (referenced by Aarseth [80]) by merging it with artistic sensibility.

In IDN, the fixed story (or "content plane of narrative" in Prince's terms [81]) of traditional media gives way to a space containing potential narratives. Furthermore, the concrete manifestation in the form of an IDN *system* supplies both content and structures (or aspects of story and discourse) and provides a flexible presentation of narratives, which cannot be adequately described by the story and plot/discourse dichotomy.

Consequently, several terms are proposed to enable a better theoretical understanding of IDN. The term *protostory* defines the concrete content of an IDN *system* as a space of potential narratives defined by settings, environment definitions/assets, characters, and *Narrative design* (see Fig 2). This division revises an earlier version [77] of the theoretical framework to included characters in a more prominent place. This change is motivated by the experience obtained in a practical implementation [82] and also enables the framework to better account for character-based emerging narrative as described by Aylett, Louchart et al [83, 84] as well as the emotional aspects outlined earlier.

Any realized narrative experience is related to the respective *protostory* through a process of instantiation. The Pragmaticist perspective described previously can serve to understand different kinds of protostories as well as particular instantiations.

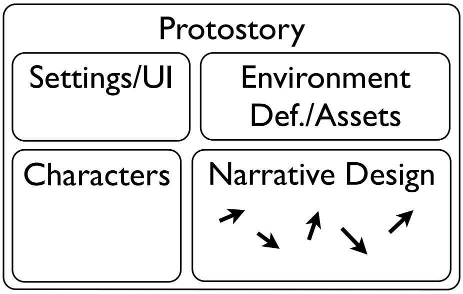

Fig. 2. Protostory and Narrative Design in an IDN System

Narrative design[1] describes the structure within a protostory that contains and enables a flexible presentation of a narrative. This includes the segmentation and the sequencing of elements and the connections between them. Additionally, the procedural logic applied in the presentation of elements is part of the narrative design. For example, the narrative design in *Façade* [2] consists of an overall story arc, the available narrative content in the form of beats and the drama manager as the controlling element. In *Afternoon* [3] the narrative design consists of the division into lexias, and the sequencing by means of ordering and placing links. The narrative design of the game *Half Life* [85] combines an episodic narrative at the beginning and end of each level interspersed by periods of narrative potential contained in a character-based emerging narrative. From this perspective, the medium-centric mapping proposed earlier can be re-applied to identify particular narrative designs.

The term *narrative vector* describes a sub-structure in a narrative design that provides a specific direction for the narrative. Narrative vectors work not as isolated structures, but rather in connection to the preceding and the following parts of the narrative. Additionally they make use of the other available elements of the protostory – the virtual environment, the assets, the characters, and the user interface The purpose of such structures is to convey important aspects to the interactor, to prevent an interactor from getting lost and to help to retain a level of authorial control. Narrative vectors can share some functional similarities with plot points in legacy media [86] as important positions within a narrative sequence that are created by the author in order to propel the narrative experience forward. Additionally in IDN Narrative vectors describe structures and functions that serve to prevent the interactor from getting lost, from missing important narrative content, and from performing out of character. Such structures can take many different forms, from the procedural hyperlinks in *Afternoon* that force repeat visits to the same lexias, to functions in *Façade*'s AI that recognize swearing and other inappropriate behavior and kick out misbehaving interactors, to the walls and tunnels in Half Life that serve a dual function as physical obstacles and as structures that force the interactor on to a particular (and often only) narrative path.

4 Conclusion

This paper provides an overview of our efforts towards a theory of IDN over the last number of years. We feel the field is at a crucial point where much has been

[1] In contrast, Mateas [16] uses the same term to describe narrative segmentation.

accomplished in terms of the theoretical investigation of IDN but, at the same time, we are in danger of growing misunderstandings since the theoretical backgrounds and conceptual leanings of researchers in an evolving field become more diverse and more difficult to trace to its origins. The overview of conflicting theoretical approaches in the first part of this paper is a clear indication of this state of affairs. Our own research directions presented here attempt to provide new perspectives and serve as a basis of our joint effort towards a unified theory.

Similarly, the number of artifacts to analyze grows constantly and merits a classification system and shared vocabulary. We have discussed our proposal in this regard with the participants of our workshops, and it will be the focus of a future research paper. A classification system should be used by many researchers or else will quickly become obsolete. Also, any effort in creating a unified theory and a shared vocabulary needs to be mindful of previous work and must take care not to substitute one ideological framework with another.

For this reason, we propose a joint iterative process, which invites participation and discussions (see [1], chapter 5 for a more detailed description of such a process). The workshops we conduct are an important part of this process. We strive to establish a model of academic inquiry, in which theoretical concepts are understood not to be finished, but will change in concert with our understanding and with an emerging practice. In a sense, we are bringing concepts from software development into academic theoretical enquiry, in which finished definitions give way to milestones and versions. In this vein we will continue our investigation.

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Contextual Affect Modeling and Detection in Interactive Text-Based Dramatic Improvisation

Li Zhang

School of Computing, Engineering and Information Sciences,
Northumbria University, Newcastle, UK
li.zhang@northumbria.ac.uk

Abstract. Real-time contextual affect detection from open-ended text-based dialogue is challenging but essential for the building of effective intelligent user interfaces. In this paper, we focus on context-based affect detection using emotion modeling in personal and social communication contexts. Bayesian networks are used for the prediction of the improvisational mood of a particular character and supervised & unsupervised neural networks are employed respectively for the deduction of the emotional indications in the most related interaction contexts and emotional influence towards the current speaking character. Evaluation results of our contextual affect detection using the above approaches are provided. Generally our new developments outperform other previous attempts for contextual affect analysis. Our work contributes to the journal themes on emotion design/modeling for interactive storytelling, narrative in digital games and development of affect inspired believable virtual characters.

Keywords: Contextual affect sensing, emotion modeling and improvisational interaction.

1 Introduction

Online interaction shows great potential to promote communication of people from different cultures and with physical barriers. It is even beneficial to (disadvantaged) young people to engage in such an online social interaction to have personalized learning/training experience. Thus our research has been focused on the production of intelligent agents with emotion and social intelligence. Since affect interpretation and detection play important roles in how effectively an intelligent agent is able to help users, we have made attempts in detecting affect from open-ended users' input previously and interpreting affect using context profiles has recently drawn our research attention.

Briefly, in our previous work, we developed online multi-user role-play software that could be used for education or entertainment. In this software young people could interact online in a 3D virtual drama stage with others under the guidance of a human director. In one session, up to five virtual characters are controlled on a virtual stage by human users ("actors"), with characters' (textual) "speeches" typed by the actors operating the characters. An intelligent conversational agent, EMMA

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(EMotion, Metaphor and Affect), has been created to interact with the human characters, assist the human director to keep the general spirit of the scenarios for improvisation and stimulate the improvisation by detecting affect from the human characters' text input. The intelligent agent has been equipped with the capabilities of detecting a wide range of affect, including basic and complex emotions and recognizing affect from a few metaphorical language phenomena (e.g. affect as external entities metaphor ("Joy ran through me"), the food metaphor and the cooking metaphor ("She knew she was fried when the teacher handed back her paper")). The animation engine adopts the detected affect implied in users' text input to produce emotional gesture animation for the users' avatars. The conversational AI agent also provides appropriate responses based on the detected affect from users' input in order to stimulate the improvisation. In our application, we used several scenarios for testing including the Homophobic bullying[1] and Crohn's disease[2] scenarios.

Our previous affect detection has been performed solely based on the analysis of individual turn-taking user input. Thus the context information has been ignored. However, since open-ended natural language inputs can be ambiguous, sometimes contextual profiles are required in order to further justify the affect implied by the speaking character. Thus for affect interpretation in a comparatively simple scenario (e.g. where relationships between characters are fairly consistent throughout the improvisation), we previously used Markov chains for the modeling of the improvisational mood for individual characters by recommending a most related discussion context to the test situation. For affect analysis in comparatively complex scenarios (e.g. relationships between characters evolve throughout), we have also used a supervised neural network application with the assistance of fuzzy logic for the modeling of local emotional context for individual characters. However, both approaches for emotional context modeling are constrained to the chosen scenarios and cannot perform across different scenarios although the neural network approach provides a more flexible way for emotion prediction in a comparatively complex story context.

Evaluations were also conducted respectively to measure the performances of the previous developments using Markov chains and neural networks. 150 user inputs extracted from four transcripts of a test scenario were annotated by two human judges and the Markov chain based affect detection using 10 most frequently used emotions. The previous context-based affect detection achieved the following inter-annotator

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[1] We briefly introduce this scenario in the following. The character Dean (16 years old), captain of the football team, is confused about his sexuality. He has ended a relationship with a girlfriend because he thinks he may be gay and has told her this in confidence. Tiffany (ex-girlfriend) has told the whole school and now Dean is being bullied and concerned that his team mates on the football team will react badly. He thinks he may have to leave the team. The other characters are: Rob (Dean's younger brother) who wants Dean to say he is not gay to stop the bullying, Lea (Dean's older sister) who wants Dean to be proud of who he is and ignore the bullying, and Mr Dhanda (PE Teacher) who needs to confront Tiffany and stop the bullying.

[2] In the Crohn's disease scenario, the sick leading character, Peter, needs to discuss pros and cons with friends and family about his life changing operation in order to make a decision. Janet (Mum) wants Peter to have the operation. Arnold (Dad) is not able to face the situation. Other characters are Dave (Peter's best friend) and Matthew (Peter's younger brother).

agreements comparing with the two human judges, 0.40 and 0.32. Comparing with the annotation of one human judge for 100 inputs from the Crohn's disease scenario using three labels: positive, negative and neutral, the neural network based affect detection achieved an average 61% accuracy rate previously. Overall, the two alternative previous developments generally were constrained to a specific scenario context and cross scenario affect detection tasks posed great challenges to such attempts.

In order to make an affect detection system applicable across different scenarios or even to other interactions without any scenario constrictions, in this paper we present the modeling of personal emotional contexts (the improvisational mood of a particular character) using Bayesian networks and social communication contexts (general emotional inclination in the recent interaction context) using an unsupervised neural network algorithm, Adaptive Resonance Theory (ART). Moreover, we also employ a supervised learning neural network, Backpropagation, to explore emotional influence from other characters to the current speaking character to further justify the affect derived from both personal and social emotion context modeling. Although training data is needed for Backpropagation, we use emotional appraisal examples gathered both from transcripts across different scenarios and from common-sense knowledge as training data to enable the system to learn about emotional influence caused by other participants.

We present the reasons why the above approaches are chosen in the following. Bayesian networks are usually employed to represent causality relationship and conditional (in)dependencies between domain variables. For example, they use arcs to link pairs of nodes to describe influences between the parent and child nodes. Thus it is used to simulate influences and dependencies between the previous emotional experience and the current emotional expression. i.e. the personal mood modeling. However, the Bayesian networks tend to gather general emotion inclination in a global manner via probability tables and respond less well to the requirements of local emotional contexts. In order to identify the general emotional indication in the local social contexts and further justify the Bayesian affect reasoning, an unsupervised learning algorithm, ART, is used. Briefly, ART is a collection of models for unsupervised learning and simulates the human learning process by linking new concepts with existing knowledge. A new structure is formed when failing to find the link with existing knowledge. Moreover, we also use this approach with the intention to make context-based affect detection capable of performing detection tasks across different application domains. Finally, a supervised learning algorithm, Backpropagation, incorporated with common sense knowledge is also employed to further reason emotional influence between characters as another channel to justify the affect embedded in social contexts. The final recommended detected emotions are derived from the outputs of the above three channels. Since concepts and emotional expressions can be described in multiple ways, in our recent developments, latent semantic analysis is used in order to identify the underlying semantic structures of the emotional inputs. It is also able to reveal the discussion themes and target audiences of each input in order to support affect detection from multithreaded conversational contexts within and out of the scope of the specified loose scenarios.

The new developments presented in this paper which enable the affect detection to perform across scenarios show improvements for the affect detection tasks.

Comparing with the previous alternative attempts, the new developments achieve a 0.43 inter-annotator agreement in good cases for the annotation of 200 user inputs using the 10 frequently used emotions.

Moreover, the presented virtual drama improvisational framework allows young people to conduct drama performance training and creative writing. Since there are only text-based loose scenarios without any detailed pre-defined scripts attached with each improvisational session, users can be creative at their role-play. The AI actor is also involved in the improvisation to play a minor role with the intention to stimulate the improvisation by proposing scenario sensitive topics. Since our application aims to enable young people to talk about emotionally difficult topics, the chosen scenarios relate to sensitive issues to teenagers such as bullying, disease and cancer. Characters are also created in a way to hold contradictory opinions and perform difficult decision-makings. Thus these scenarios are highly emotionally charged in order to allow dramatic improvisation. Also, the AI agent is capable of detecting emotions from interactions contexts and evoking emotionally charged discussions when the improvisation is not developing into any new interesting directions. In this way, it is capable of leading the improvisation on the desirable track and keeping the general spirit of the loose scenarios. Our previous user testing also proved that the AI agent's involvement was able to make a less interesting scenario (such as Crohn's disease) more favorable to users comparing with the improvisations led purely by human actors. Therefore the virtual drama framework with the incorporation of the AI agent contributes to creative interactive storytelling and virtual drama improvisation.

The paper is arranged as follows. We discuss related work in section 2, new development on contextual affect detection in section 3, and evaluation results and future directions in section 4.

2 Related Work

Much research has been done on creating affective virtual characters in interactive systems. Emotion theories, particularly that of Ortony, Clore and Collins [1] (OCC), have been used widely therein. Picard's work [2] made great contributions to building affective virtual characters overall. Prendinger and Ishizuka [3] used the OCC model in part to reason about emotions and to produce believable emotional expressions. Mehdi et al. [4] combined a widely accepted five-factor model of personality, mood and OCC in their approach for the generation of emotional behaviour for a fireman training application. Gratch and Marsella [5] presented an integrated model of appraisal and coping, to reason about emotions and to provide emotional responses, facial expressions, and potential social intelligence for virtual agents. Egges et al. [6] provided virtual characters with conversational emotional responsiveness with the assistance of emotion and personality modeling. Aylett et al. [7] also focused on the agent development of affective behaviour planning.

Recently textual affect sensing has also drawn researchers' interests. ConceptNet [8] is a toolkit to provide practical textual reasoning for affect sensing for six basic emotions, text summarization and topic extraction. Shaikh et al. [9] provided sentence-level textual affect sensing to recognize evaluations (positive and negative).

They adopted a rule-based domain-independent approach, but have not made attempts to recognize different affective states from open-ended text input. Although Façade [10] included shallow natural language processing for characters' open-ended utterances, the detection of major emotions, rudeness and value judgements is not mentioned. Zhe and Boucouvalas [11] demonstrated an emotion extraction module embedded in an Internet chatting environment. It used a part-of-speech tagger and a syntactic chunker to detect the emotional words and to analyze emotion intensity. The detection focused only on emotional adjectives and first-person emotions, and did not address deep issues such as figurative expression of emotion. There is also work on general linguistic cues useful for affect detection (e.g. Craggs and Wood [12]).

Context-sensitive approaches have also been attempted to sense affect and emotion. Ptaszynski et al. [13] developed an affect detection component with the integration of a web-mining technique to detect affect from users' input and verify the contextual appropriateness of the detected emotions. The detected results made an AI agent either sympathize with the human player or disapprove the user's emotional experience by the provision of persuasion. However, their system targeted conversations only between an AI agent and one human user in non-role-playing situations, which greatly reduced the complexity of the modeling of the interaction context. Wallis et al. [14] also discussed different methodologies of conversation analysis to illustrate what they believed to be a major deficiency in many current approaches to human-machine dialogue. They also produced a theory about how language worked from applied linguistics and used it in an iterative process to improve conversations between a robot and human users.

Our work focuses on the following aspects: (1) real-time affect sensing for basic and complex emotions in improvisational role-play situations from literal and metaphorical expressions; (2) affect interpretation based on context profiles; and (3) affect detection across scenarios.

3 Contextual Affect Sensing

Our original system has been developed for age 14-16 secondary school students to engage in role-play situations under loose scenarios in virtual social environments [15, 16]. Without pre-defined constrained scripts, the human users could be creative in their role-play within the highly emotionally charged scenarios. The language used by the secondary school students during their role-play is highly diverse with various online chatting features, such as abbreviations (e.g. 'den' (then), 'r' (are)), acronyms (e.g. 'lol' (laughing out loud)) and slang. Our previous work had pre-processing procedures to deal with abbreviations, acronyms, misspellings and slang [15]. Metaphorical language has also been used to convey emotions and feelings. In our previous work, we also detected affect from food metaphor ("u r a peach", "X is walking meat", "X has a pizza face") and cooking metaphor ("the lawyer grilled the witness on the stand", "I knew I was cooked when the teacher showed up at the door").

However, the affect detection processing we conducted previously only identifies emotions from the analysis of individual turn-taking input. Relevance theory suggested by Sperber & Wilson [17, 18] mentioned that "comprehension requires a common base of a cognitive environment that is shared by speaker and audience" and a lot of information needs to be inferenced by the audience to achieve the communication intention. Schnall [19] also further stated that the intention of communication is to achieve the greatest possible cognitive outcome with the smallest possible processing effort, i.e. "to communicate only what is relevant". From the above perspectives, emotion and interaction contexts in our application have great potential to create such a relevant cognitive environment to facilitate effective communication. The cognitive emotion research of Hareli and Rafaeli [20] also pointed out that "one person's emotion is a factor that can shape the behaviors, thoughts and emotions of other people". They also believed that "emotions may affect not only the person at whom the emotion was directed but also third parties who observe an agent's emotion". In our application domain, one character's manifestations of emotion can also thus influence others, his/her own mood and future interactions with others. Thus affect detection using personal and social interaction contexts is needed in order to detect emotions embedded in improvisational contexts more accurately.

We also gathered some linguistic indicators for contextual communication in the transcripts, including (i) imperatives, which are often used to imply negative or positive responses to the previous speaking characters (e.g. "shut up"), (ii) prepositional phrases (e.g. "by who?"), semi-coordinating conjunctions (e.g. "so we are good then"), subordinating conjunctions ("because Lisa is a dog") and coordinating conjunctions ('and', 'or' and 'but'). These indicators are normally used by the current speaker to express further opinions or gain further confirmation from the previous speakers. Also other indicators include (iii) short phrases for questions (e.g. "where?", "who is Dave"), (iv) character names (e.g. "Mrs Parton, say something"); and finally (v) some other common contextual indicators shown in Internet relay chat (such as 'yeah/yes+ a sentence', "I think so", "thanks", etc). These indicators acted as signals for the activation of the contextual affect analysis in our application previously.

However, there are still cases ("ur a batty 2 then okay", "the rest dropped out cuz they didn't want to play with a gay", "I want to talk about it now") that contextual affect analysis fails to be activated due to the limitation of the above indicators. In order to deal with such difficulties, we have focused on inputs with structures of (vi) 'subjects + verb phrases + objects'. We notice that such statement structures with first person subjects tend to convey strong opinions ("I want to talk about it now", "I am the only thing this football team has", "I hate school"), while inputs with such structures and second person subjects are inclined to convey insulting or compliment ("u r an angle", "u aint needed here", "u know dean! go boy!", "u r not my dad/friend/mate", "u r a batty 2 then okay", "u r an idiot" etc). Moreover, for the Homophobic bullying scenario used in our application, there is other contextual communication with statement structures, which implies emotion, such as "BATTY MANZ CANT RUN", "the rest dropped out cah they didn't wanna play with a gay", "every1 iz avoiding u", "sexually and personality r 2 different things" etc. Thus we also consider inputs with such statement structures as signals for contextual communication.

At the test stage, first we detect affect for each input solely based on the analysis of the input itself. The contextual affect sensing presented in the following will be activated when an input conveys ‘neutral’ with at least one linguistic indicator. The overall affect detection module is presented in Figure 1.

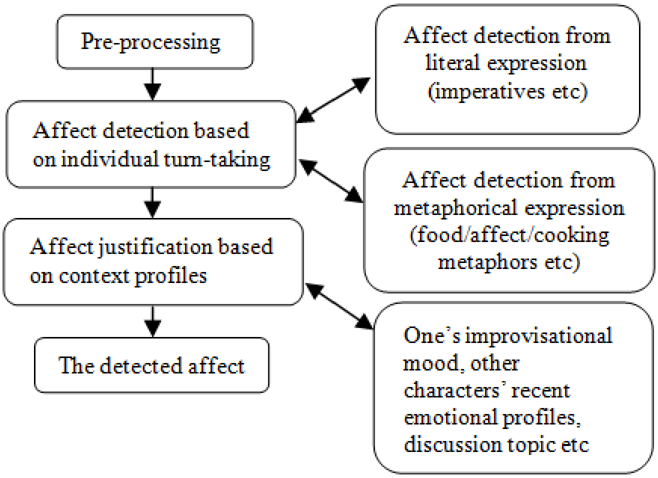

Fig. 1. The overall affect detection model

3.1 Personal Emotion Context Modeling

Lopez et al. [21] has suggested that context profiles for affect detection included social, environmental and personal contexts. In our study, personal context may be regarded as one’s own emotion inclination or improvisational mood in communication context. We believe that one’s own emotional states have a chain reaction effect, i.e. the previous emotional status may influence later emotional experience. We make attempts to include such effects into emotion modeling. Bayesian networks are used to simulate such personal causal emotion context. In the Bayesian network example shown in Figure 2, we regard the first emotion experienced by a particular user as A, the second experienced emotion as B, and the third as C. We assume that the second emotional state B, is dependent on the first emotional state A. Further, we assume that the third emotional state C, is dependent on both the first and second emotional states A and B. In our application, given two or more most recent emotional states a user experiences, we may predict the most probable emotion this user implies in the current input using a Bayesian network.

Briefly, a Bayesian network employs a probabilistic graphical model to represent causality relationship and conditional (in)dependencies between domain variables. It allows combining prior knowledge about (in)dependencies among variables with observed training data via a directed acyclic graph. It has a set of directed arcs linking pairs of nodes: an arc from a node X to a node Y means that X (parent emotion) has a direct influence on Y (successive child emotion). Such causal modeling between variables reflects the chain effect of emotional experience. It uses the conditional probabilities (e.g. P[B|A], P[C|A,B]) to reflect such influence between prior emotional experiences to successive emotional expression. The following network topology has been used to model personal contextual emotional profiles in our application.

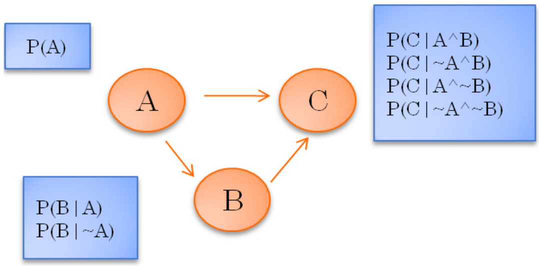

Fig. 2. An emotion Bayesian network

In Figure 2, conditional probabilities are needed to be calculated for the emotional state C given any combination of the emotional states A and B. Theoretically, emotional states A and B could be any combination of potential emotional states, so does the successive emotional state C. In our application, we mainly consider the following 10 most frequently used emotional states for contextual affect analysis including 'neutral', 'happy', 'approval', 'grateful', 'caring', 'disapproval', 'sad', 'scared', 'threatening', and 'angry'. Any combination of the above emotional states could be used as prior emotional experience of the user thus we have overall 100 (10 * 10) combinations for the two prior emotions. Also each conditional probability for each potential emotional state given two prior emotional experiences (such as P[happy| A,B], P[approval| A,B] etc) will be calculated. The emotional state with the highest conditional probability is selected as the most probable emotion the user conveys in the current turn-taking.

Moreover, it is beneficial that Bayesian networks do not require us to gather training data from other sessions of the same scenarios beforehand. We can simply use the emotional states experienced by a particular character throughout one improvisation as the prior input to the Bayesian network so that our system may learn about this user's emotional trend gradually for future prediction without any constrains set by the training data or scenario related information.

Table 1. An example conditional probability table for emotions expressed by a particular character

		Probability of the predicted emotional state C being:			
Emotion A	Emotion B	Happy	Approval	...	Angry
Happy	Neutral	P00	P01	...	P09
Neutral	Angry	P10	P11	...	P19
Disapproval	Disapproval	P20	P21	...	P29
Angry	Angry	P30	P31	...	P39
…	…	…	…	…	…

Thus we take a frequency approach to determine the conditional probabilities. When an affect has been detected from the user's input, we increment a counter for that expressed emotion given the two prior implied emotional states. An example conditional probability table has been shown in Table 1.

For a prediction for an emotion state mostly likely implied by one particular character, the two prior recent emotional states are used to determine which row to consider in the conditional probability matrix, and select the column with the highest conditional probability as the final output. Also the frequencies are sufficient to use to calculate probabilities when required thus no previous training needed. In our application, the frequencies of emotion combinations in a 100 * 10 ((A*B)*C) matrix are produced dynamically. Figure 3 shows how the Bayesian reasoning performs under different circumstances. If the previous affect detection processing without contextual inference is able to derive an affect (non-neutral) from a user input, then the Bayesian network is running in the monitoring mode and the detected emotion X is used to update the conditional probability table. Otherwise if the previous processing indicates 'neutral' implied in the current input which has at least one contextual linguistic indicator, then the Bayesian reasoning is switched to the active predication mode. Its output will also be further justified by the reasoning of the affect detection from social interaction contexts.

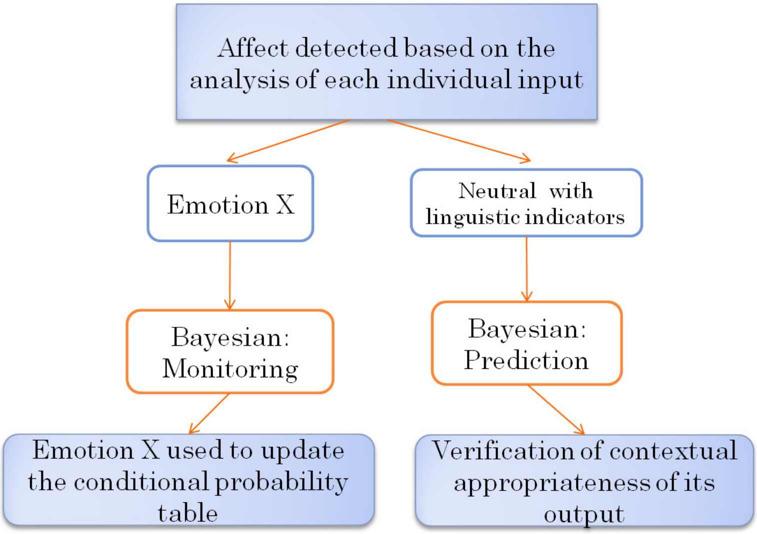

Fig. 3. The two working modes of the Bayesian network

We extract the following example interaction from the Homophobic bullying scenario. Based on the affect detection purely from the analysis of each individual input, we assigned an emotional label for each input as the first step. In this example interaction, the AI agent played the minor character, Mr. Dhanda, who tried to stop the bullying. A responding regime is also developed for the AI agent. For example, it usually responds every three turn-takings. It improves its responding frequency if it has high confidence for the detection of the affect implied in the user inputs (see the 7th input, an extra input, in the following example interaction). Otherwise it will respond less frequently if it has low confidence on the interpretation of the affect implied during the interaction.

1. Tiffany Tanktop: sorry, all I could hear was I'M A BIG GAY [insulting/angry]
2. Mr. Dhanda: TIFFANY I WILL....GET YOU EXPENDED IF YOU DONT FOLLOW MY ORDERS! YOU HOMO-FOBIC [The AI agent's response: angry]
3. Rob Hfuhruhurr: tiffany is wierd lol y she spreadn rumors etc???? (Tiffany is weird lol. Why she spreading rumors etc????) [disapproval]
4. Tiffany Tanktop: there not rumours...its the truth [disapproval]
5. Tiffany Tanktop: GGGGAAAYYYYY! [insulting/angry]
6. Mr. Dhanda: TIFFANY STOP IT NOW!!! [The AI agent's response: angry]
7. Mr. Dhanda: ILL BANG YOU [The AI agent's response: angry]
8. Rob Hfuhruhurr: god leav hm alone!!! (God, leave him alone!!!) [angry]
9. Tiffany Tanktop: ONCE A BATTY ALWAYS A BATTY [neutral] -> [angry]

Also we derive 'neutral' for the very last input without any contextual inference. Since the input is a simplified statement sentence (a linguistic contextual indicator), the context-based affect analysis will be activated to adjust the affect conveyed in the last input in the above example. The emotional profile of Tiffany (angry (1st input), disapproval (4th input), angry (5th input)) is used to construct the Bayesian probability matrix. Then the conditional probability of P[C|angry, disapproval, angry] is calculated for each potential emotion C. Finally 'angry' is regarded as the most probable emotion implied in the input "ONCE A BATTY ALWAYS A BATTY".

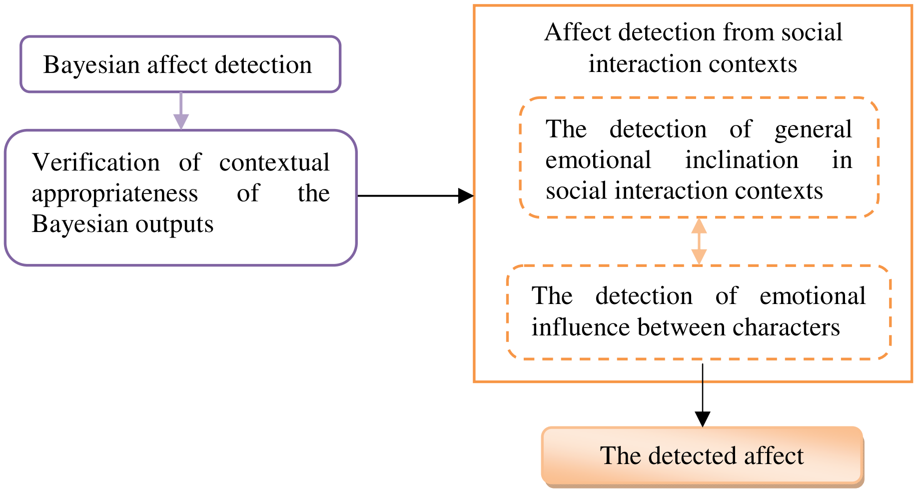

Fig. 4. The final detected emotions recommended by affect detection from social contexts based on the outputs of the personal mood modeling using the Bayesian reasoning

In this way, we can produce emotion modeling for each individual character within the same and across scenarios. However, since the Bayesian approach gathers frequencies of emotional sequences throughout improvisations and learns emotional inclination in a global manner for each character, it relies heavily on the probability table produced based on such frequencies for future prediction. It gives higher prediction for emotions with high occurrences than those with comparatively low frequencies following any two given preceding emotions even if the local interaction context indicates otherwise. Thus it may lead to affect sensing errors. Therefore another effective channel is needed to sense affect implication in the most related social interaction context to complement or verify the Bayesian inference. In the following section, we introduce emotion sensing in social interaction contexts and emotional influence of other characters to the current speaking character to justify the above reasoning. Figure 4 shows how the social context-based affect detection justifies the outputs of the Bayesian reasoning to derive the final recommended emotions.

3.2 Inference of Emotions Embedded in Related Contexts

As discussed earlier, "comprehension requires a common base of a cognitive environment that is shared by speaker and audience" and a lot of information needs to be inferenced by the audience to achieve the communication intention [17, 18]. Thus an effective user input should be meaningful in its most related context environment. If the emotion indication (positive/negative/neutral) of such most relevant social context could be recognized during the interaction, it is very helpful to justify the affect inferenced by the personal emotional context. This motivates us to derive general emotional implication in the most recent communication context by employing an unsupervised neural network, i.e. Adaptive Resonance Theory-1, (ART-1).

Such unsupervised learning algorithms deal with object identification and recognition generally as a result of the interaction of 'top-down' observer expectations with 'bottom-up' sensory information. ART-1 in particular has the ability to maintain previously learned knowledge ('stability') while still being capable of learning new information ('plasticity'). Although it mainly accepts binary input vectors, this is sufficient enough in our application currently. In our application, it would be beneficial that the positive/negative context prediction modeling is capable of both retaining previously learned information (e.g. the sensing of positive or negative context in a particular scenario) and in the meantime integrating newly discovered knowledge (e.g. the sensing of such contexts across different scenarios). Such capability may allow the emotional social context modeling to perform across scenarios. Also, ART-1 has an advanced ability to create a new cluster when required with the assistance of a vigilance parameter. It may help to determine when to cluster an emotion feature vector to a 'close' cluster or when a new cluster is needed to accommodate this emotion vector.

In our application, we use the evaluation values (positive and negative) and neutralization of the most recent several turn-taking as the input to ART-1. In detail, for each user input, we convert its emotional indication into pure positive/negative and use three binary values (0/1) to represent the three emotional implications: neutral, positive and negative. For example, for the input from Arnold in the Crohn's disease scenario, "dont boss me about, wife [angry]" when the wife character, Janet, was too pushy towards the husband character, Arnold. We use '0 (neutral), 0 (positive), and 1 (negative)' to indicate the emotional inclination ('angry' -> 'negative') in the user input. In the previous example transcript from the bullying scenario shown in the above section, for the very last input (the 9th input from Tiffany), we previously only interpreted 'neutral' based on the analysis of the input itself. The personal emotional context prediction based on Bayesian networks is used and derives 'angry' as the most probable affect implied in it. However, we still need to resort to the inference of the general emotional trend in the most related interaction context to justify the previous prediction. In our application, we take the previous four inputs, from Tiffany (5th input), Mr Dhanda (6th and 7th input) and Rob (8th input), as the most related social context for prediction since there are up to 5 characters involved in each session normally. Since Tiffany implies 'angry' (binary value combination for neutral, positive and negative: 001) by saying "GGGGAAAYYYYY!", Mr Dhanda, the AI agent, also indicating 'angry' (001) in both of its inputs: "TIFFANY STOP IT NOW!!!" and "ILL BANG YOU", followed by another 'angry' (001) input from Rob "god leav hm alone!!!", we have used the following emotion vector to represent this most related discussion context: '001 001 001 001 (Tiffany: 5th, Mr Dhanda: 6th & 7th and rob: 8th)'. This feature vector is used as the input to ART-1 to determine if the input context is 'positive/negative'. Similarly, we gather a set of such emotion vectors across scenarios. ART-1 classifies them into different groups based on their similarities and differences.

Briefly, we begin the algorithm with a set of unclustered emotional context feature vectors (emotional context) and some number of clusters (positive/negative/neutral categories). For each emotional feature vector, it makes attempts to find the cluster to which it's closest. A similarity test and a vigilance test calculate how close each emotional feature vector to the positive/negative/neutral cluster vectors. If an emotional feature vector fails the similarity or vigilance test for all the available clusters, then a new cluster is created for this emotion vector. In our application, we gradually feed emotional context feature vectors to ART-1, which will not only remain the previous classification of positive or negative context in a particular scenario, but also indefinitely integrate new positive/negative contexts extracted from other interactions across scenarios. Suppose we have the following emotional contexts from the Crohn's disease scenario, classified previously by the algorithm into three categories:

Class 0 contains:
[1 0 0 0 0 1 0 0 1 0 0 1] negative1 (neutral, sad, disapproving and sad)
[1 0 0 0 1 0 0 0 1 0 0 1] negative2 (neutral, approving, disapproving and angry)
Class 1 contains:
[0 0 1 0 0 1 1 0 0 1 0 0] negative3 (angry, angry, neutral and neutral)
[1 0 0 0 1 0 1 0 0 0 0 1] positive2 (neutral, caring, neutral and disapproval)

[1 0 0 1 0 0 1 0 0 1 0 0] neutral1 (neutral, neutral, neutral and neutral)
Class 2 contains:
[0 1 0 0 1 0 0 1 0 1 0 0] positive1 (happy, grateful, happy and neutral)

Since ART-1 is not aware which label it should use to mark the above categorization although it classifies the emotional feature vectors based on their similarities and differences and achieves the above classification, a simple algorithm is used to assign labels (positive/negative/neutral context) to the above classification based on the majority vote of the evaluation values of all the emotional states shown in each emotional feature vector in each category. For example, Class 0 has assigned 2 emotional vectors and most of the emotional states in all the feature vectors in this category are 'negative', therefore it is labeled as 'negative context'. Similarly Class 1 is recognised as 'neutral context' with Class 2 identified as 'positive context'. If we add the above example context from the bullying scenario as a new feature vector, '001 001 001 001' (contributed by Tiffany, Mr Dhanda and Rob), to the algorithm, we have Class 0 updated to accommodate the newly arrived emotional vector as output. Thus the new emotion vector is 'classified' as a 'negative context'. Therefore, the last input from Tiffany ("ONCE A BATTY ALWAYS A BATTY") is more likely to contain 'anger' with a strong intensity indicated by the capitalization in a comparatively 'negative' context, which further justifies the inference of the personal context modeling. However, sometimes the unsupervised algorithm may classify a test emotion context as 'neutral'. Therefore we still need to resort to other social context modeling, e.g. the emotional influence of other characters to the current speaking character, to assist affect interpretation.

3.3 Emotional Influence of Other Characters

The simulation of one's own improvisational mood is important but the Bayesian approach still needs emotional profiles of each character as input in order to deduce affect conveyed in the current input. However when such personal emotional profile is not available (such as at the beginning of the improvisation) or the unsupervised neural nets fail to discover any emotional implication in the most related context (or 'neutral context'), we need to resort to the modeling of other characters' emotional influence to derive/adjust the affect implied by the current speaking character. E.g., the emotional context contributed by friend or enemy characters, may (dramatically) affect the speaking character's emotional expression. Therefore we also consider supervised learning neural networks, Backpropagation, to model such effect to the current speaker and use two most recent emotions expressed by two other participant characters as inputs.

For example, in the above example transcript shown in the section of 'Personal Emotion Context Modeling', the most recent two other participant characters inputs, are from Mr. Dhanda ("ILL BANG YOU") and Rob Hfuhruhurr ("god leav hm alone!!!"). Their implied emotional states ('angry' (Mr Dhanda) and 'angry' (Rob)) are used as the input to Backpropagation. Since it is a supervised learning algorithm, we use emotional context gathered both from transcripts across different scenarios and from common-sense knowledge as training data. We obtain ‘angry’ as the predicted most probable affect conveyed in Tiffany’s last input, which strengths our previous prediction performed by the personal and unsupervised social emotional context modeling. In the next section, we further discuss how the affect sensing component functions in real-time interaction using more examples.

3.4 Real-Time Contextual Affect Sensing

We discussed personal subjective emotion context modeling using Bayesian networks, the prediction of emotion implied in the discussion context using Adaptive Resonance Theory and emotional influence of other characters using Backpropagation. These three components integrate with one another linearly to sense affect from emotional ambiguous contexts in our application. In the following, we provide another example transcript followed the previous one from the bullying scenario to show how they work together to derive affect from dramatic improvisation by combining every weak affect indicator into a stronger interpretation. This is also an example interaction which poses great challenges the previous affect detection processing.

9. Tiffany Tanktop: ONCE A BATTY ALWAYS A BATTY [neutral] -> [angry]
10. Rob Hfuhruhurr: HOMOSEXUAL NOT BATTY [disapproval]
11. Tiffany Tanktop: shut up man lea [angry]
12. Lea Hfuhruhurr: wat ur smellin tiffany, is ur mouth!lol (what you are smelling Tiffany. It is your mouth! lol) [neutral] -> [insulting/angry]
13. Tiffany Tanktop: go get ya hair did (go get your hair did) [neutral] -> [angry]
14. Dean Hfuhruhurr: lol [happy]
15. Tiffany Tanktop: ur a batty 2 then okay (you are a batty too then okay) [neutral] -> [insulting/angry]
16. Tiffany Tanktop: it’s sorted [neutral] -> [angry]
17. Lea Hfuhruhurr: dean, ur a gr8 football player. dnt let no1 stop u livin ur dream (Dean, you are a great football player. Don’t let noone stop you living your dream.) [approval]

First of all, affect is detected for each input without using any contextual inference. If an input contains any of the above discussed contextual linguistic indicators and is detected as non-emotional, then the contextual affect analysis is activated to further justify the affect implied in it.

Also based on our previous inference, the 9th input from Tiffany indicates ‘angry’ with high confidence. The affect interpretation based on the analysis of individual input has detected ‘disapproval’ and ‘angry’ respectively for the 10th and the 11th input. The 12th input has been derived as ‘neutral’ and contains a linguistic contextual indicator, a statement sentence. Thus the contextual affect detection is activated. Since this is the very first input from Lea, we do not have any emotional profile of this character at this stage as input to the improvisational mood prediction using Bayes. However, we can still resort to the social emotional context prediction and emotional influence of other characters to further justify the affect conveyed in this 'neutral' input. ART is used to sense the current emotional context ('angry (8th input)', 'angry (9th input)', 'disapproval (10th input)', 'angry (11th input)'). The input context is represented as follows:

001 001 001 001 [angry, angry, disapproval, and angry]

As discussed earlier, ART-1 has the ability to retain the previous knowledge and classification, learn and make the prediction for the newly arrived data and predicts the current input as another 'negative' context. Also the Backpropagation algorithm is used to determine which emotional state Lea is most likely to experience using the emotional profiles of other characters: 'disapproval (Rob: 10th)' and 'angry (Tiffany: 11th)' as input and emotional state 'angry' has achieved the highest probability as output. Thus Lea more likely implies 'angry' in a 'negative' interaction context in the 12th input. Similarly, we detect 'neutral' in the 13th input from Tiffany and also it carries one of the linguistic indictors for contextual communication (imperative), which indicates it may be caused by contextual interaction. Therefore contextual affect sensing is activated again. Briefly, the improvisational mood modeling, emotion sensing in most related context and emotional influence modeling of other characters have been employed to uncover the affect implied in the current input. Then we conclude the 13th input is again more likely to imply 'anger' rather than 'neutral' with a 'negative' interaction context.

Moreover, we sense 'neutral' in the 15th input without any context inference. Since it ("ur a batty 2 then okay") is a statement sentence with a structure of 'second person + copular form', which has potential to indicate insulting or compliment as mentioned earlier, we activate the contextual affect analysis as well. The following analysis is applied.

1. Emotional input profile of Tiffany: 'angry (1st)', 'disapproval (4th)', 'angry (5th)', 'angry (9th)', 'angry (11th)' and 'angry (13th)' -> Bayesian networks -> 'angry' as output.
2. Emotion sensing in the social context: 'angry (11th)', 'angry (12th)', 'angry (13th)' and 'happy (14th)', represented as '001 001 001 010' -> ART -> 'negative context'.
3. Emotional influence of other characters: 'angry (Lea: 12th)' and 'happy (Dean: 14th)' -> Backpropagation -> 'neutral' as output, which means that others' most recent contribution affects little to the current speaking character.
4. However, due to the sensed 'negative' context, the input is more likely to convey 'angry'.

In this way, by considering the potential improvisational mood one character is in, general emotional inclination in the closely related context and other characters' emotion influence, our affect detection component has been able to inference emotion based on contexts in real-time interactions.

4 Evaluation and Conclusion

We carried out user testing with 220 secondary school students in the UK schools. Generally, our previous statistical results based on the collected questionnaires indicate that the involvement of the AI character has not made any statistically significant difference to users' engagement and enjoyment with the emphasis of users' notice of the AI character's contribution throughout. Briefly, the methodology of the testing is that we had each testing subject have an experience of both scenarios, one including the AI minor character, EMMA, only and the other including the human-controlled minor character only. After the testing sessions, we obtained users' feedback via questionnaires and group debriefings. Improvisational transcripts were automatically recorded to allow further evaluation of the affect detection component.

We also produce a new set of results for the evaluation of the updated affect detection component with context-based interpretation based on the analysis of some recorded transcripts of Homophobic bullying scenario. Generally two human judges marked up the affect of 200 turn-taking user input from the recorded 4 transcripts of this scenario. In order to verify the efficiency of the new developments, we provide Cohen's Kappa inter-agreements for EMMA's performance with and without the new developments for the detection of the most commonly used 10 affective states. In the bullying scenario, EMMA played a minor bit-part character (the teacher: Mr Dhanda). The agreement for human judge A/B is 0.45. The inter-agreements between human judge A/B and EMMA with the new developments are respectively 0.43 and 0.35, while the results between judge A/B and EMMA without the new developments are only respectively 0.39 and 0.30.

Although future work is needed, the new developments on contextual affect sensing have improved EMMA's performance comparing with the previous version. Moreover, we obtain the average accuracy rate 84.2% for the personal emotional context modeling using Bayesian networks, 68.5% for the emotion sensing in interaction context using unsupervised learning, and 58% for the emotional influence modeling of other characters using Backpropagation. Since our approach gathers every weak affect indicator to draw a stronger conclusion for affect interpretation, the above three core results strengthen or reduce each other's effects for final affect annotation. Overall we obtain the average accuracy rate 88% for the contextual affect detection, while our previous contextual affect analysis using supervised neural nets & fuzzy logic achieved an average accuracy rate of 80% generally and the Markov chains' approach only obtained 69%.

Overall, we have made initial developments of an AI agent with emotion and social intelligence, which employs context profiles for affect interpretation using Bayesian networks, unsupervised and supervised neural network algorithms. Although the AI agent could be challenged by the rich diverse variations of the language phenomena used by the testing subjects and other improvisational complex context situations, we believe these areas are very crucial for development of effective intelligent user interfaces and our processing has made promising initial steps towards these areas. Also, the integration of these discussed approaches has great potential to derive affect in communication context which is closer to the user's real emotional experience. Another advantage of our implementation is that it has the potential to perform contextual affect sensing across different scenarios.

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A Methodology to Validate Interactive Storytelling Scenarios in Linear Logic

Kim Dung Dang, Ronan Champagnat, and Michel Augeraud

University of La Rochelle - L3i, Avenue Michel Crépeau, 17042 La Rochelle, France
{kim_dung.dang,ronan.champagnat,michel.augeraud}@univ-lr.fr

Abstract. Debugging is one of the main requirements for Interactive Storytelling (IS) authoring tools. During the authoring phase, authors have to specify large numbers of rules and actions as well as consider many possible paths. As a consequence, flaws may happen and finding them "by hand" is complex. Therefore the validation of an IS becomes a crucial issue and automatic assistance in this process is needful. Originated from those requirements, we propose, within the framework of this paper, a methodology using Linear Logic, based on analyzing automatically the resource allocation mechanisms, that helps authors derive a valid scenario of an IS. To do this, we model a scenario by a Linear Logic sequent, then prove the received sequent, which allows building and examining automatically all the possible branches in the scenario, thereby authors may guarantee that all the decisions (that may be made while unfolding the IS) lead to satisfactory endings of their goals. The paper ends with an example on an extract of an educational game to illustrate the methodology.

Keywords: Interactive Storytelling (IS), Linear Logic, validation of scenario, debugging, proof graph.

1 Introduction

Interactive Digital Storytelling, especially the gaming sector, nowadays, is considered as one of popular research directions that have had important and successful contribution to the edutainment domain [3, 10, 14, 13, 8]. Wong et al. [30] demonstrated that, thanks to the effects of interactivity, games brought a learning support that was more efficient than the traditional supports (non-interactive formats such as text, oral presentation, video). Indeed, the learner, from a passive role (sustains an available course), becomes active (can control the course through her/his actions during the game), and so her/his involvement in the learning process is reinforced.

However, the unfolding of a game (the unfolding of the story corresponding with the game) and its level of interactivity have commonly been thought to be opposites [18]. The former relates to a designer's control on the game s/he has created as the latter relates to a player's control on the game s/he is playing. Research to deal with this opposition, in general, is divided into two major families: scenario-driven

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approach (discourse point of view) and emergent narrative theory (character point of view) [9].

The first family [23, 31, 26, 22] aims to guarantee that the story development is coherent and leads to authors' desired effects. And hence when a player's action deviates from the pre-computed story plan, the system either re-plans (gets the story back on track), or makes the player's action have no effect on the story progress. As a consequence, the player cannot direct the story unfolding in a considerable way. In contrast, emergent narrative theory [2, 4, 28, 27] gives complete freedom to the player, who may deeply influence, through her/his actions, the evolution of the virtual world where s/he has been immersed. This means that the story will emerge from the player's interaction with the game, and the unfolding of the story is not based on any specific structure. However, its foremost limit is the quality of the created course of events, in terms of consistency and pertinence, which highly depends on the player and therefore cannot be guaranteed.

In previous works [5, 6], we showed how to use Linear Logic to model an IS thanks to which the strong points of both the discourse point of view and the character point of view are combined (*i.e.* the story development is coherent and leads to authors' desired effects while still ensuring player's freedom and her/his determinant role on the story's unfolding). These are really necessary, especially in the edutainment domain, as through the effects of interactivity, it is more interesting and efficient for the player/learner to comprehend knowledge/educational lessons transmitted by authors, and at the same time messages that authors have inserted into the game as well as the coherence of the created course of events are also guaranteed.

In [9], we studied the principle for a "good" IS controller which allows creating a discourse made by the author intention, the state of the system and player's action choices. We also gave a set of objectives that such an IS controller should satisfy: the player not to feel constrained by the game but s/he can determine its evolution; the virtual world providing a coherent environment appropriate for player's actions; the progress of the game respecting a structure of discourse (a common structure of a discourse is made of introduction; stating problems; solving them step by step; conclusion) which has been pre-defined by experts of the domain (authors/designers).

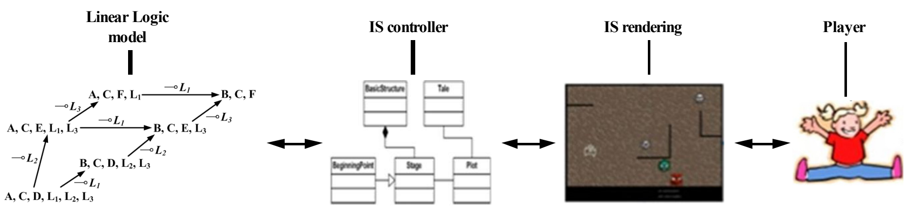

Fig. 1. Architecture of the system using Linear Logic to manage interactive video games

As a result, a system to manage interactive video games with the assistance of Linear Logic that ensures the foregoing is called for. We have realized such a system [7], composed of three architectural components: the Linear Logic model, a IS controller and the IS rendering (Fig. 1). The IS rendering directs the "rendering process" of the game (which interacts directly with the player). The IS controller aims to manage "intelligently" the unfolding of the game and to ask the IS rendering to show suitable interfaces for the game at each step, by taking into account the suggestions of the Linear Logic model, the state of the system and player's action choices (transmitted to the IS controller via the IS rendering). More concretely, it will play the role of an expert system, and so adapt the progress of the game to each player via its action choices. The *Linear Logic model* component stores a sequent that models the situation of the game at each moment (it is updated after each step; at the initial moment it models the initial situation of the game and so determines its scenario). The automatic reasoning of the sequent (the automatic sequent proof) assists directly the IS controller in managing the unfolding of the game.

The effort described in this paper presents a methodology for authors to validate their IS model represented by the Linear Logic sequent mentioned above before it becomes the input of the *Linear Logic model* component (*i.e.* in the scenario building phase). More concretely, the goal of the paper is to propose a methodology based on analyzing automatically the resource allocation mechanisms that allows authors to derive a valid scenario of an IS which guarantees that all the decisions (that may be made during unfolding a game) lead to satisfactory endings of authors' goals. To this end, our idea is to build and examine automatically the proof graph of the sequent representing all the possible branches in the current scenario, then to eliminate and/or to modify manually inappropriate ones (which do not direct toward successful endings because of problems on the resource allocation mechanisms), this process is

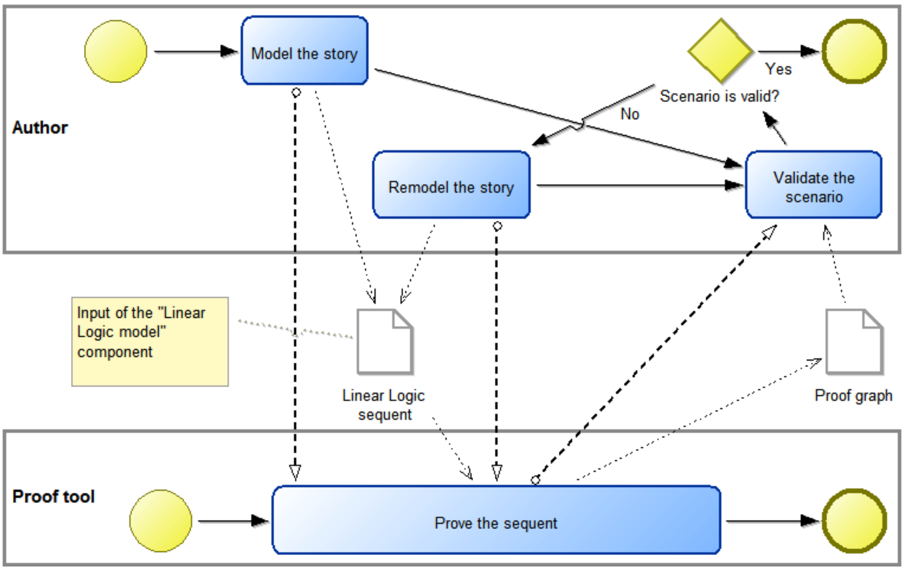

Fig. 2. Modeling process of an IS until its scenario is validated (built according to the *BPMN – Business Process Modeling Notation* standard [35]).

repeated until authors receive the most pertinent scenario for their aims. Fig. 2 describes the modeling process of an IS up to when its scenario is validated.

In the following, we set out with a presentation of related work. Then we offer a brief introduction to Linear Logic and explain the method of IS modeling by means of Linear Logic regarding both the discourse point of view and the character point of view. After that, we show in detail our solution for validating a scenario of a story and give an example on an extract of an educational game to illustrate it. In these sections, we will present and explain three main contributions of the paper: (1) introduce the connectives & and ⊕ to model the choices of the player and of the IS controller; (2) assign a priority order to each event/action in the story; and the most important one, (3) propose a novel sequent proof algorithm that is based absolutely on the meaning of the Linear Logic connectives. Lastly, we discuss about issues which should be settled and future works to be done on the Linear Logic approach for IS modeling.

But first of all, we define some important notions that are used in our approach:

- A *story* (a *game*) is a set of entities, of events/actions and of constraints that solves a set of problems, describes an evolution concerning a set of characters and/or of objects. It consists in starting from an initial situation, then in solving the given set of problems in order to reach a final situation that corresponds with one of satisfactory endings of authors' goals.
- A *discourse* is an ordered sequence of events/actions that is a possible unfolding of a story. Therefore a same story can generate various discourses. This consists in scheduling the events/actions corresponding with the story.
- A *scenario* is a set of all the possible discourses for a story. If we change anything in the story then we will receive a new scenario.

2 Related Work

Pizzi and Cavazza [24] presented an authoring approach that evolved from the development of proof-of-concept prototypes, due to the ability of IS systems to directly formalize narrative actions. They have also built tools that provide the representation of all the possible unfolding plans ensuring thus a greater visibility on the whole story space, in order to control the progress of the generated content. Its rationale is to support the authoring of a complex planning domain, by checking its completeness and its consistency. Moreover, the combinatorial aspect of content generation can quickly overflow the amount of possible paths that may be exploited if done using a brute force approach. For that reason, as an alternative to the offline generation of a complete narrative, an interactive mode allows a step-by-step generation of a solution including the visualization of all possible outcomes. After each action is selected by the user/author, the system automatically offers a list of possible subsequent actions/operators. Every operator in the planning domain is tested for applicability and whenever preconditions of an operator are satisfied, the operator will be applied to create a new state that may further be extended. For efficiency purposes, and in order to avoid redundancy, the system only develops new states that diverge significantly from their parent state. The whole tree can then be automatically scanned and all the possible solutions can be listed and visualized. The system also provides the user/author with the possibility of interaction at any time to change the current plan. Finally, several analysis tools may allow the validation of the generated narrative content. Thus, in short, Pizzi and Cavazza have used the direct analysis of actions' sequence to evaluate consistency and so could validate preliminarily the generated narrative.

Vega and Natkin, in [29], considered the ability to describe non-deterministic structure of the game narration, gave a semi formal approach and proposed the use of Petri nets for game analysis and specification. Their approach leaded to define and determine the dynamic structure of a game from a bottom up method: from transactions to levels, thanks to which it was possible to guarantee that the actions carried out by the player remained coherent within the framework of the game. To this purpose, they used techniques of subnet construction so that if each of these subnets was coherent then the whole also remained coherent. Their proposal was illustrated on the well known game *Myst* and could be considered as a starting point for a Game Design method and an authorware tool.

KANAL [20] is a tool which helps users to create sound plans by simulating them, checking for a variety of errors, and presenting the results in an accessible format that allows users to see an overview of the plan steps or timelines of objects in the plan. Indeed, this tool checks process models specified by users, reports possible errors and provides specific suggestions to users about how to fix those errors. Therefore, it helps users building or modifying process models by detecting invalid statements and pointing out what additional knowledge needs to be acquired and what existing knowledge needs to be modified. However, the pity that it is not designed for validating interactive scenarios in the gaming sector.

3 Brief Introduction to Linear Logic

Linear Logic is a substructural logic, introduced by Girard [11] as an executable formal model and a refinement of Classical Logic, where uses of the *Contraction* and *Weakening* rules are carefully controlled. In addition, it also considers atoms and formulas as resources that are consumed and/or produced. As a result, in Linear Logic, two instances of an atom (or of a formula) are different from one instance. Unlike Classical Logic, Linear Logic is not applied to determine whether an assertion is true or not, but it is employed to represent the validity of how resources (atoms and/or formulas) are used when proving an assertion. In other words, we are interested in writing the proof and in analyzing the resource choices made during this phase. Besides, Linear Logic is well suited to model the natural reasoning through the mechanism of sequent calculus introduced by Gentzen [17]. In addition, the linguistic theory uses a subset of Linear Logic (intuitionist multiplicative and non commutative), that corresponds to Lambek calculus [1]. Consequently, Linear Logic provides a semantic framework to model causality, automatic reasoning as well as resource allocation mechanisms for a story (for interested readers, [25] is a good reference to have more information on how to model resource allocation problems in Linear Logic, while [19] showed a complete computational interpretation of several fragments of Linear Logic and established exactly the complexity level of those fragments).

In order to model an IS, in this paper, we do not employ all the features of Linear Logic, but just the following connectives:

- *⊸: linear implication (imply)*, expresses the possibility of deduction. Example: "1$ ⊸ 1kg strawberries" means that we can give 1$ to buy 1kg strawberries.
- *⊗: multiplicative conjunction (times)*, expresses multisets of resources. Example: "1$ ⊸ 1kg strawberries ⊗ 1kg tomatoes" means that we can give 1$ to buy 1kg strawberries and 1kg tomatoes.
- *&: additive conjunction (with)*, expresses an external choice to the system (for instance coming from a player) if it is in the left part of the sequent (this connective does not make sense (and so is not used) if it is in the right part of the sequent in our approach). Example: "1$ ⊸ tea & coffee" means that we (the player) can choose tea or coffee when we give 1$ to an automatic machine.
- *⊕: additive disjunction (plus)*, expresses an internal choice to the system (for instance coming from an IS controller) if it is in the left part of the sequent. Example: "1$ ⊸ tea ⊕ 1$" means that it is the automatic machine which decides it will give us tea or return to us 1$ depending on the availability of tea in the machine, if this formula is in the left part of the sequent. If the connective ⊕ is in the right part of the sequent, it is only used to connect distinct consequents. For example, if the right part of a sequent is "tea ⊕ coffee", this means that if the sequent is provable, then from the left part of the sequent, we can receive either tea or coffee.

A sequent is an expression $\Gamma \vdash \Delta$, where Γ and Δ are sequences of atoms and/or of formulas; ⊢ (turnstile) is used to separate its left (antecedents/available resources) and right (consequents/conclusions) parts. For example, "A ⊗ (A ⊸ B) ⊢ B" (or "A, A ⊸ B ⊢ B") means the possibility to produce a copy of "B" by consuming the available resources "A" and "A ⊸ B" (we can substitute the connective ⊗ between two atoms, between two formulas, or between an atom and a formula in the left part of a sequent by the comma "," to be briefer). From the left part of a sequent, we may lead to many valid conclusions/consequents, and at the same time, a proof (how to reach a conclusion/consequent) is not unique, meaning that there exist many ways of reaching a same conclusion/consequent. In order to prove a sequent (*i.e.* showing that it is syntactically correct) we have employed the sequent calculus [17]. This consists in rewriting the sequent, by making a substitution of its formulas until obtaining initial sequents (a sequent is called an initial one if it is in the form "A ⊢ A" where A is any atom). Thus for a same sequent, there may be several successful proofs as well as several unsuccessful ones. As a result, the proof strategy becomes crucial in using Linear Logic to reason on the logic of discourse and on the resource allocation mechanisms for a story.

4 Interactive Storytelling Modeling by Means of Linear Logic

According to Greimas' analysis [16], an abstract formula, called a *narrative program* (whose logic is close to the concept of *linear implication* in Linear Logic), is used to represent an event/action and the progress of a story (an ordered sequence of events/actions) may be described by a *narrative program array*. More concretely, *"Doing (action) is defined as a temporal succession from a state to the opposite state, effected by any agent (the subject of doing) and affecting any patient (the subject of state). A state may be broken down into a subject of state and an object of state and the junction between them, which is either a conjunction (the subject is with the object) or a disjunction (the subject is without the object)."* [16, p.57] *"The subject of doing may or may not correspond to the subject of state; in other words, what accomplishes the action may or may not be what is affected by it."* [ibid., p.58] *"A NP* [i.e., Narrative Program] *array is composed of at least two NPs between which at least one temporal relation (succession, simultaneity) or one presential relation (simple or reciprocal presupposition, mutual exclusion, comparing/compared, etc.) is identified"* [ibid., p.59].

Based on these ideas, we have proposed a method to model an IS by means of Linear Logic, in which we take into account the states of the story, the (player and non-player) characters' states, player's action choices as well as action choices of the IS controller.

4.1 Method Description

Our method is briefly described as follows:

- Player and non-player characters are modeled by atoms in the left part of the sequent. An atom corresponds to a state of a character considering a certain point of view. Therefore a character at a moment can be modeled by various atoms which constitute the character's situation at that moment and are put in a state vector corresponding with the character. Thus, the size and the component of the state vector of a character may vary during the unfolding of the story.
- States of the story are modeled as atoms in the left part of the sequent. These atoms represent the discourse point of view (the authors' desired effects) in the modeling process.
- The availability of the characters' states and of the states of the story is considered as the availability of the corresponding atoms in the left part of the sequent.
- Player's action choices are represented by inputs. This means that the player decides her/his occurrence in the unfolding of the story by entering the inputs. These inputs are modeled as atoms in the left part of the sequent and will become available after being entered into the story by the player.
- An additive conjunction (disjunction) formula in the left part of the sequent represents action choices of the player (the IS controller) in the progress of the story.
- An event/action may modify the situation of a (or some) character(s) and/or the states of the story. This is similar to the working of the connective $\multimap$. As a result, we link a linear implication formula to an event/action of the story. Besides, in order to help authors control better the unfolding of a story, each

event/action is assigned a priority order (the smaller the priority order is, the higher is the priority of an event/action). Therefore, the event/action with the smallest priority order (the highest priority) will be selected if there are many satisfied events/actions at a same moment. For example, let us see the sequent A, D, A ⊸ B, D ⊸ E ⊢ B ⊗ E. It has two available atoms A and D, two events/actions A ⊸ B (priority order = 1) and D ⊸ E (priority order = 2). As the event/action A ⊸ B is more priority than the event/action D ⊸ E, although at this moment both the events/actions are satisfied, the event/action A ⊸ B will be executed before the event/action D ⊸ E. Thus the transformation order of the sequent is: (A, D, A ⊸ B, D ⊸ E ⊢ B ⊗ E) ⟶ (B, D, D ⊸ E ⊢ B ⊗ E) ⟶ (B, E ⊢ B ⊗ E).

- An outcome (goal/conclusion/consequent) of a story is an authors' desired ending. It corresponds to an atom, or a set of atoms (connected between them by the connective ⊗) in the right part of the sequent. Outcomes of the story are connected by the connective ⊕.
- A proof expresses the actions/events (linear implication formulas) to be executed, to reach a consequent of a sequent (may be successful or unsuccessful), and hence it is equivalent to a discourse which is an ordered sequence of events/actions that is a possible unfolding of the story.
- From a sequent, we are able to build all the ways of writing proofs. Therefore it corresponds to a scenario which is a set of all the possible discourses for a story.

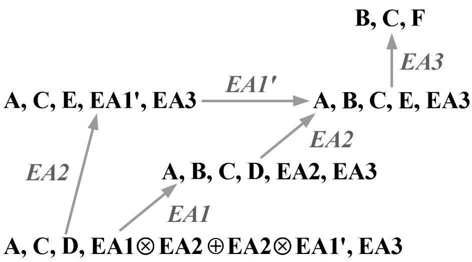

Fig. 3. All the possible discourses in the scenario corresponding to the sequent A, C, D, EA1 ⊗ EA2 ⊕ EA2 ⊗ EA1', EA3 ⊢ B ⊗ C ⊗ F where EA1 (priority order = 1): A ⊗ C ⊸ A ⊗ B ⊗ C; EA2 (priority order = 2): D ⊸ E; EA1' (priority order = 3): A ⊗ C ⊸ A ⊗ B ⊗ C; EA3 (priority order = 4): A ⊗ C ⊗ E ⊸ C ⊗ F; each node corresponds to the left part of the sequent at a moment; each edge is one executed event/action.

For instance, let us consider the sequent A, C, D, EA1 ⊗ EA2 ⊕ EA2 ⊗ EA1', EA3 ⊢ B ⊗ C ⊗ F where EA1 (priority order = 1): A ⊗ C ⊸ A ⊗ B ⊗ C; EA2 (priority order = 2): D ⊸ E; EA1' (priority order = 3): A ⊗ C ⊸ A ⊗ B ⊗ C; EA3 (priority order = 4): A ⊗ C ⊗ E ⊸ C ⊗ F. The scenario corresponding to this sequent has six atoms/states A, B, C, D, E, F in which A, C, D are available; four events/actions EA1, EA1', EA2, EA3 in which the priority of EA1 > EA2 > EA1' > EA3; one outcome B ⊗ C ⊗ F including three atoms/states B, C and F; one choice made by the IS controller (choose either EA1 ⊗ EA2 meaning that the sequent becomes A, C, D, EA1, EA2, EA3 ⊢ B ⊗ C ⊗ F, or EA2 ⊗ EA1' meaning that the sequent becomes A, C, D, EA2, EA1', EA3 ⊢ B ⊗ C ⊗ F). All the possible discourses in the scenario (two successful discourses/proofs/paths/branches) are given in Fig. 3 (simplified to the substitution of the events/actions): EA1 → EA2 → EA3 and EA2 → EA1' → EA3. Besides, it is easy to find that, the IS modeling by Linear Logic helps us know the shape of a scenario of a story as well as modify it simply.

4.2 Two Principal Improvements of the Modeling Method in Comparison with Previous Works

Within the framework of the previous works [5], we did neither employ the connectives & and ⊕ to represent action choices of the player and of the IS controller in the progress of the story, nor assign any priority order to the events/actions (their priority was the same). As a consequence, all the possible discourses in a scenario came from the possibilities of scheduling its events/actions (if there were many satisfied events/actions at a same moment, each of them would be selected one after another). For example, let us see the sequent A, C, D, EA1, EA2, EA3 ⊢ B ⊗ C ⊗ F where EA1: A ⊗ C ⊸ A ⊗ B ⊗ C; EA2: D ⊸ E; EA3: A ⊗ C ⊗ E ⊸ C ⊗ F. The scenario corresponding to this sequent has six atoms/states A, B, C, D, E, F in which A, C, D are available; three events/actions EA1, EA2, EA3 (their priority is the same); one outcome B ⊗ C ⊗ F including three atoms/states B, C and F. All the possible discourses (possibilities of choice) in the scenario are given in Fig. 4 (simplified to the substitution of the events/actions): EA1 → EA2 → EA3, EA2 → EA1 → EA3 and EA2 → EA3 (two successful discourses and one unsuccessful discourse).

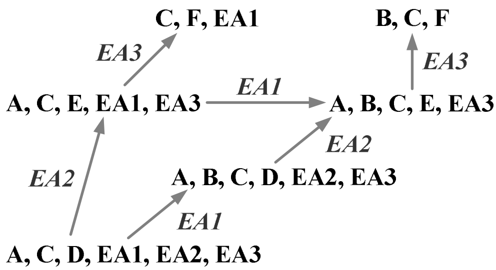

Fig. 4. All the possible discourses in the scenario corresponding to the sequent A, C, D, EA1, EA2, EA3 ⊢ B ⊗ C ⊗ F where EA1: A ⊗ C ⊸ A ⊗ B ⊗ C; EA2: D ⊸ E; EA3: A ⊗ C ⊗ E ⊸ C ⊗ F (within the framework of the previous works [5]).

However, such modeling of an IS has met the following inconveniences (which will be surmounted through the two main improvements of the IS modeling method described in this paper):

- authors cannot determine that which possibilities of choices in the scenario are decided by the player, which ones are decided by the IS controller. For instance, in Fig. 4, at the first node of the graph (A, C, D, EA1, EA2, EA3), there are two possibilities of choices (execute either EA1 or EA2) but we cannot know who (the player or the IS controller) will decide that. The use of the connectives & and ⊕ in this paper allows authors to deal with that ambiguity;

- it is difficult to express the following kind of choice: choose one event/action in a list of events/actions and after executing the chosen event/action, it is not allowed to execute the remaining events/actions in the list. For instance, let us see the sequent in Fig. 4, we cannot determine: choose either EA1 or EA2 and after executing EA1 (EA2), it is not allowed to execute EA2 (EA1), because after executing EA1, we always have the possibility of executing EA2 and vice versa. The use of the connectives & and ⊕ in this paper allows authors to determine that, indeed, we can modify the sequent as follows: A, C, D, (EA1 & EA2), EA3 ⊢ B ⊗ C ⊗ F;
- it is complex for authors to define the priority order in choosing the events/actions. For instance, for the sequent in Fig. 4, we cannot express that EA1 is more priority than EA2 and so it has to be chosen at the first node of the graph (A, C, D, EA1, EA2, EA3). This also makes the authors' control on the possibilities of choices in the scenario limited, more concretely, there may exist other possibilities besides authors' intentional discourses. For instance, let us reconsider the sequent in Fig. 4, if authors desire that EA3 is executed last (after both EA1 and EA2), although the discourse EA2 → EA3 is not in their intention, it still can happen. In this paper, by proposing a priority order between the events/actions (therefore the event/action with the highest priority will be selected if there are many satisfied events/actions at a same moment), this weak point is solved. For example, the sequent in Fig. 3 only includes two discourses EA1 → EA2 → EA3 and EA2 → EA1' → EA3 as the priority of EA3 is lowest.

5 A Methodology to Validate a Scenario Modeled by a Linear Logic Sequent

5.1 Problem to Settle

As presented above, a Linear Logic sequent models a scenario of a story and a way of proving the sequent expresses a discourse. Thus we can validate the scenario by building and examining automatically the proof graph of the sequent which includes all the possible discourses in the scenario. As each discourse corresponds with a choice made either by the player or by the IS controller in the story unfolding, the problem to settle in this paper is as follows: We will automatically build the proof graph of the sequent, each branch of which is one possibility of choice in the scenario. These choices come from the player (using the connective & in the left part of the sequent), and/or from the IS controller (using the connective ⊕ in the left part of the sequent). The final received result of each discourse is compared with each outcome/goal of the story, thereby we will receive all the discourses (branches/paths) leading to unsuccessful and/or successful endings as well as some important statistical information on the scenario such as: number of discourses, number of successful/unsuccessful discourses, number of successful discourses for each outcome/goal. Thanks to these feedbacks, authors may quickly have an overall view on the current scenario, then they can improve it if necessary and so receive a new sequent/scenario (this process is repeated in the scenario building phase until authors receive a scenario that is the most pertinent for their aims, in other words, until the scenario is validated – see Fig. 2).

For example, let us consider a scenario corresponding to the sequent A, C, EA1 & (EA2 ⊕ EA3) ⊢ B ⊗ F ⊕ A ⊗ F where EA1: A ⊗ C ⊸ B ⊗ F; EA2: A ⊸ E; EA3: C ⊸ F. The player can choose between two possibilities: either EA1 or EA2 ⊕ EA3. If s/he chooses EA2 ⊕ EA3, then the IS controller will decide which event/action (either EA2 or EA3) will happen. Thus the proof graph of the sequent includes three discourses/branches/paths (to be briefer we keep the labels EA1, EA2 and EA3 if they are not executed):

(1) Execute EA1: (A, C, A ⊗ C ⊸ B ⊗ F & (EA2 ⊕ EA3) ⊢ B ⊗ F ⊕ A ⊗ F) → (B, F ⊢ B ⊗ F ⊕ A ⊗ F)
(2) Execute EA2: (A, C, EA1 & ((A ⊸ E) ⊕ EA3) ⊢ B ⊗ F ⊕ A ⊗ F) → (E, C ⊢ B ⊗ F ⊕ A ⊗ F)
(3) Execute EA3: (A, C, EA1 & (EA2 ⊕ (C ⊸ F)) ⊢ B ⊗ F ⊕ A ⊗ F) → (A, F ⊢ B ⊗ F ⊕ A ⊗ F)

As there are two outcomes/goals B ⊗ F and A ⊗ F, we compare the final received result of each discourse with each of these outcomes. Lastly, we have the following conclusion on the scenario:

- if the player chooses EA1 (discourse 1), this discourse will go to one successful ending of the goal of the story (B ⊗ F);
- if the player chooses EA2 ⊕ EA3
  - if the IS controller decides that EA2 will happen (discourse 2), this discourse cannot go to any successful ending of the goal of the story;
  - if the IS controller decides that EA3 will happen (discourse 3), this discourse will go to one successful ending of the goal of the story (A ⊗ F);
- in short, the scenario has three discourses: two successful discourses (one discourse reaches the outcome B ⊗ F, one discourse reaches the outcome A ⊗ F) and one unsuccessful discourse.

Thanks to these feedbacks, authors can improve the current scenario if necessary (so receive a new sequent/scenario) and then repeat the validation process until obtaining the best possible scenario (*i.e.* the scenario that is the most pertinent for their aims).

We can find that the Linear Logic sequent proof plays a key role in our approach. The next section will speak of some existing solutions to prove a sequent and explain why they are not really suitable for the problem mentioned above.

5.2 Some Existing Linear Logic Sequent Proof Solutions

Proving a sequent consists in rewriting the sequent, by making a substitution of its formulas until obtaining initial sequents. As for a same sequent, there may be several successful proofs as well as several unsuccessful ones, the proof strategy becomes crucial in using Linear Logic to reason on the logic of discourse and on the resource allocation mechanisms for a story. We introduce here some existing solutions concerning this question.

Petri Nets

It has been shown [12, 21] that there is an equivalence between a Linear Logic sequent and a Petri net (with some restrictions). Thus the proof of a Linear Logic sequent corresponds to the firing of a sequence of transitions in its equivalent Petri net, starting from the initial marking and going to the expected marking. Our previous works in [5] has implemented this Linear Logic sequent proof strategy in order to generate the set of discourses for the given scenario/sequent. However they have encountered some problems:

- Among the possibilities of choice verified while proving a sequent, there may be many discourses/branches that the verification is useless when we consider the different priority order between the events/actions. For example, let us see the sequent A, C, D, EA1, EA2, EA3 ⊢ B ⊗ C ⊗ F where EA1 (priority order = 1): A ⊗ C ⊸ A ⊗ B ⊗ C; EA2 (priority order = 2): D ⊸ E; EA3 (priority order = 3): A ⊗ C ⊗ E ⊸ C ⊗ F. If we use a Petri net corresponding to the sequent to prove it like [5] did, the Petri net will verify all three discourses/branches EA1 → EA2 → EA3, EA2 → EA1 → EA3 and EA2 → EA3 (see Fig. 4) because for the previous works, the priority order of EA1, EA2 and EA3 is not considered. However, this sequent, in reality, only includes one successful discourse EA1 → EA2 → EA3 as the priority of EA1 > EA2 > EA3. Therefore it is useless to verify the discourses/branches in the proof graph of a sequent that do not respect the priority order between its events/actions (such as EA2 → EA1 → EA3 and EA2 → EA3 in the considered example), which results in quickly the combinatorial explosion as the complexity of the scheduling algorithm of events/actions is exponential.
- The transformation from a Linear Logic sequent into a Petri net has also brought us some restrictions. Indeed, we have neither been able to use all the four connectives (⊗, &, ⊕, ⊸) and nor been able to model complex events/actions in the previous works [5]. More concretely, the left part of the sequent has only accepted the connectives ⊗, ⊸; its right part has only accepted the connectives ⊗, ⊕; and it has only been possible for us to model simple events/actions corresponding with a unique format of the linear implication formulas (A1 ⊗ A2 ⊗ … ⊗ An ⊸ B1 ⊗ B2 ⊗ … ⊗ Bm, where Ai, Bj are atoms), in other words, we have not been able to model more complex events/actions, such as A ⊸ (B ⊸ C) or (A ⊸ B) ⊸ (C ⊸ D). As a consequence, the transformation from a Linear Logic sequent into a Petri net has reduced the power of Linear Logic and so it has been impossible for us to

model complex systems. Besides, the "reciprocal transformation" between a sequent and its corresponding Petri net (almost) after each step during unfolding the story causes a "waste" of time and computer resources to process. Thus, another solution which calculates directly on Linear Logic models (does not have to base on Petri nets) is necessary.

- Besides, in order to avoid the combinatorial explosion, we have applied a dynamic analysis which consisted in generating each local part of the proof graph by considering a limited window of events/actions while unfolding the story. Nevertheless, that strategy has had several weak points: (1) it always eliminates unsuccessful discourses just after detecting them during executing the game, as a consequence, it reduces the scenario's variety; (2) it does not guarantee that the unfolding of the story is always successful. For instance, let us see the sequent A, EA1, EA2, EA3, EA4, EA5 $\vdash$ D where EA1: A $\multimap$ B; EA2: A $\multimap$ C; EA3: A $\multimap$ D; EA4: B $\multimap$ E; EA5: E $\multimap$ F. We consider in this example a window of size 3 (*i.e.* a window of 3 events/actions). In the beginning, after verifying the whole of the possible discourses made up of 3 events/actions, the IS controller detects that if the player chooses either EA1 or EA3, there is not any problem, but if s/he chooses EA2, it is an unsuccessful discourse. Therefore, it eliminates EA2 (unfortunately this makes the scenario's variety reduced), the sequent becomes A, EA1, EA3, EA4, EA5 $\vdash$ D. Then for example, the player executes EA1, so the sequent becomes B, EA3, EA4, EA5 $\vdash$ D. The IS controller continues to verify the whole of the possible discourses made up of 3 events/actions, it finds that now there is only one discourse which is unsuccessful. However, this moment is too late to change and so it is impossible for the IS controller to do anything. Thus the dynamic analysis by considering a limited window of events/actions mentioned in [5] has not guaranteed that the unfolding of the story was always successful. As a result, we should propose another approach to solve this inconvenience, and at the same time to maintain the scenario's variety (*i.e.* not have to eliminate any discourse).

Other Linear Logic Sequent Proof Tools

In addition to Petri nets, in order to prove a Linear Logic sequent, we may also employ Lolli [33], Lygon [34], LINK prover [15], and especially Linear Logic Theorem Prover *llprover* [32]. However, they do not respond exactly to our requirement:

- These available tools can only be used to show whether or not a sequent is proved, which does not offer enough necessary information. Concretely, they cannot divide the sequent into branches and hence, we cannot know how many branches there are, which branches are successful and which branches are unsuccessful (our purpose is not only to conclude if a sequent is true or false but also to build its proof graph which corresponds with all the possible discourses in the given scenario).
- They do not consider the priority order of the linear implication formulas (similarly to our previous works in [5]). As a consequence, among the possibilities verified while proving a sequent, there may be many branches that

the verification is useless, besides, in some cases, the received result is not correct. For example, let us see the sequent A, B, EA1, EA2 ⊢ E where EA1 (priority order = 1): A ⊸ C; EA2 (priority order = 2): B ⊸ D. These tools will verify all two branches EA1 → EA2 as well as EA2 → EA1 (because they do not care the priority order between EA1, EA2) and conclude that the sequent is false. However, this sequent, in reality, only includes one unsuccessful discourse EA1 → EA2 because EA1 is more priority than EA2. Therefore it is useless to verify the branch EA2 → EA1. Another example, the sequent A, B, EA1, EA2 ⊢ C ⊗ D where EA1 (priority order = 1): B ⊸ D; EA2 (priority order = 2): A ⊗ B ⊸ B ⊗ C, according to these tools, is true because they find the successful branch EA2 → EA1 but in reality, this sequent is false because it only includes one unsuccessful discourse EA1 → EA2 in the corresponding scenario.

- Besides the foregoing, Lolli, Lygon and the LINK prover do not handle completely all the four connectives (⊗, &, ⊕, ⊸); *llprover* includes all of them but it deals with the connective ⊕ in the left part of the sequent differently from our approach. More concretely, Lolli and Lygon do not consider the sequents containing ⊕ in the left part; the LINK prover is only applied to the multiplicative fragment of Linear Logic; for *llprover*, it deals with the connective ⊕ in the left part of a sequent as follows:

$$\frac{\Gamma 1, \Gamma 2, \Gamma 4 \vdash \Delta \qquad\qquad \Gamma 1, \Gamma 3, \Gamma 4 \vdash \Delta}{\Gamma 1, \Gamma 2 \oplus \Gamma 3, \Gamma 4 \vdash \Delta} \oplus L$$

This means that *llprover* is interested in the truth of the sequent Γ1, Γ2 ⊕ Γ3, Γ4 ⊢ Δ and will conclude it is true if and only if both the subsequents Γ1, Γ2, Γ4 ⊢ Δ and Γ1, Γ3, Γ4 ⊢ Δ are true. If it finds that Γ1, Γ2, Γ4 ⊢ Δ is false, it will conclude the sequent Γ1, Γ2 ⊕ Γ3, Γ4 ⊢ Δ is false and does not prove Γ1, Γ3, Γ4 ⊢ Δ. This mechanism is not really identical to our approach. Indeed, we are only interested in the truth of the two subsequents, not in the truth of the original sequent. In other words, in any case we will consider both the subsequents and conclude the truth for each of them, not for the original sequent.

5.3 A Novel Algorithm to Build and Examine Automatically all the Possible Branches in a Scenario

The foregoing shows that the application of the solutions presented in Section 5.2 to deal with the problem posed in Section 5.1 is not really suitable. Thus, in order to settle directly and entirely this problem as well as overcome all the inconveniences mentioned above, we have proposed a novel algorithm of sequent proof that is based absolutely on the meaning of the Linear Logic connectives (does not have to base on any Petri net), which will be explained in detail in the following.

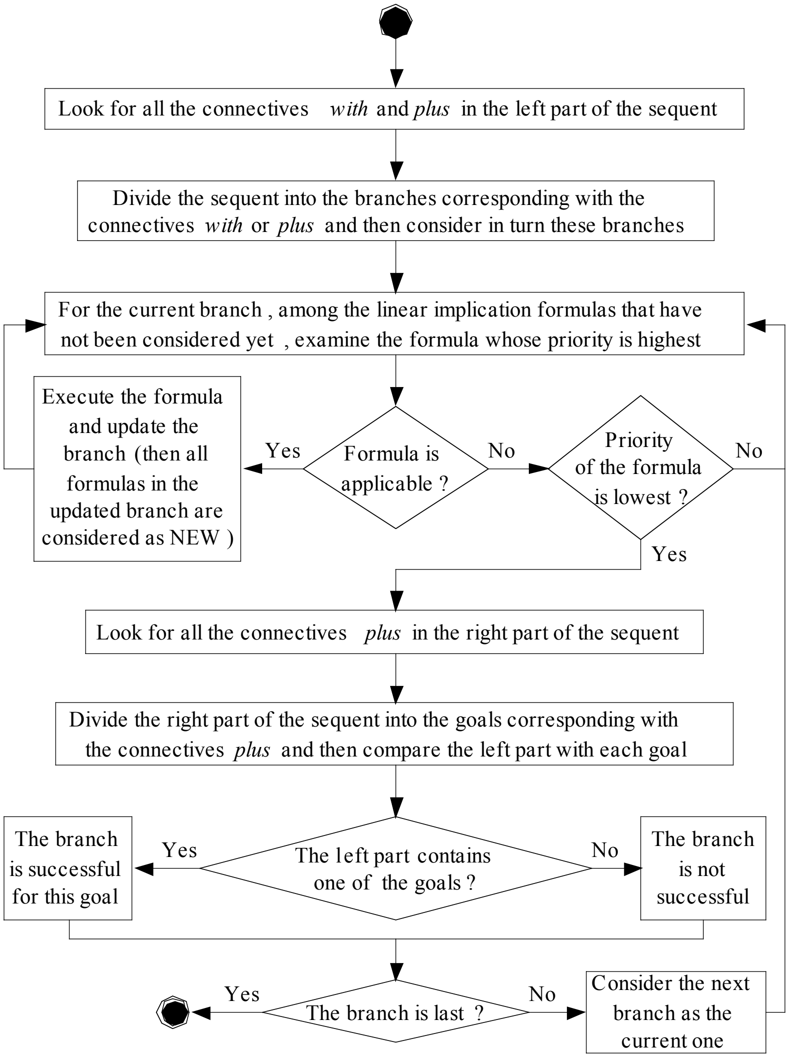

Fig. 5. Outline of the algorithm

Before beginning, it is necessary to note that we do not intend to prove a Linear Logic sequent in general case, but just apply the algorithm to validate a scenario of a story which is modeled by a sequent in our approach. As a consequence, within the framework of this paper, the following "components" in the syntax of Linear Logic are not considered (because they do not appear in the sequent received after the modeling process): linear negation (*e.g.* $A^{\perp}$); the connective & in the right part of the sequent; the connective ⅋; the constants 1, 0, T, ⊥; the exponentials !, ?; and the quantifiers ∀, ∃. Besides, the proof of a Linear Logic sequent is a very complex question and results in combinatorial explosion, so we have proposed some constraints to make the algorithm simpler as well as to increase the processing speed of the program. We will present these constraints below together with the detailed description of the algorithm.

Fig. 5 gives the outline of the algorithm thanks to which we can build and examine automatically the proof graph of a sequent, thereby receive all the discourses (branches/paths) leading to unsuccessful and/or successful endings as well as some important statistical information on the corresponding scenario such as: number of discourses, number of successful/unsuccessful discourses and number of successful discourses for each outcome/goal.

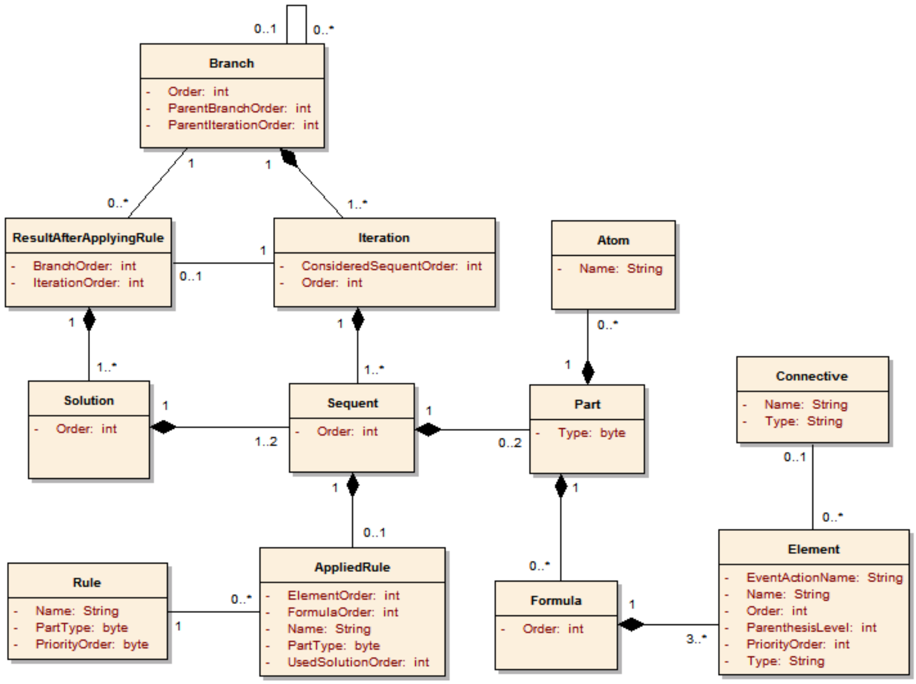

Fig. 6. Components used in the algorithm and their relation

The components used in the algorithm and their relation are described in Fig. 6 which is concretely explained hereinafter:

- *Connective:* In the IS modeling by means of Linear Logic, we employ the four following connectives (all of them (⊗, &, ⊕, ⊸) are used in the left part of the sequent, but only two of them (⊗, ⊕) are used in the right part of the sequent because & and ⊸ do not make sense in our approach):
    - Name = times; Type = Multiplicative Conjunction
    - Name = with; Type = Addititive Conjunction
    - Name = plus; Type = Addititive Disjunction
    - Name = imply; Type = Linear Implication

- *Rule:* There are seven rules considered in the process of proving a sequent (the rule &R (applied to the connective & of a formula in the right part of the sequent) is not used)
  - Name = Multiplicative Conjunction; PartType = 1; PriorityOrder = 1: This rule is applied to the connective ⊗ of a formula in the left part (PartType = 1) of the sequent. It is employed to rewrite a sequent (means substituting the connective ⊗ between two atoms, between two formulas, or between an atom and a formula in the left part by the comma ","). Its priority order is 1 (the highest priority), so this rule is always executed at first if possible.

$$\frac{\Gamma 1, \Gamma 2, \Gamma 3, \Gamma 4 \vdash \Delta}{\Gamma 1, \Gamma 2 \otimes \Gamma 3, \Gamma 4 \vdash \Delta} \otimes L$$

  - Name = Additive Conjunction; PartType = 1; PriorityOrder = 2: This rule is applied to the connective & of a formula in the left part of the sequent. There are two choices depending on the player.

$$\frac{\Gamma 1, \Gamma 2, \Gamma 4 \vdash \Delta}{\Gamma 1, \Gamma 2 \,\&\, \Gamma 3, \Gamma 4 \vdash \Delta} \&L \qquad \frac{\Gamma 1, \Gamma 3, \Gamma 4 \vdash \Delta}{\Gamma 1, \Gamma 2 \,\&\, \Gamma 3, \Gamma 4 \vdash \Delta} \&L$$

  - Name = Additive Disjunction; PartType = 1; PriorityOrder = 3: This rule is applied to the connective ⊕ of a formula in the left part of the sequent. There are two choices depending on the IS controller.

$$\frac{\Gamma 1, \Gamma 2, \Gamma 4 \vdash \Delta}{\Gamma 1, \Gamma 2 \oplus \Gamma 3, \Gamma 4 \vdash \Delta} \oplus L \qquad \frac{\Gamma 1, \Gamma 3, \Gamma 4 \vdash \Delta}{\Gamma 1, \Gamma 2 \oplus \Gamma 3, \Gamma 4 \vdash \Delta} \oplus L$$

    The rules &L and ⊕L are employed to divide a sequent into sub-branches. Their priority order is 2 and 3 respectively, so these rules are verified just after the rule ⊗L.

  - Name = Linear Implication; PartType = 1; PriorityOrder = 4: This rule is applied to the connective ⊸ of a formula in the left part of the sequent to execute that linear implication formula. It is considered after the rules &L and ⊕L, so its priority order is 4.

$$\frac{\Gamma 1', \Gamma 4' \vdash \Gamma 2 \qquad \Gamma 1'', \Gamma 3, \Gamma 4'' \vdash \Delta}{\Gamma 1, \Gamma 2 \multimap \Gamma 3, \Gamma 4 \vdash \Delta} \multimap L$$

    Thus, in order to prove the sequent Γ1, Γ2 ⊸ Γ3, Γ4 ⊢ Δ, we will have to prove both Γ1', Γ4' ⊢ Γ2 and Γ1'', Γ3, Γ4'' ⊢ Δ. Here Φ' is a subset of Φ and Φ'' = Φ - Φ', where Φ is Γ1 and Γ4 respectively. For example, if Γ1 = A, B (its subsets are {∅}, {A}, {B}, {A, B}), then either Γ1' = ∅ and Γ1'' = A, B; or Γ1' = A and Γ1'' = B; or Γ1' = B and Γ1'' = A; or Γ1' = A, B and Γ1'' = ∅. Although there are many solutions to consider in turn (depending on the combination between Γ1'/Γ1'' and Γ4'/Γ4''), if the original sequent is proved, then only one of them is successful (the others are unsuccessful). As a consequence, we will have to try each solution until either we find a successful one (the sequent is proved), or on the contrary, all of them are unsuccessful (the sequent is not proved). For instance, let us consider the sequent A, A ⊗ B ⊸ D, B ⊢ D, we have Γ1 = A, Γ2 = A ⊗ B, Γ3 = D, Γ4 = B, Δ = D, so:

- either Γ1' = ∅ and Γ1'' = A; or Γ1' = A and Γ1'' = ∅;
- either Γ4' = ∅ and Γ4'' = B; or Γ4' = B and Γ4'' = ∅.

Thus, we will have to try the four following solutions:

- ∅, ∅ ⊢ A ⊗ B and A, D, B ⊢ D (means that Γ1' = ∅, Γ4' = ∅, Γ1'' = A, Γ4'' = B): It is unsuccessful;
- A, ∅ ⊢ A ⊗ B and ∅, D, B ⊢ D: It is unsuccessful;
- ∅, B ⊢ A ⊗ B and A, D, ∅ ⊢ D: It is unsuccessful;
- A, B ⊢ A ⊗ B and ∅, D, ∅ ⊢ D: It is successful.

As we have found one successful solution, the original sequent A, A ⊗ B ⊸ D, B ⊢ D is proved.

- Name = Linear Implication; PartType = 2; PriorityOrder = 5: This rule is applied to the connective ⊸ of a formula in the right part (PartType = 2) of the sequent. Although ⊸R does not make sense in our IS modeling approach, we still have to consider this rule because it may appear during the sequent proof process. More concretely, it is a consequence while executing some complex linear implication formulas in the left part (such as (A ⊸ B) ⊸ (C ⊸ D)). Therefore, this rule is verified after the rule ⊸L, so its priority order is 5.

$$\frac{\Delta 1, \Gamma \vdash \Delta 2}{\Gamma \vdash \Delta 1 \multimap \Delta 2} \multimap R$$

- Name = Additive Disjunction; PartType = 2; PriorityOrder = 6: This rule is applied to the connective ⊕ of a formula in the right part of the sequent. As the right part expresses a list of outcomes that authors want to obtain, in the proof process we choose each outcome one after another, and verify whether or not the current branch is successful for that outcome. This rule is only considered after executing all applicable linear implication formulas in the left part, so its priority order is 6.

$$\frac{\Gamma \vdash \Delta 1}{\Gamma \vdash \Delta 1 \oplus \Delta 2} \oplus R \qquad \frac{\Gamma \vdash \Delta 2}{\Gamma \vdash \Delta 1 \oplus \Delta 2} \oplus R$$

- Name = Multiplicative Conjunction; PartType = 2; PriorityOrder = 7: This rule is applied to the connective ⊗ of a formula in the right part of the sequent. Its working is similar to the one of the rule ⊸L (see above) and it is only verified after dividing the right part into goals by the rule ⊕R, so its priority order is 7.

$$\frac{\Gamma' \vdash \Delta 1 \qquad \Gamma'' \vdash \Delta 2}{\Gamma \vdash \Delta 1 \otimes \Delta 2} \otimes R$$

To increase the processing speed of the algorithm, and make it simpler at the same time, we have proposed the following constraint: If in a formula, there are two types of connective: either &, ⊕ and ⊸ (if the formula is in the left part) or ⊕ and ⊗ (if the formula is in the right part), the formula will be transformed so that the connectives &, ⊕ (in the left part) and ⊕ (in the right part) are always the "principal one" of the formula. The usefulness here is that we can divide the sequent into "smaller" ones (by the rules &L, ⊕L, ⊕R) before applying the rules ⊸L, ⊗R. For example, consider the sequent A, A & B ⊸ C ⊢ C. For the formula A & B ⊸ C in the left part, its principal connective is ⊸, so we have to transform the formula into (A ⊸ C) & (B ⊸ C), its principal connective now is &. And hence, the sequent becomes A, (A ⊸ C) & (B ⊸ C) ⊢ C, therefore we can divide it into two sub-sequents A, A ⊸ C ⊢ C and A, B ⊸ C ⊢ C by the rule &L, then we continue to apply the rule ⊸L to prove these simpler sequents.

- A *sequent* is composed of two *parts* (separated by ⊢): Left part (Type = 1) and Right part (Type = 2) but each may be empty. A part includes *atoms* and/or *formulas*. The atoms' name represents their sense. The formulas are distinguished by the *Order* attribute (= 1, 2,…) which shows the formulas' order in the left part or in the right part of the sequent. Each formula is composed of at least three *elements* (atom, connective, atom). The elements are distinguished by their order number (= 1, 2,…) which expresses their position in the formulas. There are seven types of element:
  - Type = "Open Parenthesis", Name = "(", EventActionName = "", PriorityOrder = "0", ParenthesisLevel is the level of the parenthesis;
  - Type = "Close Parenthesis", Name = ")", EventActionName = "", PriorityOrder = "0", ParenthesisLevel is the level of the parenthesis;
  - Type = "Additive Conjunction", Name = "with", EventActionName = "", ParenthesisLevel = "0", PriorityOrder = "0";
  - Type = "Additive Disjunction", Name = "plus", EventActionName = "", ParenthesisLevel = "0", PriorityOrder = "0";
  - Type = "Multiplicative Conjunction", Name = "times", EventActionName = "", ParenthesisLevel = "0", PriorityOrder = "0";
  - Type = "Linear Implication", Name = "imply", ParenthesisLevel = "0", its *EventActionName* and *PriorityOrder* attributes store the name and the priority order of the corresponding event/action in the game;
  - Type = "Atom", EventActionName = "", ParenthesisLevel = "0", PriorityOrder = "0", the element's name represents its sense.

As every formula always has one principal connective, it always has one and only one applicable rule corresponding with this connective. Thus, a sequent may have at the same time a lot of applicable rules depending on its formula number. We have to choose only one rule among them by considering the priority order of the rules (see above). If there are some rules with the same priority order, the rule corresponding with the "most left" formula will be selected (in the case that there are several applicable rules ⊸L, the rule corresponding with the event/action with the highest priority in the story will be selected). For example, let us analyze the sequent A, B, C ⊕ D, (A ⊸ D) & ((A ⊸ E) ⊕ (B ⊸ F)) ⊢ F. The left part (Type = 1) A, B, C ⊕ D, (A ⊸ D) & ((A ⊸ E) ⊕ (B ⊸ F)) has two available atoms A and B, two formulas C ⊕ D (Order = 1) and (A ⊸ D) & ((A ⊸ E) ⊕ (B ⊸ F)) (Order = 2). The first formula C ⊕ D owns three elements, the second one (A ⊸ D) & ((A ⊸ E) ⊕ (B ⊸ F)) owns nineteen elements. In the second formula, there are four open parentheses and four close parentheses. The level of the open parentheses is 1, 1, 2, 2; the level of the close parentheses is 1, 2, 2, 1 respectively. The right part (Type = 2) only has one atom F. As there are two formulas C ⊕ D and (A ⊸ D) & ((A ⊸ E) ⊕ (B ⊸ F)) in the left part of the sequent, we can apply two rules ⊕L and &L. However, the priority of the rule &L is higher (PriorityOrder = 2), and hence it is the unique rule used for this sequent at the first step of the algorithm.

- *AppliedRule:* This component is employed to represent the rule applied to the sequent at each iteration step in the proof process. We use the following attributes to describe it:
    - FormulaOrder: It is the order of the formula to which the rule is applied.
    - PartType = 1 (or = 2) if the formula is in the left (right) part of the sequent.
    - ElementOrder: It is the order of the connective corresponding with the rule in the formula.
    - Name: It is the name of the rule corresponding with the type of the connective (Multiplicative Conjunction, Addititive Conjunction, Addititive Disjunction, Linear Implication).
    - UsedSolutionOrder: This attribute shows the order of the solution used in the result after executing the applied rule to the sequent, its objective is to keep the trace while proving the sequent. As presented above, depending on each rule, the received result may be composed of: either one solution including one sequent (⊗L, ⊸R), so UsedSolutionOrder is always 1; or two solutions that each include one sequent (&L, ⊕L, ⊕R) so UsedSolutionOrder is either 1 or 2; or many more solutions (⊸L, ⊗R) that each include two sequents, so UsedSolutionOrder = 1, 2, 3, 4,…

For instance, let us review the sequent A, B, C ⊕ D, (A ⊸ D) & ((A ⊸ E) ⊕ (B ⊸ F)) ⊢ F. The rule applied to it is &L. This rule, used for the second formula in the left part, corresponds to the sixth element (the connective &) of the formula. The result received after applying the rule is composed of two solutions that each include one sequent:

- Solution 1: A, B, C ⊕ D, A ⊸ D ⊢ F. If we use this solution as the received result, the applied rule will be represented by the following XML code segment:

```
<Sequent>
   <Part Type="1"> … </Part>
   <Part Type="2"> … </Part>
   <AppliedRule Name="Additive Conjunction" FormulaOrder="2"
   ElementOrder="6" PartType="1" UsedSolutionOrder="1"/>
</Sequent>
```

- Solution 2: A, B, C ⊕ D, (A ⊸ E) ⊕ (B ⊸ F) ⊢ F. If we use this solution as the received result, the applied rule will be represented by the above XML code segment with one difference (**UsedSolutionOrder="2"**).

- A proof graph is composed of one or many *branches* depending on the possibilities of choice of the player (using &L) and/or of the IS controller (using ⊕L). The branches are distinguished by their order number (= 1, 2,…). Each branch may have one or many *iteration* steps which are distinguished by their order number (= 0, 1,…). Each iteration step may have one or many *sequents* which are distinguished by their order number (= 1, 2,…). The first iteration step (Order = 0) in the first branch (Order = 1) will contain the original sequent (Order = 1). For each iteration step, in the beginning, we always consider its first sequent, if it is an initial one, then we continue to consider the second one and so on. The order of the considered sequent is placed in *ConsideredSequentOrder* (its default value is 1). If all sequents in the current iteration step are initial ones, then the branch corresponding with this iteration step is successful. If the considered sequent is not an initial one then we have to look for a rule applicable to it (paying attention to the priority between the rules ⊗L, &L, ⊕L, ⊸L, ⊸R, ⊕R and ⊗R).
  - Find a rule applicable to this sequent, we continue as follows:
    - Add this rule to the sequent to keep the trace of the proof process.
    - Record the received result after applying the rule to the sequent in *ResultAfterApplyingRule*:
      - ✓ BranchOrder is the order of the current branch.
      - ✓ IterationOrder is the order of the current iteration step.
      - ✓ One result may own one, two or many more *solution(s)* which are distinguished by their order number (= 1, 2,…). Each solution may include either one or two sequent(s), so their order number is 1, 2 respectively.

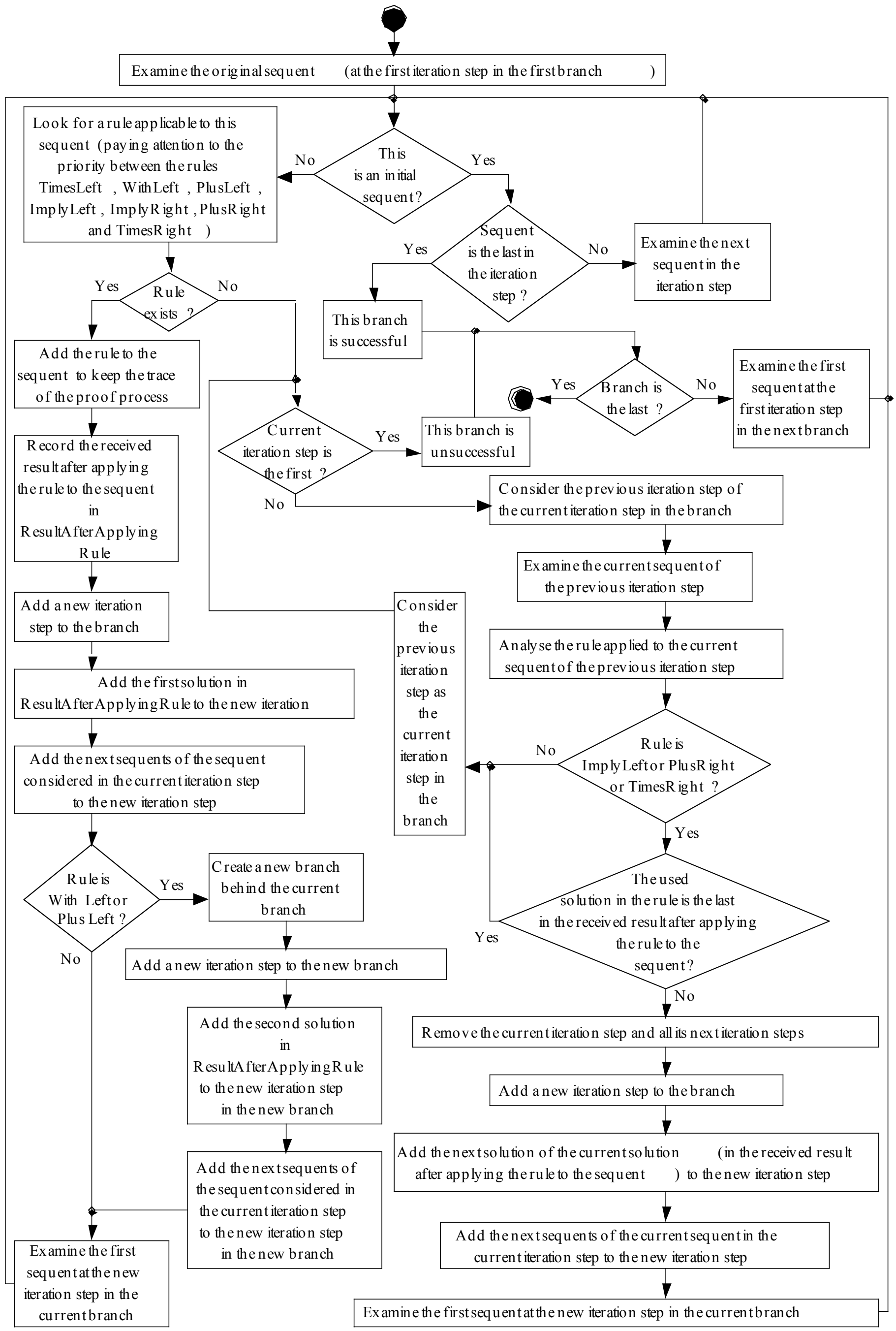

Fig. 7. Detailed operation process of the algorithm

    - Add a new iteration step to the current branch whose order is the order of the current iteration step plus 1. The new iteration step will contain the first solution in ResultAfterApplyingRule. If in the current iteration step, there is (are) one (some) sequent(s) following the considered sequent, we have to add it (them) to the new iteration step (behind the sequent(s) of the first solution).
    - If the applied rule is either &L or ⊕L, then we will add a new branch whose order is the order of the current branch plus 1, the order of its parent branch (ParentBranchOrder) is the order of the current branch, the order of its parent iteration step (ParentIterationOrder) is the order of the current iteration step (for the first branch, ParentBranchOrder = 0 and ParentIterationOrder = 0). After that, we add a new iteration step (Order = 0, ConsideredSequentOrder = 1) to the new branch which contains the second solution in ResultAfterApplyingRule. If in the current iteration step, there is (are) one (some) sequent(s) following the considered sequent, we have to add it (them) to the new iteration step in the new branch (behind the sequent(s) of the second solution).
  - Do not find any rule applicable to this sequent, if the current iteration step is the first one in the current branch, then this branch is unsuccessful. On the contrary, we continue to consider the previous iteration step of the current iteration step. If the rule applied to the current sequent of the previous iteration step is ⊸L or ⊕R or ⊗R, we will use the next solution of the current solution in ResultAfterApplyingRule as the received result after applying this rule to the current sequent of the previous iteration step.

Fig. 7 describes the detailed operation process of the algorithm which is a kind of depth first search that pays attention to the priority between the rules ⊗L, &L, ⊕L, ⊸L, ⊸R, ⊕R and ⊗R. It settles directly and entirely our requirements as well as overcomes all the inconveniences of the existing solutions, in which the most important thing is that the new algorithm reduces considerably the combinatorial explosion while proving a Linear Logic sequent. Its output (that contains necessary information on the considered scenario) is described in the next section.

5.4 Output

In order to facilitate the execution of the algorithm for users, we have developed a tool which helps them create a Linear Logic sequent (that models a scenario of a story), build and examine automatically its proof graph as well as show some important statistical information on the corresponding scenario (number of discourses, number of successful/unsuccessful discourses and number of successful discourses for each outcome/goal).

For example, let us see the sequent A, (A ⊸ B) & (A ⊸ C) ⊢ C. Its proof graph (drawn by the tool) is given in Fig. 8, where:

- Si: List of sequents to prove at each iteration step
    - S1 (original sequent): A, (A ⊸ B) & (A ⊸ C) ⊢ C
    - S2: A, A ⊸ B ⊢ C
    - S3 (2 sequents): A ⊢ A and B ⊢ C
    - S4: A, A ⊸ C ⊢ C
    - S5 (2 sequents): A ⊢ A and C ⊢ C
- The rule applied to the sequent which is examined at each iteration step is as follows:
    - L-Fi (R-Fi): The rule is applied to **F**ormula ***i*** in the **L**eft (**R**ight) part of the sequent
    - T, W, P, I: They are the rules corresponding with the connectives ⊗ (**T**imes), & (**W**ith), ⊕ (**P**lus), ⊸ (**I**mply) respectively.

  For instance, the rule L-F1-W means that we apply the rule &L to the formula 1 in the left part of the considered sequent.

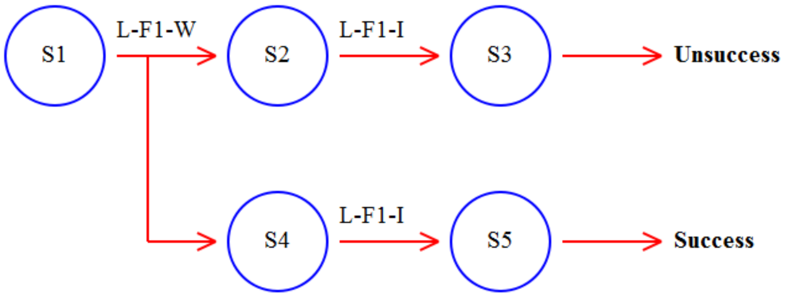

Fig. 8. Proof graph of the sequent A, (A ⊸ B) & (A ⊸ C) ⊢ C

Thus, we conclude that the proof graph of the sequent includes two branches/discourses, in which the first one is unsuccessful but the second one is successful.

6 Example on Validation of Scenario of a Story

Let us consider an example that illustrates how to use the proof graph of a sequent to validate the scenario corresponding to this sequent, and at the same time not to restrict the player's freedom. It is an extract of an educational game which warns of domestic electrical accidents whose objective consists in causing an electric shock for the player [6]. At first, the game designer anticipates that the player, from her/his initial position, will go to the kitchen, where the IS controller will start the strategy of causing the electric shock for her/him, via appliances there such as a fridge, a microwave oven, an electric cooker,… However, what will happen if the player does not go into the kitchen, but has other choices, for instance, staying at the initial position to work or going to the bathroom? We model this game by means of Linear Logic as follows:

- *States of the game:* Gi - Being at the initial situation (this state is available); Gk - Starting the strategy of causing the electric shock for the player in the kitchen; Gr - Reaching the goal (the player has got the electric shock).
- *States of the player:* Pi - Being at the initial situation (this state is available); Pw - Working at the initial position; Pk - Being in the kitchen; Pb - Being in the bathroom; Pe - Getting the electric shock.
- *Inputs of the player (her/his action choices):* Iw - Deciding to work at the initial position; Ik - Deciding to go to the kitchen; Ib - Deciding to go to the bathroom.
- *Events/actions of the game:* The player decides to work at the initial position (EA01: $Pi \otimes Iw \multimap Pw$) by choosing Iw; the player decides to go from the initial position to the kitchen (EA02: $Pi \otimes Ik \multimap Pk$) by choosing Ik; the player decides to go from the initial position to the bathroom (EA03: $Pi \otimes Ib \multimap Pb$) by choosing Ib; the IS controller starts the strategy of causing the electric shock for the player in the kitchen (EA04: $Pk \otimes Gi \multimap Pk \otimes Gk$); the player gets the electric shock (EA05: $Pk \otimes Gk \multimap Pe \otimes Gr$).
- *Outcome of the game:* $Pe \otimes Gr$ - The player gets the electric shock.
- Finally, we have the following sequent, in which the events/actions are replaced by their label: $Gi, Pi, Iw \otimes EA01 \ \& \ Ik \otimes EA02 \otimes EA04 \otimes EA05 \ \& \ Ib \otimes EA03 \vdash Pe \otimes Gr$. It gives all the possible discourses (scenario) of the game. Its proof graph is represented in Fig. 9.

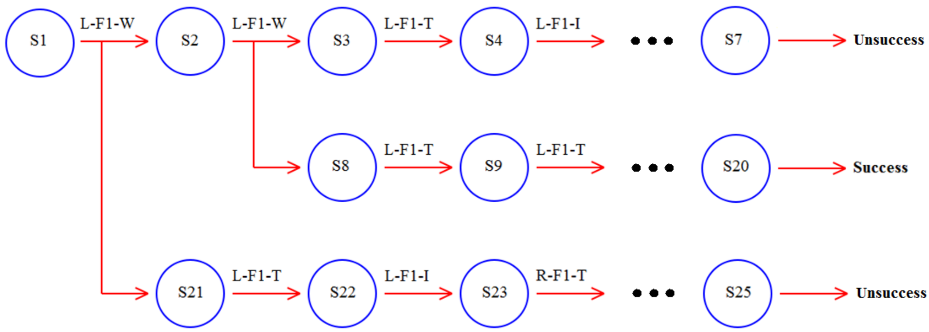

Fig. 9. Proof graph of the desirability sequent in an invalid scenario

We can see that there are two branches which lead to unsatisfactory endings of the goal of the game (if the player decides to work at the initial position or to go from the initial position to the bathroom). Therefore we have two possibilities:

- either remove the actions of the player causing the unsatisfactory endings (EA01 - Working at the initial position and EA03 - Going to the bathroom), but that may restrict the player's freedom, so we do not choose this possibility;
- or enrich the contents of the plot:
  - o if the player decides to work at the initial position, then the IS controller will ask him to go to the kitchen (for example, a non-player character asks him to take an apple in the fridge);
  - o if the player decides to go to the bathroom, then the IS controller will start the strategy of causing the electric shock for him there (by tools such as a hair-dryer, a light bulb,…).

Thus we remodel the game as follows:

- *States of the game:* Gi - Being at the initial situation (this state is available); Ga - Asking the player (who is working at the initial position) to go to the kitchen; Gk - Starting the strategy of causing the electric shock for the player in the kitchen; Gb - Starting the strategy of causing the electric shock for the player in the bathroom; Gr - Reaching the goal (the player has got the electric shock).
- *States of the player:* Pi - Being at the initial situation (this state is available); Pw - Working at the initial position; Pk - Being in the kitchen; Pb - Being in the bathroom; Pe - Getting the electric shock.
- *Inputs of the player (her/his action choices):* Iw - Deciding to work at the initial position; Ik - Deciding to go to the kitchen; Ib - Deciding to go to the bathroom.
- *Events/actions of the game:* The player decides to work at the initial position (EA01: Pi ⊗ Iw ⊸ Pw) by choosing Iw; the player decides to go from the initial position to the kitchen (EA02: Pi ⊗ Ik ⊸ Pk) by choosing Ik; the player decides to go from the initial position to the bathroom (EA03: Pi ⊗ Ib ⊸ Pb) by choosing Ib; the IS controller asks the player (who is working at the initial position) to go to the kitchen (EA04: Pw ⊗ Gi ⊸ Pw ⊗ Ga); the player (who is working at the initial position) goes to the kitchen according to the request of the IS controller (EA05: Pw ⊗ Ga ⊸ Pk ⊗ Ga); after the player goes from the initial position to the kitchen by deciding to choose Ik, the IS controller starts the strategy of causing the electric shock for her/his via appliances there (EA06: Pk ⊗ Gi ⊸ Pk ⊗ Gk); after the player goes from the initial position to the kitchen according to the request of the IS controller, the IS controller starts the strategy of causing the electric shock for her/his via appliances there (EA07: Pk ⊗ Ga ⊸ Pk ⊗ Gk); the IS controller starts the strategy of causing the electric shock for the player in the bathroom (EA08: Pb ⊗ Gi ⊸ Pb ⊗ Gb); the player gets the electric shock in the kitchen (EA09: Pk ⊗ Gk ⊸ Pe ⊗ Gr); the player gets the electric shock in the bathroom (EA10: Pb ⊗ Gb ⊸ Pe ⊗ Gr).
- *Outcome of the game:* Pe ⊗ Gr - The player gets the electric shock.
- Lastly, we have the following sequent, in which the events/actions are replaced by their label: Gi, Pi, Iw ⊗ EA01 ⊗ EA04 ⊗ EA05 ⊗ EA07 ⊗ EA09

& Ik ⊗ EA02 ⊗ EA06 ⊗ EA09 & Ib ⊗ EA03 ⊗ EA08 ⊗ EA10 ⊢ Pe ⊗ Gr. It gives all the possible discourses (scenario) of the game. Its proof graph is represented in Fig. 10.

We can notice that all the branches lead to the satisfactory endings of the goal of the game (which means the player always gets the electric shock in any case), and at the same time her/his freedom is also guaranteed. Thus this example demonstrates the Linear Logic model is effective in determining whether a proof graph contains error branches. In other words, it is efficient in validating a scenario of a story.

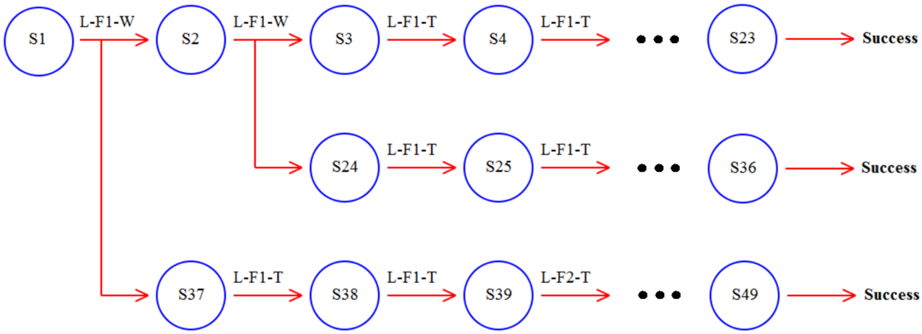

Fig. 10. Proof graph of the desirability sequent after manually modifying the scenario. Now valid, all branches lead to success.

7 Conclusion

In this paper, we have presented a methodology using Linear Logic, based on analyzing automatically the resource allocation mechanisms, that allows authors to derive a valid scenario of an IS. This methodology, which is executed in the scenario building phase of a story, guarantees that all the decisions (that may be made during unfolding the story) lead to satisfactory endings of authors' goals. Besides, it also helps authors have quickly an overall view on the corresponding scenario, such as: number of discourses and number of discourses for each outcome/goal.

The main contributions of the paper are: (1) to introduce the connectives & and ⊕ to model the choices of the player and of the IS controller; (2) to assign a priority order to each event/action in the story; and the most important one, (3) to propose a novel sequent proof algorithm that is based absolutely on the meaning of the Linear Logic connectives. Thus, we can enhance the modeling capacity and the authors' control on the unfolding of the story, as well as overcome the inconveniences that our previous works and other Linear Logic sequent proof solutions have met (especially the new algorithm eliminates the combinatorial explosion caused by the scheduling algorithm of events/actions (whose complexity is exponential), because it considers the priority order between the events/actions in the proof process, thereby reduces considerably the calculation time while proving a Linear Logic sequent). Besides, we have developed a graphical tool to facilitate the execution of the algorithm for users.

We also realize that, despite the promising results achieved with the Linear Logic approach for the development of formalism supporting IS modeling, a number of issues still need to be addressed. Firstly, we have only used four connectives &, ⊗, ⊸, ⊕, although they can express almost anything necessary in the IS modeling, we will supplement several other features of Linear Logic such as the connective "!" and the constant "1" to enhance the modeling capacity. Secondly, we can actually validate a scenario but have not evaluated its quality yet. In other words, how to show an "interesting/ludic scenario" for a game? In [5], we have proposed a new class of properties (impartiality, complexity, concurrence) that allows estimating the relevance of a scenario, and as a result, we will have to quantify theses properties for each game as well as test them by Linear Logic.

Finally, concerning future works to be done on the Linear Logic approach, in order to reduce the complexity in employing Linear Logic to model an IS for ordinary users, we must develop a solution so that Linear Logic remains hidden from them. To this purpose, we will apply a model transformation method, in which users model the story by means of a graphical editor (built on a metamodel that does not contain the notions of Linear Logic); the system then generates automatically a Linear Logic sequent that models the corresponding scenario of the story.

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Digital Storytelling and Educational Benefits: Evidences from a Large-Scale Project

Nicoletta Di Blas and Paolo Paolini

Department of Electronics and Information, Politecnico di Milano,
Piazza Leonardo da Vinci 32, 20133, Milano, Italy
{nicoletta.diblas,paolo.paolini}@polimi.it

Abstract. In this paper we investigate the potential of digital storytelling in the context of formal education (i.e. as a classroom activity). Our discussion is based upon the empirical evidence provided by a six-years' experience in Italian classes of all school grades (including pre-school), which has involved so far more than 17,000 students. The evaluation data come from surveys, direct interviews and focus groups with hundreds of teachers. Digital storytelling seems to provide substantial benefits of various kinds, ranging from knowledge acquisition, to media literacy and improved attitudes and behaviors. Nearly 700 narratives, created so far, can be accessed at www.policulturaportal.it.

Keywords: eLearning, Digital Storytelling, Authoring-Delivery Environment, Computer Supported Collaborative Learning.

1 Introduction

This paper is about digital storytelling in formal education. The issue we would like to address is if digital storytelling at school can provide educational benefits, what kind of benefits and under which conditions. The paper is based upon the data collected in PoliCultura (www.policultura.it), an initiative by HOC-LAB of Politecnico di Milano (Italy) that invites students, of all school grades, to create their own multimedia "narratives". PoliCultura has involved more than 17,000 Italian students from school year 2006 to June 2011. They will become more than 20,000 by June 2012. The extensive monitoring of the impact has included online surveys, skype interviews, focus groups with the teachers as well as the analysis of the students' artifacts performed each year by a panel of experts. The digital storytelling activity turns out to be like a pebble thrown in a pond: it promotes not only curricular benefits (e.g. like increased knowledge of a subject matter), but also non typical benefits, like the development of a professional attitude and improved relationships within the class.

A few distinctive features of our approach to digital storytelling must be clarified before digging into details:

A. In order to let participants free to integrate the activity into the curriculum, we take the concept of narrative in a very broad sense, which includes but is not limited to fiction. Authors can (and actually do) mix different literary genres at their will and they can narrate stories about virtually any subject.

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B. Multimedia narratives are a collaboration of the entire class, not the result of individual efforts [8; 12]. There are two reasons for this: first, we want to promote team building and group work within the class as educational benefits: individual talents are encouraged to serve a common end. Secondly, it is known from literature [18; 21] that a team effort provides great opportunities for inclusion of underperforming and marginalized students and again, inclusion is one of the benefits we wish to promote.
C. The narrative creation is embedded into a larger framework of standard curricular activities; it is not a discrete enterprise. No teacher would devote 2-3 months to creating a multimedia narrative if it was totally unrelated to the curriculum; even if they wanted to, it would not be possible, since curricula (in Italy and in most countries), are quite prescriptive.
D. All the narratives, even if they embed fiction, may be defined as “serious”, in the sense that they are linked to some school activity (a research, a project, a subject…) and are aimed at educational benefits.
E. Teachers can play various roles: facilitator, supervisor, co-author, “director”, trainer, producer, etc. A PoliCultura narrative is obviously a product by the students *and* the teacher, but the involvement degrees vary a lot. Some teachers orchestrate the whole work, others take care of content only, leaving students to play, at their will, with technology; others let the students organize themselves, etc. There is an obvious general pattern: younger students (from 5 to 8 years of age) require more intervention than older students.

This paper is organized as follows: in section 2 we describe the PoliCultura initiative, providing also brief examples of narratives. In section 3 we present the evaluation data and we discuss their interpretation. In section 4 we present some related works. In section 5 eventually we draw conclusions and present our future directions.

2 The Experimental Context

PoliCultura is an initiative by HOC-LAB of Politecnico di Milano, started in school year 2006. HOC-LAB had developed at that time an authoring tool (“1001stories”) for quick and easy production of multimedia applications that was then used (and still is) by the lab’s staff for applications in the fields of eCulture, eTourism, corporate communication and so on [11; 26].

Some of the tool’s features led us to think that it might work well in school environment too: it was very easy to use and it could support group work quite well. Eventually, the final narrative could be delivered over multiple channels and devices, which are beloved by youngsters: Web for PC, iPad, iPhone, tablet PCs, podcast… Thus in 2006, we launched a national competition on digital storytelling based on our tool (which was offered as a free web service). High schools only were involved. Following a number of requests, all school grades were included over the years. On the whole, more than 17,000 students and 700 teachers have taken part in PoliCultura so far, with a high number of registrations for the current year (Table 1).

Table 1. PoliCultura: participation from 2006 up to 2012 (the latter being a forecast)

	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	**TOT**
Pre-School	-	-	25	10	13	10	**58**
Primary s.	-	55	69	52	60	50	**286**
Junior H.S.	-	36	57	36	44	50	**223**
High School	57	38	40	45	56	50	**286**
Narratives	***57***	***129***	***191***	***143***	***173***	***160***	***853***
Students	***1,425***	***3,225***	***4,775***	***3,575***	***4,325***	***4,000***	***21,325***

Schools are notified of the initiative by the regional branches of the Italian Ministry for Education. Typically, two or more teachers from the same school decide to participate together. HOC-LAB provides participants with a short guide on how to make a multimedia narrative: the guide is 12 pages long and it addresses both communication and technological issues (how to use the 1001stories toolkit, how to record MP3 files). The technological requirements for using the authoring environment are light and in addition no specialized technological skills are required. So almost any teacher from any kind of school can take part: pedagogical knowledge is much more necessary than technical knowledge to successfully complete the experience [13; 24]. When the work is completed, participants can decide whether to take part in the national competition or not. A jury selects the finalists, who are invited to the LAB's premises in Milan, in June, for the celebration day. Workshops (for the students) and focus groups (for the teachers) are organized, in order to allow the LAB's researchers investigating the impact of the toolkit with its direct users.

2.1 The Authoring Environment: 1001stories

1001stories is the authoring environment with which schools create the narratives; it is made available as a free web service. It consists of three main components: a Content Management System, a Preview Engine and a Generator (that can be used by staff people only). The CMS is needed in order to clearly separate the authoring phase, performed via a web service, from the actual delivery of the narrative through multiple channels (Figg.1 and 2).

Fig. 1. and 2. Web for PC version (left) and mobile version (right, on iPhone) of a multimedia narrative by pre-school children

The CMS supports a number of functions: creation and editing of the narrative's structure, data entry of text, images, audio and preview of the narrative. The authoring interface (Fig. 3) is quite easy to manage: the average learning time in a primary school is 20 minutes. The Preview engine allows playing the content at any stage of the work, thus providing an immediate reward to the authors.

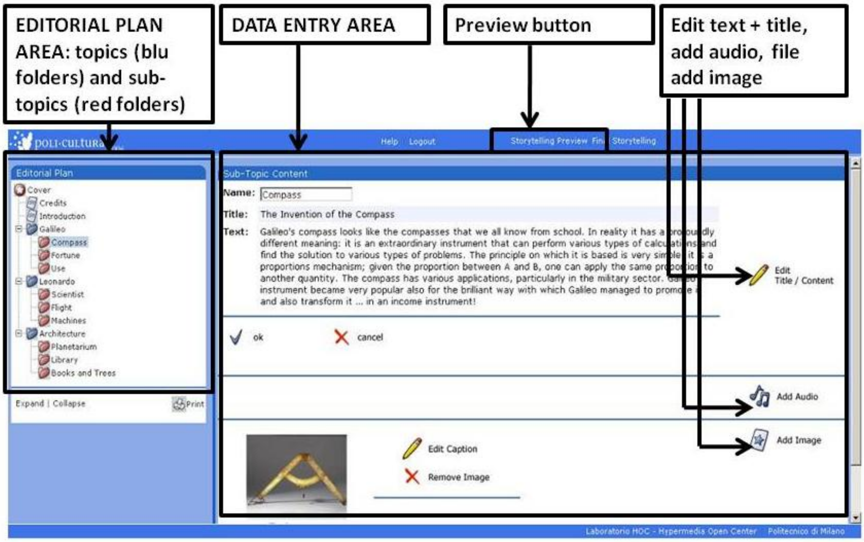

Fig. 3. 1001stories: the authoring interface

The Generation engine takes the data from the CMS and transforms them into playable applications for a number of devices and channels: standard web, downloadable application, application for tablet or smart-phone, etc. Even the delivery on paper is included, in the form of posters and booklets. Images and audio are turned into video files that can be moved around independently (e.g. for hosting them on YouTube).

2.2 Creating a Narrative

The narratives can be organized according to two kinds of information architectures: "complete" or "compact". A complete narrative is organized according to a tree-structure, with topics and subtopics (Figg. 4 and 5). A compact narrative instead is a linear sequence of topics, without sub-topics. Each content item (topic or subtopic) consists of an audio, a number of images with captions and a text. The optimal length of the audio for each content item is 1 minute approximately (corresponding to a text of 120-200 words), with 6-8 images.

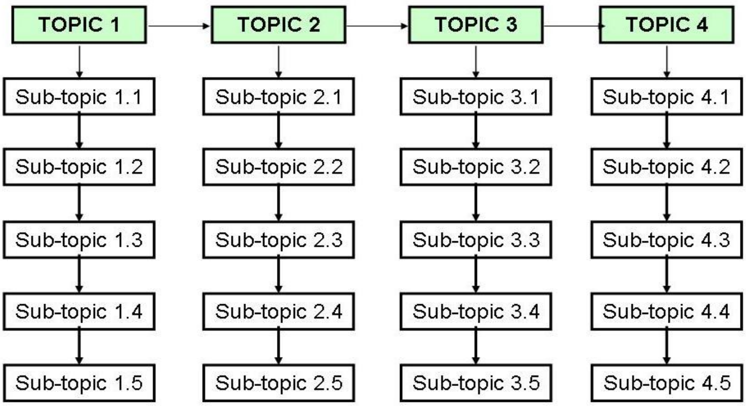

Fig. 4. The information architecture for a “complete” narrative

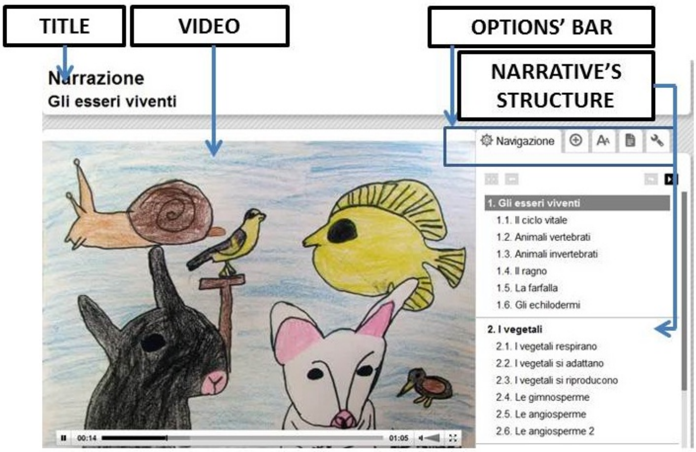

Fig. 5. The web interface of a “complete” narrative

The interaction possibilities vary according to the device/channel being used. For example, touch is used on iPad while playlists are used for MP3 players like iPod. In all cases, two basic patterns are available: the passive one (the application pushes content) and the active one (the user selects what she is interested in).

As the reader can see, the work is channeled by a number of constraints which at first sight may appear as limitations: the information-architecture is rigid, the length of each content item is limited and the direct use of videos is not allowed (the engine generates videos from the images). The reason behind these constraints is this: we wanted to involve as many schools as possible (not only the best ones) and the humanities teachers (the ones that are likely to be the least tech-savvy).

Thus authoring had to be easy and accessible, and authors had to concentrate on communication rather than on technical issues (like how to edit a video, which is not a trivial task) or design issues (like deciding how to structure content). Six years of experience have shown that these apparent limitations are a trigger for creativity: participants interpret the information architecture in their own way to support various kinds of narrative's structures; kids in primary school create their own drawings which are then scanned and used to generate the videos; the audio component, which we meant as a vocal commentary of the images, in the students' interpretation may become a "music plus voice" commentary, music only, a song by the students, etc.

The suggested production workflow is composed of 5 main steps: (1) theme selection; (2) sketching of the editorial plan; (3) gathering of the material; (4) content's production and refinement; (5) content upload. This basic schema is not always followed: for example, in some cases the topic of the narrative is the object of some other school activity, independent from PoliCultura, therefore a huge amount of material is already there and instead of "gathering the material" the issue is adapting it to the 1001stories format. In other cases, since the class is divided into groups, each group follows its own workflow. As regards the narrative's topics, at first there were two tracks only: local history and local cultural heritage. Now, virtually any subject is allowed, though some special tracks are still suggested, like for example "archeology in your local territory".

2.3 The "Scent" of the Narratives

Over the years schools have shown that even with the rather strict constraints described above there is plenty of room for creativity. The multimedia narratives stem from the most various experiences: school outings, social projects, researches, curricular subjects… They are related to almost all the school disciplines, with a preference for humanities. Different multimedia solutions are devised: in many cases music is added to the voice reading the texts as background or in some cases as main communication medium (e.g. a Sicilian boy singing a typical local song). The interested reader can explore our online portal (www.policulturaportal.it), where all the narratives produced so far (700 approximately) are gathered. Let us see now some examples.

The "Stories of the circus" (primary school, 2008) is an example of free interpretation of the "complete" information architecture (Figg. 6 and 7). In the instructions manual, the main topics are described as "summaries of the subtopics", while in the case of the Circus application each topic is not a summary, but a short introduction to a comical story which runs through the sequence of sub-topics (Fig. 7). Thus, the whole application is composed by sequences of short stories. The teacher reported that she had divided the class into groups and each group was in charge of a story. The work was based on a school project in which students had met with circus people.

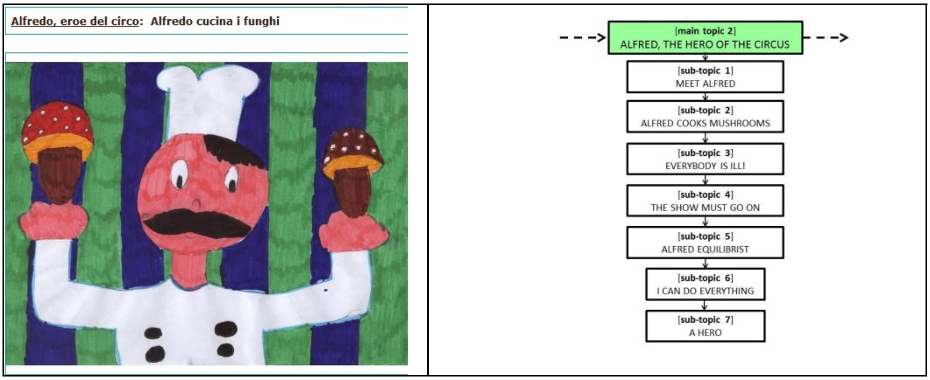

Fig. 6. and 7. The "stories of the circus" (2008, primary school). On the left, Alfred the cook in a drawing by the kids; on the right, the stories' steps: Alfred is the circus cook; he cooks bad mushrooms and everyone falls ill; he plays everyone's parts to save the show and becomes the circus hero.

Especially in the case of narratives by pre-school or primary school students, fiction gets mixed with other literary genres. For example, in the narrative "Pirate Diego and the laws of floating", the sequence of main topics tells the story of the many attempts by the shipwrecked little pirate Diego to build a new ship and the teachings by his parrot (Archimedes) about the laws of floating. In the sub-topics, quizzes are given to the young readers to check whether they are learning too (Fig. 8).

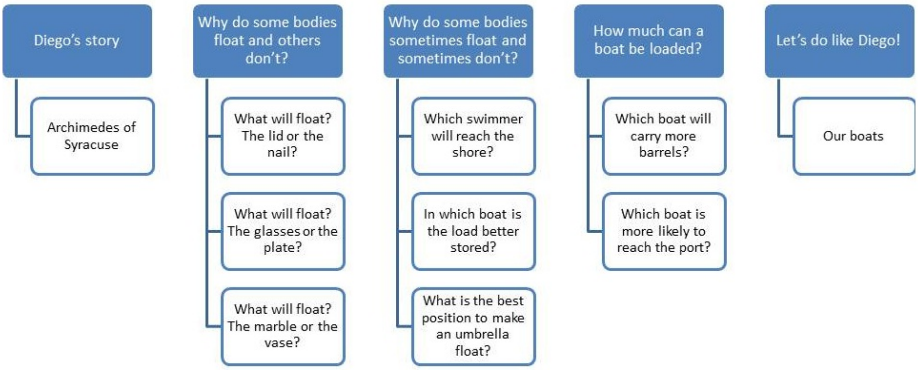

Fig. 8. The information architecture of the narrative "Pirate Diego and the laws of floating"

In the "History of aviation" narrative high-school students decided not to use vocal commentaries but music only as audio. But the music is highly meaningful: for example, when dealing with the Vietnam war, the audio is a powerful music with American soldiers' voices and the sound of helicopters and weapons, which make the narrative's impact quite dramatic (Fig. 9).

Fig. 9. "History of aviation" (2010, high-school). The audio is music with soldiers' voices, weapons, helicopters; the text, available on demand, tells the story of the Vietnam war.

The narrative called "Padua pocket", by high-school students, capitalizes on the multichannel delivery: it is a multimedia audio guide that takes users around the town of Padua, including the Scrovegni chapel with Giotto's frescos (Fig. 10).

Fig. 10. "Padua pocket" (high-school, 2010), on iPhone

Many narratives deal with the students' local art or history: the narrative that bears the funny title of "A guide for students who are tired of sitting at their desks" tells the story of a school outing to a famous Italian cathedral and its museum. The content is based on a number of interviews with art experts and the museum's curators (Fig. 11).

In some cases students introduced interviews to experts or relevant people in the narratives. That is the case of "I did it just because I'm a man", a narrative by high-school students about Giorgio Perlasca, a man who during the second world war saved thousands of Jews risking his own life. The students interviewed Perlasca's son and skillfully edited the audio to use it in the narrative, again with a quite dramatic effect.

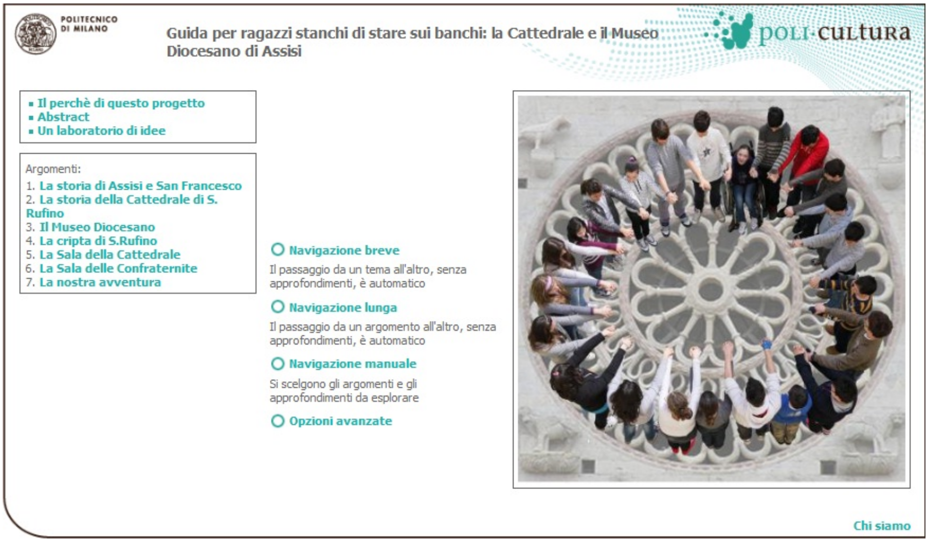

Fig. 11. The front page of a narrative about the Italian cathedral of Assisi (2011, junior high-school); using Photoshop, students placed themselves on the rose window

3 Evaluation

Every year, from 2006, the impact of PoliCultura is tested through a number of means: online questionnaires, direct interviews (via skype), focus groups and the analysis of the students' artifacts. Online questionnaires are administered both to the teachers who complete the narrative and take part in the competition and to those who do not complete the narrative and therefore do not take part in the competition. Interviews are taken when the activity is about to start, to investigate the teachers' expectations, and at the end, to investigate the results. Interviews undergo a refinement process which generates a number of documents: the transcript, the "features extraction schema" (in which the main features of the experience are organized), the experience description etc. All these materials are made available through a public online repository, which is being developed in the frame of a national research project (www.learningforall.it).

Focus groups are held each year during the celebration day of PoliCultura: HOC-LAB researchers sit together at a round table with 20-30 teachers and school principals. Examples of issues dealt with are: what is the role of technology in education? Would a similar activity – storytelling – work right the same even without the technological support? Do technology-based activities foster inclusion? Do all the students take part in the activity? etc. Eventually, the narratives themselves are object of analysis by a panel of experts.

From 2006 up to now 1400 teachers approximately have filled in 2800 surveys (one before and one after the experience), 100 teachers have been involved in focus groups, 65 teachers have granted in-depth interviews and more than 50 narratives have been closely analyzed. In addition, we meet and discuss every year with more than 150 students, when they come for the award ceremony. We do not involve further students in the evaluation for this reason: educational benefits (and not just satisfaction and involvement) are our ultimate goal and their assessment is typically the teachers' job. Therefore we ask teachers to report on their students' improvements. In addition, in other large-scale educational programs (based on MUVEs, with more than 9,000 participants over a period of 5 years), in which surveys were administered to teachers *and* students, we saw that the surveys' results about benefits always provided comparable results between teachers and students. So, after a while, we stopped double checking, since we found it devoid of any additional information.

3.1 Benefits

We briefly present in this section the educational benefits that according to teachers are generated by PoliCultura. Numbers come from the surveys that we administer every year, quotations come from interviews or focus groups. We report the data from the latest edition (2011).

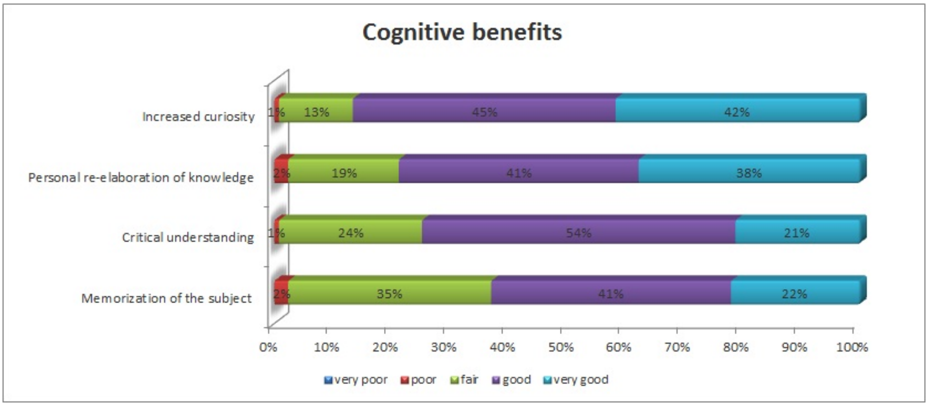

Fig. 12. Students' achievement of cognitive benefits (127 teachers, year 2011)

From the point of view of cognitive benefits (Fig. 12), PoliCultura performs quite well, generating curiosity towards the subject dealt with and favoring the re-elaboration of knowledge (obviously, given the need to build a narrative).

A teacher reports: "The students in my school (a Technical Institute) seem uninterested in learning the techniques of writing, and disaffected about culture in general. The teachers' job gets harder, as we struggle to find strategies for motivating students to express their thoughts in correct forms. The opportunity offered by PoliCultura, that made available to schools such a friendly product of advanced technology to communicate culture, was well accepted: all students in the class could collaborate to create the interactive narrative. Educational results have been excellent, because writing – together with other forms of expression – has become a useful tool, which students use now with increased confidence."

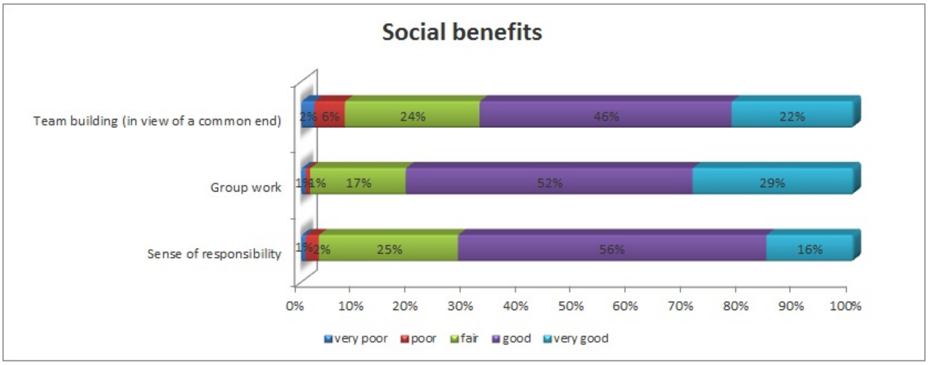

Fig. 13. Students' achievement of social benefits (127 teachers, year 2011)

PoliCultura fosters the development of group-work capabilities: from the interviews we learn from teachers that almost always the whole work is divided into sub-tasks, assigned to small groups of students (2-4 students per group). In addition, the submission deadline and the fact that the work will be made public in the PoliCultura website trigger the students' sense of responsibility and the feeling of cooperating towards a common end: finishing the work on time and hopefully winning the competition.

A teacher reports: "my students are reaching the awareness that group work means coordinating, listening to each other, assigning the tasks etc."

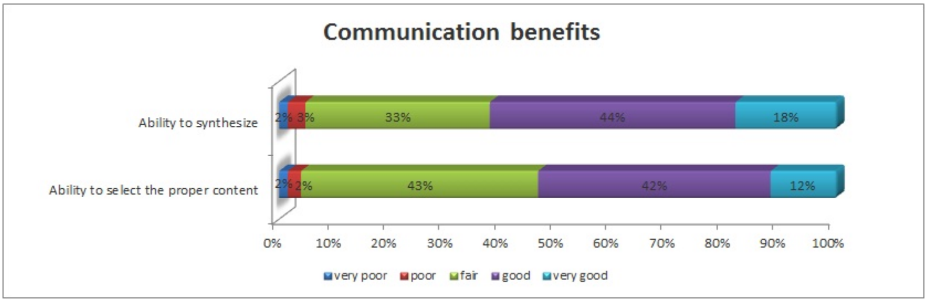

Fig. 14. The students' achievement of communication benefits (127 teachers, year 2011)

The ability to communicate in small content fragments, which is typical of multimedia communication, was in our intention a major benefit, but surprisingly enough teachers hardly mentioned it in the expectations' interviews. Still, when the activity was finished, they did acknowledge it. The reason why teachers tend not to mention communication benefits in the expectations interview is probably the fact that "communication" is not on the official agenda of the curriculum (in Italy).

A teacher reports: "since texts had to be short and 'to the point', students have developed good analysis and synthesis abilities, which in normal school activities are not triggered".

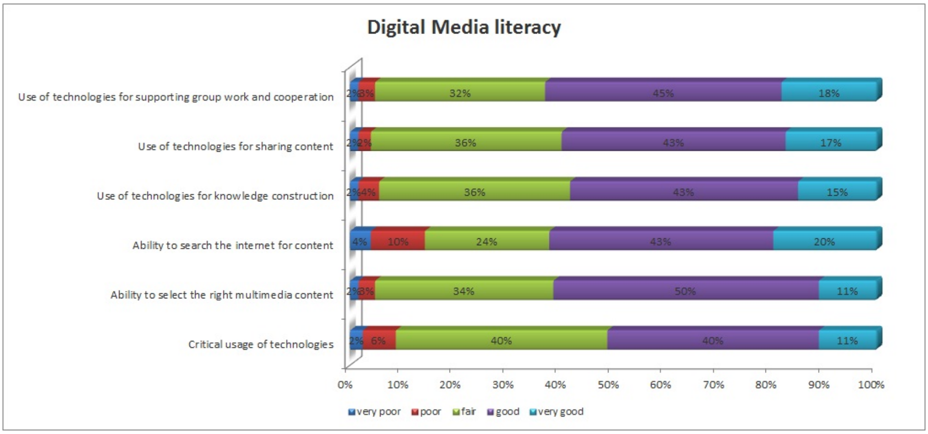

Fig. 15. The students' achievement of digital media literacy (127 teachers, year 2011)

Digital media literacy was an obvious benefit that we expected (Fig. 156). A teacher reports: "the alliance between history and new technologies is highly innovative: it brings students to communicate in a concrete, succinct and visual way; it fosters creativity and the surfacing of personal talents".

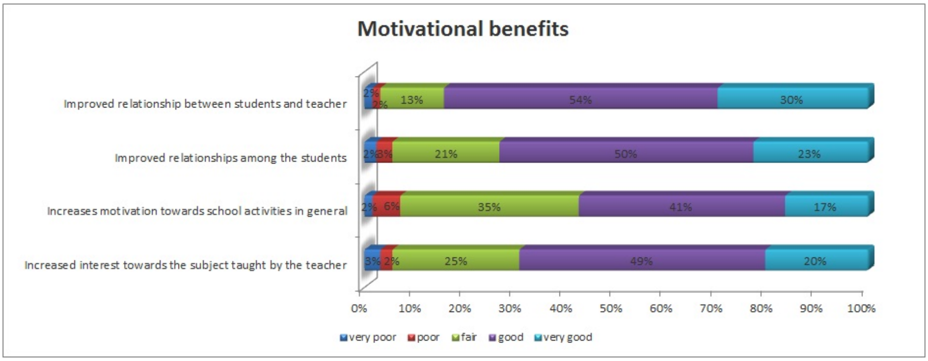

Fig. 16. The students' achievement of motivational benefits (127 teachers, year 2011)

Our experience with technology-based programs is that they can be highly motivating for students and that there is a strong correlation with overall school performances. Teachers report: "PoliCultura has triggered aggregation inside the class; students were so motivated that they worked even beyond school hours"; "PoliCultura generates enthusiasm: students show prolonged attention and they thrive to improve their performances".

3.2 Inclusion

ICT can be a powerful means to involve less performing students, especially if they support collaborative activities [18; 21].

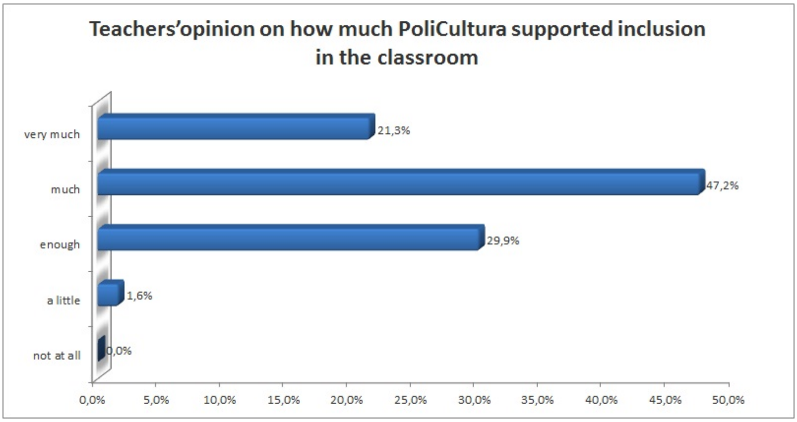

Fig. 17. Inclusion benefits (127 teachers, year 2011)

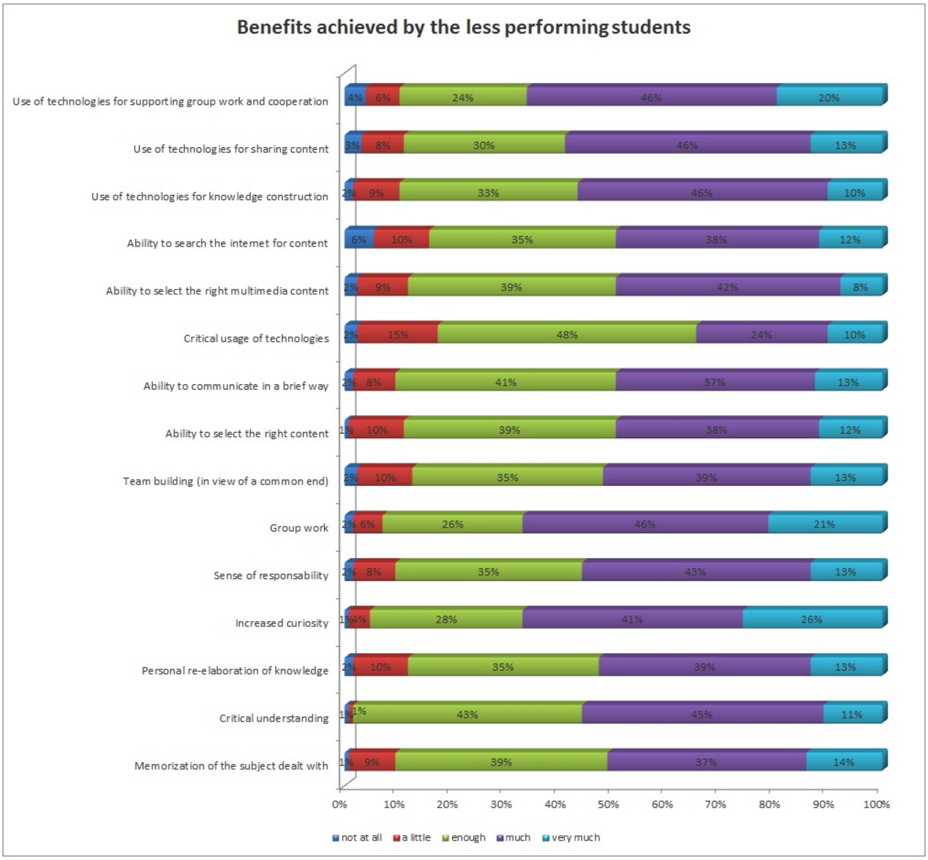

Fig. 18. Inclusion benefits (127 teachers, year 2011)

In order to double check the overall opinion of the teachers about inclusion, and in order to understand the fine grain of how it worked, we asked more specific questions about the benefits for less performing students (Fig. 18).

Teachers report: "in my class there is a dyslexic kid. He tried to record his part 15, 20 times. He did not want to give up! The whole class stood around him cheering and in the end, he made it"; "PoliCultura has been an occasion to know my students better, especially some kids who proved invaluable in this work, whereas in regular school activity they do not usually stand out".

3.3 When PoliCultura Does Not Work

Is PoliCultura the "perfect" experience? Obviously not. Data show that the large majority of the participants who get to the end and create their narrative, even when the result is not fully polished, feel a sense of accomplishment and obtain substantial learning benefits. But every year 50% approximately of the classes that start do not finish the work. In year 2010-2011, for example, 325 classes registered. 173 classes (53.2%) completed the narrative, 149 of which on time for the competition, and 25 later, but still before the end of the school year. When and why did 152 classes (46.8%) stop working at PoliCultura?

More that 56% of the classes that stop their work do this very early, somehow realizing that the enterprise is too demanding (Fig. 19). The question is: what happens to those classes that drop out when 50% (or more) of the work is already done? Why do they fail?

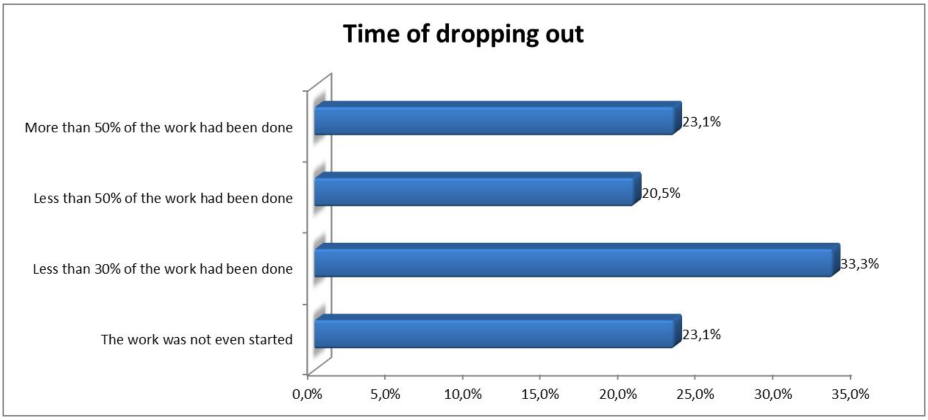

Fig. 19. When classes stop working at PoliCultura

Most of the motivations for dropping out are related to the "context" in a broad sense (time, resources, lack of support by the principle and the school council, etc.) but not to the idea of building a multimedia narrative. In other words, participants do not drop out because they think that creating a multimedia narrative is not worthwhile but for other practical or contextual reasons (Fig. 20).

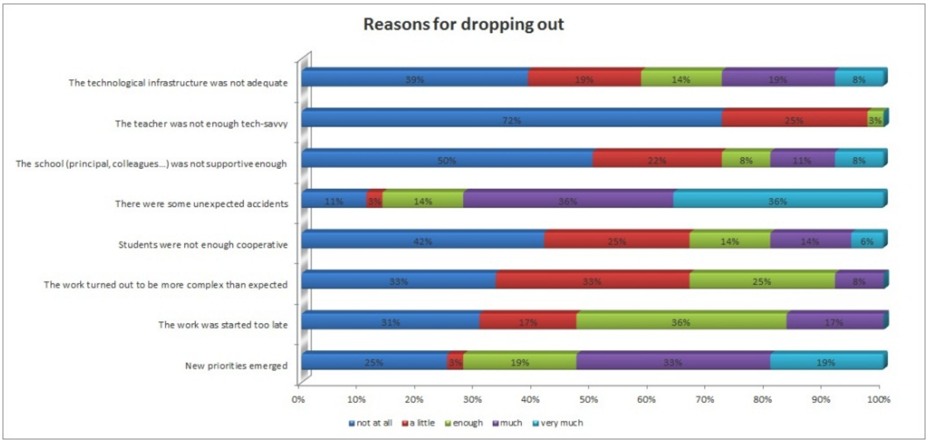

Fig. 20. Why classes stop working at PoliCultura

4 Related Works

Digital storytelling is quite a huge field; due to the focus of this paper, in this section we will introduce systems that are meant for educational use and more specifically for *authoring* multimedia digital stories rather than for supporting passive consumption [19]. We must warn the reader that none of these systems was a source of inspiration for PoliCultura and 1001stories, which, as explained above, was created to support professional authoring of multimedia content in the field of cultural heritage and was then transferred as it was into school environments for educational use.

Authoring tools for digital storytelling have been mainly developed for young children, being the educational value of authoring a story strongly backed by those pedagogical theories that consider learning as knowledge building rather than knowledge transmission [15]. A number of tools have been developed to support this activity, both in the academic and commercial arena. Still, commercial products tend to see users more as listeners than authors; if they are considered as authors, then they are generally provided with readymade characters with which they can play role-games at most. These products are often CD-rom based, they impose strong limitations to creativity and almost never allow cooperation or sharing of the stories with other peers [2]. Academic prototypes and projects afford more creativity [7; 17; 25]. Many approaches make use of physical elements to trigger the process of story-making. For example, MIT's StoryMat records and recalls children's voices as they play with stuffed animals on a colorful, story-evoking, quilt [6]. Other approaches, like SAGE [4] and PET [14], integrate tangible elements (like stuffed animals) into the technology-enhanced storytelling process. StoryRoom also adopts a physical approach by providing kids with room-sized interactive storytelling spaces where they share a theatrical experience [1]. ShadowStory, eventually, is a digital storytelling system inspired by traditional Chinese shadow puppetry. Using a Tablet PC children at primary school level create digital characters and perform live stories together on a projection screen [22]. Other approaches provide children with online tools for supporting the story creation process. A recent development is G-Flash, an authoring tool for primary school children that supports that story creation using illustrated flashcards, with characters and scenarios [20]. Wayang is another online authoring platform, developed by the dimeb Research Group of Bremen University, meant to allow students to express their cultural diversity. Children create either individual or collaborative stories by using digital puppets [29].

Other approaches make use of virtual environments in which the stories take place, like PUPPET, an autonomous agents-populated virtual environment where children play multiple roles in creating narratives [23]. Collaborative storytelling has also been explored, but mostly at experimental level. MOOSE crossing, for example, allows kids to cooperatively design and build objects and virtual characters in a virtual space [5]. The FaTe project allows very young kids (aged 5 to 8) to develop stories together in a shared 3D environment [16]. ToonTastic is a tool, still in its beta phase, meant to enable children to collaboratively create a story using an interactive, multiple-pen display [28]. Eventually, CBC (Canadian Broadcasting Corporation) 4Kids's StoryBuilder is one of the rare examples of large-scale exploitation of a digital storytelling system. Children can create multimedia comix-style stories, based on the typical mechanism of "add-a-sentence-to-a-story". They can then save their stories in an online personal space and also publish them and share them with friends, via email [2]. Digital drawing, especially if collaborative, has also been considered a form of storytelling, like in the KidPad project [3].

What differentiates 1001stories with respect to the above systems? First of all, 1001stories addresses a wider audience of users, aged between 4 to 18 (and even more, if professional usage is considered). In addition, it must be noted that the tool does not undergo any form of adaptation to fit the various age-ranges. Second, no ready-made element that could influence the story-creation process is introduced, like stuffed animals, virtual character, themes or story-patterns. Third, when used in formal education it supports (like some of the above systems do) collaborative storytelling, with an educational aim. Fourth, the simplicity of the authoring process goes with a sophisticated multi-channel delivery (web for PC, smartphone, playlist for MP3 players, multi-touch tables etc.). 1001stories approach could be summarized with a metaphor by the famous architect Mario Botta, who used to say that even without a full palette of colors, but with just a black and white pencil, it is possible to make beautiful drawings. 1001stories is almost trivial in its simplicity, but it allows drawing beautiful things.

5 Conclusions

Six years of deployment of PoliCultura with more than 17,000 participating students demonstrates that digital storytelling can be successfully introduced in school environment and produce educational benefits. In our opinion, the reasons why this initiative works well are:

- the authoring environment is easy to use, so that non tech-savvy teachers can join the activity;
- the final result is highly innovative for school standards (multimedia, multi-device, interactive, …) and thus it is perceived as "cool" by the students. All the interviewed teachers say that without the perspective of a multimedia narrative the class would not have worked in the same way. A comparative study, comparing traditional storytelling with 1001stories, confirms the crucial role of technology [27];
- hints on the workflow are provided in the instruction manual, but the pedagogical implementation of the activity is 90% in the hands of the teacher and the pupils;
- the storytelling activity is not isolated but strictly related to the curriculum and the educational goals.
- visibility of the final work, in a public website, is a strong "kick". It was spontaneously mentioned by 75% of the interviewed teachers as one of the main motivating factors for the students.
- the competition also acts as a powerful motivation factor. Being goal directed is one of the many characteristic that in Csikszentmihalyi's option an activity should have in order to foster a sense of flow (i.e. deep involvement) in the participants [8; 10].
- PoliCultura is a collaborative activity to which classes take part as a whole. Thus students learn that their individual efforts and talent are a resource for the group and they learn how to deal with group work issues;
- last but not least, the narrative creation based on technology triggers a re-shuffling of roles and the surfacing of new talents. This change, if well coordinated by the teacher, generates inclusion, in the sense that even less performing students get more motivated and get a feeling of accomplishment, thanks to the fact that they are part of the team;

Our main research direction now is to further investigate through detailed interviews to teachers the educational benefits and the way they are related to the pedagogical implementation. As far as authoring is concerned, our future steps are:

- expanding the narrative formats, especially improving the versions for mobiles and tablets;
- adding new features to our authoring environment specifically meant to support the final phases of the narrative's creation, to allow authors to check and make changes in a quick and efficient way;
- integrating the authoring environment with a LMS (Learning Management System) in order to support all the phases of the narrative creation, including the collection of the material, the groups' organization, the discussion, etc.

Finally our new international portal (www.policulturaportal.it) is the occasion for providing more national visibility and, more important, to start making PoliCultura an international adventure.

Acknowledgments. We warmly thank the HOC-LAB staff who passionately work for making PoliCultura a success every year, especially Elena Maccari, PoliCultura's project manager.

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Collecting Aboriginal Stories for Education through Immersion

Cat Kutay

Computer Science and Engineering,
The University of New South Wales
ckutay@cse.unsw.edu.au
http://www.cse.unsw.edu.au/~ckutay

Abstract. This research is in the area of life-long learning through storytelling, focusing on the use of multiple individual stories to create an immersive environment for learning cultural concepts or recreating historical environments. We take the approach that while an individual's story is developed through collecting stories from different times, more conceptual community narratives are developed through collection from many individuals from different perspectives.

We have focused on stories explaining the experience of Aboriginal and Torres Strait Islander people in Australia at the 'cultural interface' [1], an approach we explain in this paper. There is no one story of this experience, and some historians ([2]; [3]; [4]) claim that different people's stories could conflict. We consider here ways to either avoid or use these conflicts.

This work is also aimed at enabling Indigenous people, who are more skilled users of multimedia than text, to construct useful learning material that retains their cultural values and intent. This will involve creative software tools, especially for surmounting the vast difference in culture and learning processes between the Indigenous and non-Indigenous communities in Australia.

Keywords: Group Storytelling, Community narrative, Indigenous Knowledge.

1 Introduction

This paper covers two projects in the area of Indigenous Knowledge sharing using web services. The projects are part of an ongoing initiative to develop services to support the community requirements in IT, covering areas such as usability, access and trust. The projects vary in their audience. One is focused at communities developing resources for informing government employees in their region, the other on Aboriginal students creating material for use by all students at University.

To teach cultural understanding, we want those who are immersed in one culture to be able to explain this culture to those who are not. It is preferable that a form of immersion then also takes place for the learner. Also is has been

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found that adult learners are more motivated when re-living real life scenarios [5]. However it is not feasible to provide this experience in real life for the many people in Australia who wish to learn about Aboriginal or Torres Strait Islander culture, prior to their work on projects with communities, or who may wish to broaden their understanding of the local cultures. Hence we are looking to virtual worlds and cloud learning tools to support this process.

To develop suitable educational design we have drawn from wider theories of the interface between cultural knowledge systems and traditions as developed by Verran [7]. This considers the complexities at the interface between Aboriginal and non-Aboriginal cultures as a critical aspect of Indigenous learning [6].

The focus of our work is to collect the stories and embed narratives in lifelong learning and University courses. From her work with North American Aboriginal people, Battiste [8] argues that animating the voices and experiences of Aboriginal people and integrating them into education creates a balanced centre from which to analyse European culture and learning. Therefore we are using online teaching using storytelling from Aboriginal students and community, focusing on Aboriginal knowledge sharing forums (see [9] for other applications and [10] for Indigenous Australian teaching site). We are using shared website in an open-source Wiki format, which allows the design of a series of 'focus' pages with archival or introductory material. The users are able to comment and link these to segments of existing material (text, images, video and audio).

2 Indigenous Storytellers

This work is motivated by an interest in the wealth of knowledge that exists as oral memory within an Indigenous culture, and in particular how this knowledge may be used to reflect on cultural assumptions by those who have lost their location in time and space, their link to a specific area of land, and the type of environmental and social knowledge that is embodied in such a lifestyle.

While much Indigenous knowledge has been brushed aside as irrelevant to modern society, there is now growing interest in re-gaining this knowledge in areas such as: conservation; understanding the techniques of a purely observational science; and critiquing how we relate to each other in an individualist society. Most of our work is based in New South Wales so deals specifically with Aboriginal people. However there are similar themes within Torres Strait Islander knowledge and we hope to expand the projects into this area.

Nakata [1] describes the contested space between the two knowledge systems as the cultural interface where things are not clearly black or white, Indigenous or Western. In this space he sees many aspects, including the knowledge technologies, which condition how we all come to look at the world and the knowledge we practice in our daily lives.

In introducing Indigenous knowledge into the academy, Nakata provides issues to consider:

1. Indigenous knowledge should not be conceptualised simply in opposition to the standpoint of scientific paradigms.

2. Indigenous knowledge should be documented in ways that does not disembody it from the people who are its agents or this dislocates it from its locale, and separates it from the social institutions that uphold and reinforce its practice.
3. Avoid the disintegrations and transformations that occur when Indigenous Knowledge is redistributed across Western categories of classification, when it is managed in databases via technologies that have been developed in ways that suit the hierarchies, linearity, abstraction and objectification of Western knowledge [6], p.9.

We are re-creating a process of community narrative as was seen in the development of the story of the Stolen Generations in Australia [11]. These stories are about the period when Aboriginal children were removed from their community, up until the 1970's. The parents and children all had their stories, and mixed feelings of guilt and neglect. The enforced cultural distance within Australian society and the geographical barriers created by their removal often to distant orphanages, prevented the two groups from meeting to combine their stories. It was only with the advent of the 'Link Up' network to assist the searching of family records that their stories also linked up, and the real historical reasons and consequences of this period of Australian history became known outside the Aboriginal community [3].

For Aboriginal and Torres Strait Islander people, storytelling is the main mode of knowledge sharing and this requires much repetition for the learner to hear various version from different story tellers in order to understand all the different nuances. In fact, singing a traditional story is considered the ultimate way of knowing [12]. While the specific needs addressed in this work apply to the Indigenous people of Australia, there are similar storytelling modes of knowledge sharing in other Indigenous cultures.

3 Related Work

Museums have instigated web sites to curate material (see United States Holocaust Memorial Museum [13] and Creative Art Networks developed by Media-Matic Labs [14]. Also software tools have been developed for groups to create their own online archives, such as Omeka [15]. These can then develop into social networks, where people can contribute comments and separate into debated [16]. The web has become a location for sharing information within and between societies, providing resources for trans-cultural education.

Other research projects such as 'Live Memories' at Trento University [17] was created to provide web resources for communities to collect and link multimedia resources about places in the past and how they used to look. For instance after the earthquake in L'Aquila, people in the region wished to develop a site where they could share memories of their community before it was destroyed. Researchers on this project have found the main obstacle is gathering stories to place on their web site, and in this work we consider some of the issues that arise when seeking contributions to such sites for Indigenous groups in Australia.

This work has a similar motivation to that dealt with in the development of the Virtual Campfire cultural archive by Klamma et al. [18] with Web 2.0 features for user-generated content, linkage of multimedia accounts to locational maps and models, and collecting related artefacts into a learning interface.

The present system is aimed at increasing the collaboration features within a storytelling context, similar to the approach taken in the proprietary software VoiceThread [19], linking multimedia artefacts within a discovery environment.

To do this we draw on Indigenous knowledge for different traditions [20] and teaching and learning paradigms, particularly in undergraduate teaching, for example seeing knowledge as performance and data as artefacts of prior knowledge production episodes [21] where tagging or annotation is by location, time, author and practice, and Langton and Ma Rhea [22] who look at need for community involvement and protocols in the storage and sharing of biodiversity information.

Looking specifically at the use of databases and IT for knowledge storage, Verran [7] discusses the issues involved in learning from knowledge databases, and the need to recreate the knowledge sharing performance while Verran and Christie [23]) cite the difficulty in representing Indigenous knowledge through video instruction.

Much of what people bring to cross-cultural learning is tacit and unspoken knowledge, those assumptions by which we make sense and meaning in our everyday world [6], and this work is about supporting the process of eliciting this tacit knowledge while retaining the performance [25].

We have established two factors in our research of the literature for learning culture. Firstly that the storytelling and experiential teaching method used in traditional societies may be the best to convey that particular type of knowledge [23], and secondly that this method is often appropriate for many learners who are not necessarily Indigenous, as people's learning styles vary according to the domain or learning [26].

There are been other approaches to using personal stories for learning. Existing storytelling systems used to elicit tactic knowledge through conceptual maps rely on an instructor in a Coordinator role, and work in a closed learning environment [29]. Alternatively systems use an Editor role to extract innovative features from a work repository [30]. These systems developed their own grammar in tagging and linking objects, within a specialised domain of study.

Another relevant area of research is in adaptive e-Learning [31], which allows different teachers to re-uses learning environments with different learning goals. This has been developed for closed learning domains. For this work we are looking at an open domain context.

Also we are interested in the use of audio processing, to extract significant features of speech. An application where speech was analysed from a group of people, within limited domains, is discussed in [32], however the audio material was created synchronously in that study.

To enable a storytelling approach we need to use the Aboriginal students and community in the teaching process. In this we acknowledge the experience of the Aboriginal students, staff and community, as the source of the knowledge we are trying to pass onto to non-Aboriginal students. This process would be invalid without their 'translation' of their experiences into the new context [27]. In particular, we need to reverse the present "systemic under-valuing of local knowledge and Aboriginal culture, a deeply ingrained unwillingness to 'see' more sophisticated Aboriginal knowledge and processes" [28], p.105.

As part of the process of respecting cultural requirements on knowledge sharing, as well as retaining the link between knowledge and author, and information and context, we have researched the use of annotation software. This involves developing an XML 'wrapper' software and web services to verify the suitability of multimedia for viewing. When media is to be streamed from its repository, the software service for interpreting the wrapper links to a public, intranet or local repository to identify the files or segments (depending on the detail of tagging annotation) containing that person and to instantly 'switch off' these from viewing or listening.

Also to assist the annotation of multimedia, we are using recent advances in HTML descriptions that supports the use of multimedia chopping such as Annodex [42] for enabling the download of only the required or permitted segments (and thus also decrease download time for non-broadband connections). Previous work in this area has proposed an online repository where the media is always located [41], however this is hard to enforce, and does not deal with the situation where local media material is stored within an isolated intranet then may be shared, for instance made public on a broader network or the Internet.

4 Requirements for the System

4.1 Software Requirements

Consistency. Research into the issue of Aboriginal Australian history suggests conflicts in oral histories tend to arise when stories are gathered without recognition of variation in context. For example, stories from different locations, and hence often different historical interaction with white settlers, provide a variety of experiences of colonisation (see [4]; [33]). By providing focus material for the community narrative, we are providing a way for authors to locate their story in the appropriate domain, location or concept, giving the authors control of building up the group narrative.

Coherency. To support learning we need to provide a way to link different contributors' stories in a coherent manner, as in isolation they may be easily misunderstood. Also we wish the learning experience, listening to the stories, to be immersive and engaging.

Usability. We are dealing with novice users as contributors, who often have limited access to the Internet, except through the mobile network. Such people are often not confident to express themselves in written English. Hence the system is required to support multimedia sharing of knowledge, utilising audio, video and image artefacts, and mobile access.

Web-2.0 Functionality. It is important that the recording, upload, storage and retrieval of these stories be managed by the authors of the material. In this way the contributors can know how and where their stories will be viewed. The process of combining the various stories or parts of the whole, must be controlled as much as possible by the contributors, who can edit previous artefacts is access is not restricted, link their material to other items and add their own artefacts.

User interfaces. The initial users are the contributors/authors of the focus material and of the stories that enhance this material. The contributors may be on mobile or PC. Subsequently these artefacts are used by editors or teachers who selecting a subset of the material to use in a game format. Finally the learner-users log in to learning within the gaming system.

Gaming.Our use of gaming tools to enhance immersion and learning within the story environment has been limited to allowing the teacher to select simple pathways, and select from the option of hearing stories within culture, or of cultural conflict. However, when the teaching mode is better understood we may be able to use other techniques, such as the search and solve mode used by Spaniol et al. [5] to guide students through the multimedia resources. The game we are developing is a point and click game, into which we can add an element of discovery for students to extract their own understanding of cultural differences.

4.2 Educational Design

Learning method. The first concern in providing the educational framework derives from the difference between Aboriginal and non-Aboriginal learning methods. Indigenous educational research recommends a focus on practical, discovery learning [34] with opportunity for cultural and personal relevance in learning ([35]; [36]). Other work has focused on self and identity in learning and how this greatly influences students' outcomes ([37]; [38]).

Focus Material. The community story that we may wish to convey often does not exist in any coherent form,such as a syllabus or a specific teaching document. These are ill-defined areas of learning. If some coherent context for cultural learning is to be developed, this should form part of the process of developing the resources. That is the context and the resources should be developed together.

Supporting Identity. While much of the aim in Indigenous education is to encourage these students at tertiary institutions to study mainstream courses, their learning is enhanced by a better understanding of where their prior cultural learning fits into the broad spectrum of learning styles and cultural practices ([37]. This project was designed as a way both of allowing Aboriginal students to comment on the focus material and how it relates to them, and acquiring the student's expert knowledge for teaching others [39].

Validity of story.We must ensure the access to this knowledge retains respect for ownership, which rests with the community. For instance there is possible conflict between individual contributors and the community authority to share knowledge. We are therefore restricting our repositories to dealing with stories that are based on personal experience.

Storytelling Protocols. There are important cultural protocol relating to the authority to tell a story. This protocol is understood and generally adhered to by individuals in the community [24] and [25]. This includes issues such as not telling the story of another person without their permission, and not telling particularly important stories without all the relevant knowledge holders present. These protocols are hard to maintain within an environment which is recorded, although still oral.

Enforcing Protocols There are also protocols relating to respect for the recently deceased. Aboriginal people do not wish to have material relating to a recently deceased person to be seen or heard, by anyone.

4.3 Trust Issues

Acknowledgment of source. We wish to support both cultural concerns relating to intellectual property as well as access to items of material from or about deceased individuals. The first issue relates to the history of co-option and denigration of indigenous knowledge [28], and the second to the desire to respect the deceased for a period of certain time, depending on their status in the community, by not listening to their voice or viewing them.

Sharing of data. Other centres involved in research of oral collections have expressed interest in gaining access to the stories, to test various methods of linking and locating stories. In particular other researchers would like to allow the stories to be shared 'in the cloud'. Indigenous multimedia authors however have expressed concern about this approach. As a trust issue, we need to permanently tagging artefacts with author information and the location of the material, before it is considered for making publicly available.

Access control. The research into trust has a broader application than the stories we are collecting. Research is needed into the development of Indigenous Media archives for the large collection of stories, audio and video, and images held by Indigenous media organisations around Australia. In particular access control needs to be implemented that:

1. Enables authors and individuals with authority in traditional indigenous affairs to control access to material in accordance with Indigenous protocols
2. In particular enforces the withholding of material during mourning periods, in line with Aboriginal protocols.
3. Supports collaborative authentication access to annotation and tagging sites containing restricted material
4. Enforces these access restrictions by limiting access to relevant segments of multimedia material

Offline mode. There are two processes for tagging multimedia which will be available. A user may access the service on a web site with secure login and data storage. This will include an approval process for files to be made public for viewing through the wrapper service. Alternatively any user may use the service locally on a community centre computer to handle their own community data, for possible later upload to the web. This will also support communities with low upload speed (e.g. on satellite link) who can set overnight batch uploads.

Compatibility. While allowing localised version of the training system to work on local data only, the wrapped media items should be transferable between secure systems, for which we propose a centralised web server to store the latest information on viewing rights for any community.

Clearing Process. To ensure the enforcing of this mourning process does not exaggerate the cultural protocols we are developing a software process for deciding when an individual's material can again be viewed. This involves recording at the time of the creation of an artefact or the recording of participants names in a central database, those who will have authority over their mourning (when they are deceased).

Collaboration. Collaborative editing of the annotation will be required to provide data on viewing rights and add or change meta-tagging at any time.

Centralised server. Enabling local systems to run, possibly off the Internet, relies on a level of coordination, or a synchronised web repository for Internet access. The data to be shared is about authors and multimedia participants and includes their kinship links within the community and who is responsible for their affairs.

Usability. Any protected media within the XML wrapper must still be readable by the default local multimedia viewer of any machine, and thus be appropriate and flexible to the need and range of computers and available software.

Cloud use. The final area of concern is to support an increasingly common practice where people, particularly young Indigenous people, upload and share work on sites such as Facebook, YouTube, etc. We wish to ensure protocol will be maintained on these sites. We envisage that even encrypting the encoder for the XML wrapper will not ensure that those outside the culture will respect the protocol, if encoded items can be downloaded. Hence the aim is for the annotation software to be adopted by public and social network sites in future. With this in mind we are looking at the extension of this protocol to encompass requirements of western knowledge system for restricting access, for instance by children, to certain information. The design will be to include this flexibility as a lever to promote broader use of such services.

5 Software Design

We describe here how the requirements have been met through various aspects of the design and implementation. Figure 1 shows how the main issues are handled by selected technology.

Using these tools, the initial interface for uploading the focus material has been developed. This allows the display of a single collection of material, in the

	Database	Trust	Domain Expert	Contributor	Learning Interface
Pylons	RESTful interface for access	Establish access privileges to each item	Provide learning context for immersion	View others contributions	Search items according to themes and links in story
SQL	Repository of audio, images, video material	Retains information on original context		Links to focus material	
HTML5	Login based on family connections	Segment media for access	Implement Annotation		
XML	Access protocol to data	Metadata package- author and participant	Implement MPEG-7/21 annotation	Link to segmentation	Contributions accredited
Themable Widget Library	Store paths		Develop path sequences and feedback	Retain original context for contributions	Provide feedback
Game Library	Contributions within focus context			Select avatar identity	Provide paths

Fig. 1. Implementation of Repository, Trust issues and Interfaces

form or text, audio or visual artefacts, by an Aboriginal person expert in the domain knowledge. This interface requires some training at present and provides the annotation tools and allows the manipulation of the media, such as chopping.

Contributors can link their artefacts to the focus material using a simple commenting tool. The interface for contributors enables either browser upload on mobiles, or MMS transmission of files to the server. This has been developed using email, but will use MMS decoder for future implementation.

We have developed this initial system using Pylons, which can be run as a desktop application. Further annotation tools have been developed as Pylons forms, which are rapid to develop and enable the use of drop down lists and auto fill. This decreases the dependence on keyboard entry and the standardisation of spelling across the many different language words used in the shared Aboriginal English.

We are using python xml.dom for MPEG-7/21 encoding of the media. This creates an XML document from the multimedia items to be viewed or listened to. While within the existing web service, this wrapper will ensure that author information and access protocol is respected.

We use the free and open-source server Annodex [42] for video/audio time-coding designed to chop continuous streams. This enables the annotation of segments of videos for details relating to viewing rights, and also supports local caching to reduce download time, as many users are not on broadband. Together with other project [43], we are adapting this annotation system for HTML5. Given the contributors come from a mobile-using population, the trend away from Flash for products such as iPad and iPhone supports this approach. At present Annodex only handles ogg format, so we are linking to format converters.

We are using MPEG-7 standard to describe links to items within multimedia and MPEG-21 [41] for setting ownership and rights of access. Also the database

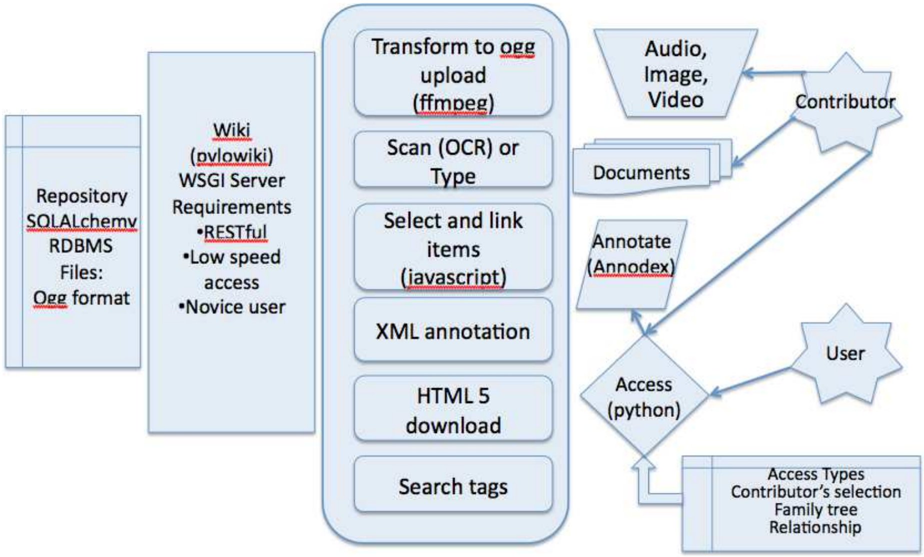

Fig. 2. Architecture showing location and structure of elements

of material retains information on where the contributor placed it within the focus material, as a description of context for the artefact.

In Figure 2 we show how the different technologies are linked to the different parts of the architecture of the present tool for developing and displaying the repository of stories.

6 Learning Framework

Knowledge in Indigenous stories as told in Australia are usually presented through sequential locations. A story is a collection of items, usually on one theme, that is recounted in sequence according to the track or storyline followed through the landscape. The time location is less significant than the theme and location of the event. The design of this learning framework is to emulate the environmental storytelling process in communities, where stories are told by different contributors, at different times, but linked to a specific theme or 'location' in the learning.

At present we are developing two systems. The first is a history of the life of Aboriginal people around the Clarence River area during early settlement, and up to the present. This site is being developed as educational material for government workers, who have a high turnover rate in the area. The stories are located within a small geographical area, and a single language group, the Bundjalung people. Within this framework they are then linked to the separate themes to the site. The themes were selected by Elders from the area. These themes are started by collecting archival material from early settlers, newspapers and government reports on the area, then contributors add audio material.

The second system uses the video of an existing cross-cultural workshop as the focus material. The workshop is based on the Aboriginal kinship system and is being run at University level with Law, Social Work and Education students. It is designed to introduce students to knowledge about Aboriginal kinship in the New South Wales region and the responsibilities this entails. From here the instructor leads into stories of how European assumptions have come into conflict with the local culture. This video material can be enhanced and updated with links to external material, or audio comments. Then we are running computer workshops with students to collect their insights into the culture, and the conflict at the 'interface'.

There are three main interfaces types for both systems, which we now describe. In particular, some of the tools developed for the first system will be repeated for collecting contributions for the second system. We look at the present system and explain the designed extensions.

6.1 Domain Expert

The domain expert is required to put the focus material on web site. This is a set of documents, images, text files, or recordings that have been gathered usually by one individual, the domain expert, and uploaded to the site. These are 'paged' on the website to provide the topics and threads for the storytelling. These threads can be added to or changed through menus, as the project proceeds.

This initial material includes an explanation of the domain knowledge. This is used as a simple introductory interface for the Aboriginal community members, students and trainers to add their stories.

In the second system there is an extra interface designed for the domain expert to develop learning games using the repository. This is discussed in Section 7.

6.2 Contributor

As discussed above, this process aims to develop a community narrative in a coherent form, without overly enforcing a logical or sequential structure onto the whole. Contributors are able to view the focus material and most of each others contribution, although some retain privacy, which assists them to refine and develop their ideas. They are also invited to provide feedback to the project on how to organise the knowledge better.

The stories are tagged in the repository by their links to other artefacts and by thematic descriptions. This enables a contributor to select the thematic context of their own story. Also learner-users can focus on themes during their learning.

6.3 Learner-User

In the first system the learning themes are selected by the community before the site was developed. In the second system we use various types of themes, such as the users' workplace. This is designed to support people who wish to know more about working in their field with Indigenous Australians. This focuses their learning to relevant stories, such as understanding how the historical experience of Indigenous people with the law courts colours their actions in such an environment. Law enforcement officers and lawyers could be better equipped and less prejudiced if they are aware of some of the oral history their clients are bringing with them.

The user accesses the site and follows the focus material. At different points they are shown the contributors' material, with links to the relevant text or image highlighted. In the second system this is enhanced with a point and click game to navigate the stories. Figure 3 describes the design of this system.

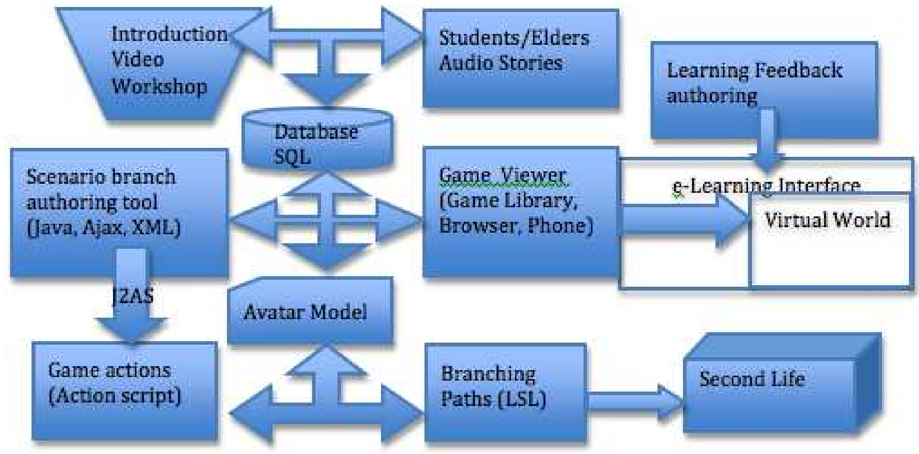

Fig. 3. Architecture showing gaming development

6.4 Clarence River History

The aim of this website was to collect and display oral stories, untranscribed, in a web interface. The first topic used was the History of the Clarence River area. To make this useful, learners can search and navigate the interface for relevant and related material. The first site used archival text and tape material in a wiki format. This data is used to present a thematic history of the area, covering topics that the community felt displayed the historical experience of people in the area, both Aboriginal and non-Aboriginal.

The interface is still being enhanced for future projects, Also the system framework can be re-initialised and tailored to new repositories in future. In particular the annotation system is easily extensible. Tags are added to the database by the original domain expert, then extended by the contributors. These tags or options can then be offered as topics to the learner-user when they move around the learning environment. This feature is also used by contributors who are able to view the existing resources under each category, and allows them to add to the story in a relevant manner.

Community members are given an account on the site and can log on and add comments. These comments are usually audio comments. Training has been done one to one, plus a workshop where community members got together to put together the stories they remembered, for later recording. The contributor records their comments then upload them on the relevant page, linking to paragraphs or images. The first stories have been chopped, with the contributer present, and then linked to a specific section of site. However as the site fills we expect the stories will focus more to the themes.

The workshops also provided usability testing for the contribution collection system. It was hard for novice users, and a different editor has now been incorporated. Contributors need to be able to bookmark text and recordings, to indicate where they wish their comment to be inserted in the story, and the tools to do this had to be developed.

Also the site was over full with text material before we started, so contributors did not know where their comment was most relevant, and tended to combine many comments in a single recording at first, until more familiar with the site. It was in fact the previous recordings that guided subsequent ones and so a story grew from contributions.

This site is for government employees to study before they move to this remote area. One issue is that stories cannot be located as is done by text searching, however we do not feel this detracts from the value of the site. We rely on manual annotation and on the link to the focus material or other artefacts selected by the contributor.

The main issues for usability that arose from the workshops were:

1. Aboriginal people are concerned that learning a new piece of software is not useful, as this will not help them in the ever changing world of computer tools. They tend to focus on common tools, such as those developed by Microsoft.
2. People need to see the value of their contribution, what it is going to achieve
3. Related to the previous point, people need to believe that their story is worth telling, that others will gain from hearing it.

The stories that we collected on the history site were two types. Firstly the personal stories of people's experience with non-Aboriginal settlers, and the odd assumptions made about their people. Other contributors spoke more about the sort of stories their family shared, which they could not tell explicitly outside the family but which they felt illustrated particularly important cultural experiences and priorities.

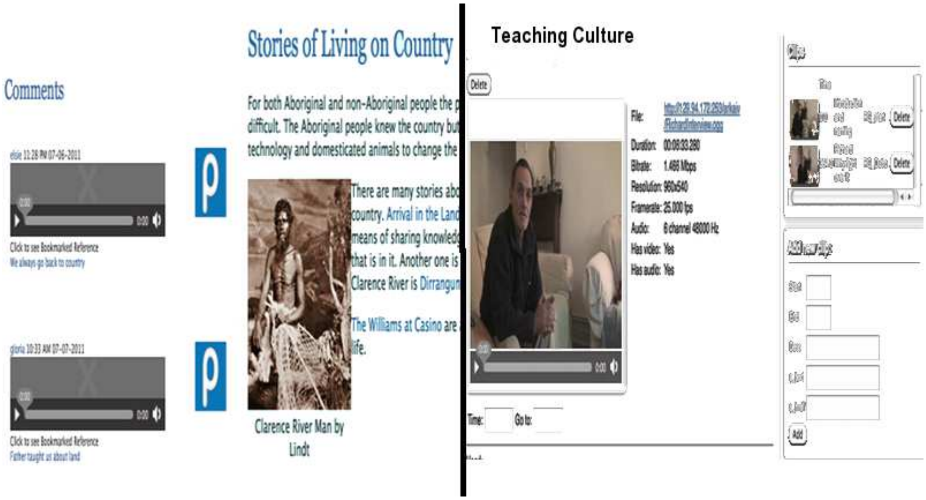

Fig. 4. Interface to wiki comments (lhs) and annotation (rhs)

We are incorporating the chopping of audio and video material on the site so that material can be presented in smaller units, while retaining them as part of the whole recording. For this we are adapting the Arkaiv tool developed by Crowdy [44].

The two interfaces shown in Figure 4 allow learners to hear stories (left figure) and use the annotation tool (right figure). This annotation tool is used by contributors to assign different segments of their story to different contexts or pages in the wiki focus material. Using this annotation tool, a user may also insert their story as a link within another person's presentation. The first presentation can be paused while the new story is played.

6.5 Kinship Game

This game is being developed under an Australian Learning and Teaching Council Innovation and Development Grant. This involves developing a game from the material collected using software similar to the History project described above. The interface will be for teachers at University to use these resources for learning, within a gaming environment.

The original focus material is a video of a workshop developed to explain the Aboriginal Kinship system. The face-to-face workshop describes the Aboriginal kinship system and uses stories to show how this strict form of relationship effects relations between Aboriginal and non-Aboriginal people. Now contributors can interleave into the workshop discussion of their individual experience of the conflict between cultural requirements. This has the advantage of providing more stories for future learners, and allowing the repository of stories to continually be updated.

Much of the original workshop relates to how to negotiate with people within the Aboriginal kin relationship roles. Also we are told the reason for these rules and how they strengthened the people and their community. We in turn find from the stories that the rules and regulations of this culture are still relevant in today. Some of these process are useful in devising ways to share tacit knowledge during rapid turnover in employment teams [25], reduce stress on the environment and cope socially with the influx of refugees in many countries. Most importantly these rules explain the different priorities and experience of Indigenous people within Australian society, and help expose much of the assumptions mainstream society has made for many years on how we should regulate through law, and how we should relate to each other.

Once we have completed the series of workshops collecting stories contributed by students and community members we will develop the workshop game into a simple virtual world. This game is based on the original workshop and involves giving users a kinship role in the system. They will pass through various scenarios, in the past and present, and hear how the culture was experienced by Aboriginal people, and the conflict with western ideas.

We are also providing a separate interface for an instructor to select the stories they wish to use for a particular group of students. We will offer the software for use in three University courses (Law, Education and Social Work). The game will be used in class, with an instructor guiding learning. Towards the completion of this project, we are planning to develop a small sample for multi-player use. This is designed to augment into the University Virtual Campus being developed.

As an example learning goal, we consider aspects of the Indigenous knowledge tradition that significantly effect the way people relate and learn. For example, knowledge communication in Indigenous societies is often specific to the kinship relation between the listener and teller. This process will be respected in the game. The user can select a kinship role and journey through a community network using generic aspects of present-day communities, or in another scenario, they select a theme such as a public location (law court, university, etc). The interface enacts the rules of kinship through the path games set up by the domain expert, and possibly by a teacher, in the game design. That is, the learning paths available will present the learning 'rules'.

Each learner-user is given an arbitrary kinship role. Then they have open access to information from siblings and cousins. You have levels of responsibility for the information from some kin. You may have no access to the information of your in-laws. The learner-user moves around the learning environment encountering different scenarios, not as a testing game, but as an experiential game. Also the adherence to some basic protocols, such as talking to the correct people, and listening to their answers, is part of the strategy to learn.

The main aim by using the workshop as focus, is to actually limit what can be a wide range of material on cross-cultural conflict and awareness. We hope that by limiting the material, we will be able to focus on how to support learning within this domain. In particular, while many teaching and learning projects in

Australia in the Indigenous area are focusing on collecting this vast oral history, such an interface can be used around different themes to embed these narratives in tertiary, and possibly secondary, course work.

7 Gaming Design

The gaming system is built on top of the repository collected in the existing system. The design provides for separation of the domain content, the learning context and the teaching control including feedback. The context is contained in the repository, and the context is the focus material which provides the basic learning path. However the teaching control is developed later, for each subject area and by each teacher.

The control interface is designed to enable the teacher to select the stories they wish to use, the story 'paths' linking available material which learners will navigate, and the system responses to user activities, including: assigning a kinship role to each user; and determining when to change from 'in culture' stories to 'cultural conflict stories'. This can be understood by considering the learning experience of the learner-users.

When logging into the learning interface the learner-user will select the knowledge they seek (e.g. their course area), and be assigned their kinship relationship within the system, etc. The interface will then display a sequence of scenarios (contexts) based on the focus material (kinship workshop video). In each scenario, various paths will be offered as visual links between speakers, with different stories available depending on the path sequence chosen. For each user's selections there will not always be specifically relevant stories in the repository. If there is no story tagged exactly to that selection, no further links from the user's previous selection, and no guidance from the teacher's story paths, the story returns to the workshop structure to select a new scenario.

Within each scenario, the learner can follow the kinship rules and learn how others have followed them, the benefits that they provide in different situations, etc. Also the learner may chose not to follow the protocol, or be instructed not to by an outside, European protagonist. This will cause the game to provide the stories on cultural conflict.

The value of the selected material will depend on the number and range of contributed stories. Also it will depend on the level of annotation contributors make. In the first historical site, users' comments remain on a particular page, and are visually linked to a particular piece of text or image. This was the only linkage required for this system. A learner-user can access a theme from the menu on the wiki, and follow the thread within that theme, listening to comments on each page.

In the kinship game we need more sophisticated linkages. We are developing more services to improve annotation as we understand better the tags and comments used. A contributor can listen to the workshop video and pause to record and upload their story. This location can be used to automatically code annotation. Also we will offer other possible related artefacts as a drop down list of additional tags. However, what is required is improvements in speech recognition which will enable better annotate and link related recordings, subject to author verification.

We are also aware that users may not listen to each story to their completion. As in the History site, we are encouraging contributors to chop each long piece into segments, and tag, so that these annotations can be used to focus stories more to the user. The users are also made aware that they are viewing a segment, and can select the whole story from that person.

The game structure is initially fairly simple, but we hope to expand this. For example, a Virtual Campus in Second Life could be populated by student-selected avatars which tell these stories. This would be a more open learning environment, but is one area we would like to explore.

8 Conclusion and Further Work

Providing the medium for Indigenous users to share knowledge poses many issues. This includes the need to allow Indigenous people to first learn and discuss their own 'story' before claiming we know what is to be taught through a learning interface. The next concern it to retain as much of the original cultural approach to storytelling and knowledge sharing as possible in the learning environment that is derived using any knowledge repository.

By using innovative technology, together with well-designed interfaces, we aim to support community members sharing their narratives. We have not previously had the resources to verify the learning outcomes from the first of these systems, as it was developed for government employees to use at their leisure. However the second version of the system will have a specific learning interface developed as a game and tested. Research into innovative software for wrapping multimedia and collaboratively annotating artefacts will increase the trust and accessibility of these resources.

We focus on open-source systems as we hope to engage the broader software community in this project, while trying to retain an interface that is user friendly for those more skilled in multimedia than text.

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Narrative Threads: A Tool to Support Young People in Creating Their Own Narrative-Based Computer Games

Katherine Howland, Judith Good, and Benedict du Boulay

Interactive Systems, School of Informatics
University of Sussex, Brighton, BN1 9QJ, UK
{K.L.Howland,J.Good,B.Du-Boulay}@sussex.ac.uk

Abstract. This paper introduces Narrative Threads, a suite of tools designed to support 11-15 year olds in creating their own narrative-based computer games. Authoring interactive stories in game form has strong educational potential, but although there are tools which make game creation possible for young people, they have provided little to no interface support for the storytelling aspect of the task until now. Here we describe the design and implementation of Narrative Threads, which provides this support. After giving the background to the tool, we describe the extensive participatory design process which built on existing theory. Finally, an initial evaluation is presented, which indicates that games created using Narrative Threads are rated more highly than those created without the additional support provided by these tools.

Keywords: Multimodal game narratives, authoring tools for young people, participatory design, story representations.

1 Introduction

Many young people find computer game authoring to be motivating, and the challenging, yet appealing, nature of the task makes it promising as a learning activity [14, 21]. Researchers have explored game creation as a method of introducing children to computer science [31, 33], teaching mathematics skills [22, 32] and developing metacognitive skills [16, 21]. This research is motivated by work which suggests that game creation has the potential to support storytelling for young people aged 11-15 [14, 35].

Although some theorists argue that the relationship between games and narrative is problematic [8, 10], it is generally agreed that narrative elements are important to many games [9, 11, 20]. Creating an interactive narrative can involve the practice of traditional writing skills, when creating text-based conversations, as well as using other representational modes such as visual appearance, movement and sound to convey story elements.

Multimodal theory describes how meaning-making increasingly takes place through a variety of representational modes, with writing no longer holding the privileged position it once did [24]. In order to communicate effectively today, young people must make use of multiple representational modes, and additionally, understand and design for the interactivity of their readers. It is no longer sufficient for

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educators to teach children how to convey a message through linear text, they also need to know how to make effective use of modes such as video, image and audio, and to plan branching pathways through the content they create.

Computer and video games are a particularly prominent medium, embodying multiple modes and high levels of interactivity. Creating a narrative-based game involves conveying a complex interactive storyline through a range of representational modes, and the activity can be very motivating for young people [14]. For these reasons, game creation has a strong educational potential.

However, creating a narrative based game is a highly complex task: the narrative is composed of many different components which are woven together when the game is played to allow the story to unfold in one of a number of ways as the player explores the game world. A branching narrative can quickly get unwieldy as each choice point brings additional possible paths. Whilst working in a game creation toolset, the disparate elements of conversations, character appearances and behaviours, the design of locations and the placement of objects and characters are all represented separately.

External representations are crucial for writing [39], but there is little representational support currently available for creating and managing an interactive, multimodal narrative. Tools that do offer support along these lines are aimed at adults and are designed to support advanced tasks such as design and debugging in virtual reality environments [42] and creating interactive digital stories with emergent narratives and intelligent plot management [28, 41].

For young users, creating even a simple interactive narrative with relatively few branching points can be challenging. When creating a game-based story there is no equivalent of reading back over what has just been written. Instead it is necessary to exit the toolset, load up the game and play through it; a laborious process which can only be done intermittently. This can interrupt the flow of writing as the 'reading' of a game is necessarily detached from composing and revising.

With no integrated representational support in a game creation toolset it may be harder for our target users to create a compelling storyline for their games, and develop the associated skills which will be so potentially useful to them. Additional representational support for storytelling should allow designers to get a better sense of how their game narrative is developing while they are in the act of creating it, helping them to write a better story and to gain a deeper understanding and command of the multimodal and interactive writing skills they are using.

In contrast to work concerned with dynamic story generation based on narrative theories (e.g. [25, 26]) our focus is on assisting young game authors in weaving their own branching narrative from game elements such as characters, objects, conversations and area design by introducing software-based support for plot management as well as character and object creation.

In the next section we examine existing game creation tools in relation to our objectives. In Section 3 we describe the design of the tool, including the use of theory and previous work to devise broad requirements, and an extensive participatory design process. In Section 4 we describe the suite of tools, with notes on usage and relation to the design process. Section 5 outlines an initial evaluation of the tool and presents some key findings. Finally, in Section 6, conclusions are drawn and future work is outlined.

2 Existing Game Creation Tools

There are many tools available which make it possible for young people to create their own games. Some focus on support for programming and scripting [2, 3, 6], other tools focus on making 3D area design accessible [4, 7], and some include functionality designed specifically to support storytelling, such as Looking Glass [5] and Adventure Author [1].

Looking Glass (formally Storytelling Alice) offers support for storytelling by providing high level animations involving social interactions, as well as character and scene resources in keeping with the stories target users want to tell [23]. However, the tool is primarily designed for building linear animations rather than interactive stories. Additionally, storytelling is not the end goal of the tool; it is used as a means of encouraging middle school girls to engage in programming activities.

Adventure Author [38] makes use of a game making toolset (shown in Fig. 1) which is sold with a commercial role-playing game, Neverwinter Nights 2 (NWN2) [30]. This toolset allows users to create fully interactive games which have a similar look and feel to popular commercial games. The readymade art resources and an easy to use area editor allow young learners without 3D graphics skills to create games that are visually impressive. Another benefit of the toolset is that it allows young designers to quickly get to the stage of working on high-level narrative elements without concern for low level tasks such as implementing movement. Adventure Author scaffolds the creative process of game design through a suite of plugins which offer excellent support for ideas generation and evaluation, as well as an improved interface for creating interactive conversations. However, conversations are only one component in communicating a narrative in the form of a game. The Adventure Author project offered evidence that one of the most interesting elements of game-making is the way in which a story can be told through visual elements such as character appearance and behaviours, and landscaping of areas, as well as through textual means [37]. Narrative Threads aims to provide support for authors using the full range of representational modes available to convey a narrative.

A decision was made to design Narrative Threads as a plugin for the NWN2 toolset, in line with the approach taken by the Adventure Author project, because this software provides excellent support for 3D graphical design, has a good plugin architecture, and because tools to support other key aspects of game creation were either already available or being developed for this toolset [4, 29].

3 Design Process

The design was grounded in theory and developed using a learner-centred design (LCD) methodology, based on the CARSS framework [13, 36], which offers guidance on five key aspects of participatory design of technology enhanced learning with children; context, activities, roles, stakeholder and skills. In this section we explain how the overall aims of the tool were established, and describe the extensive participatory design process.

3.1 Design Model

A design model which focuses on directing learner attention to desired aspects of a task through foregrounding and backgrounding different tasks with representational choices was developed. The model synthesises theory on the use of external representations in educational tools, and is presented in full in [18]. The key recommendations of the model are that users should be able to carry out tasks unrelated to learning goals quickly and simply without need for reflective cognition [29], whilst tasks important to learning goals should be carried out thoughtfully and carefully, using reflective cognition. The model states that representational support for complex tasks should allow learners to avoid cognitive overload by storing intermediate results externally [27], should support re-use of learner created elements, and crucially that designers should avoid loss of motivation by aligning effort with learner goals where possible. Key aspects of the design model and the related theory are explained in detail below with reference to specific design decisions.

3.2 Evaluation of Existing Toolset Interface

As an initial design stage the existing toolset interface was evaluated against the design model, key underlying theories, and previous experience the authors had had using the toolset with young people [14, 19]. In keeping with most game authoring tools the NWN2 toolset interface centres on a 3D area view, as can be seen in Fig. 1. The built in mechanisms and representations in the NWN2 toolset encourage users to focus on 3D area design, whilst the storyline being developed is invisible. This is most evident in two key areas: in the creation of characters and other game objects, and in the overall visual representation of the game.

Character and Object Creation. The toolset contains a number of 'blueprints' or readymade versions of characters, objects and scenery items. The existing method of character creation involves users clicking on a name in the blueprints list and moving the mouse into the 3D area editor to see a 3D representation of their chosen character. They can then either place that character somewhere in the world or cancel the operation and choose another blueprint to preview. After the user creates a character they can open a properties window with over a hundred editable fields and customise the character. However, important fields like those which define traits, skills and the character's disposition towards the player are not salient in amongst a variety of obscure fields which users are unlikely to understand or want to change. The process is the same for creation of other in-game objects.

This drag-and-drop based interaction method encourages a habit of adding multiple readymade characters into a game under creation, with elements sometimes left in the game simply by default. Since characters and objects can be hugely important components of a game-story, this unreflective approach is not beneficial. It can also encourage young people to add purely functional characters which have a gameplay role (such as increasing challenge) but no relation to the plot.

Visual Representation of Game. In the existing toolset interface the only visual representation of the game under creation is a 3D area view, which shows the level the designer is currently working on. The objects added to the game are visible, but there is nothing to indicate whether a given object or character has a crucial role in the story, or is simply scenery. There are lists of conversations and scripts which the designer has written, but these are not connected to the visual representation. A quest creation tool integrated with an in-game journal is provided, but it does not give a visual representation of the game story, and additionally, is hard for young designers to use and could encourage a focus on a solely quest-driven plot. At present, attempting to consider the branching plot of a game involves a user keeping higher-level ideas about the storyline in their mind. This lack of representation of story elements can cause users to focus on the areas which are better supported by interface representations, as is reflected in the large amount of time given to area design according to participant estimates at previous workshops [35].

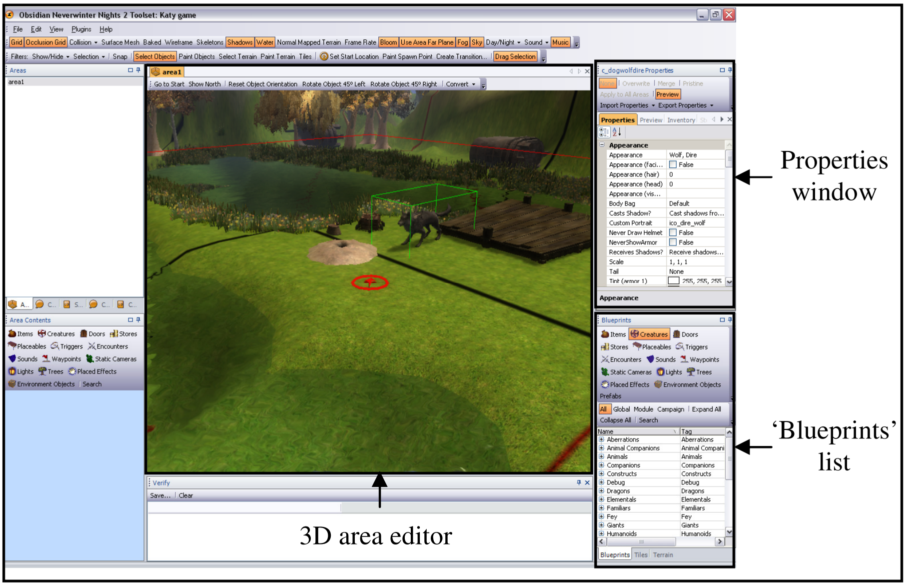


Fig. 1. Neverwinter Nights 2 Toolset Interface

3.3 Tools Summary

From the assessment of the existing interface provision, and helpful input from the Adventure Author project team, the key areas for improvement in storytelling support were identified. To prevent the creative process from being interrupted it was deemed important that the support should be an integral part of the game creation activity.

It was determined that addressing the two key areas required functionality across three separate tool categories:

1. Character and object wizards with associated visual representations: supports character and object creation by scaffolding the task.
2. Augmented 3D map view showing story event locations: improves visual representation of game by showing where important plot events are located on the map.
3. Branching narrative diagramming tool: improves visual representation of game by displaying the high level plot structure of the game to the user.

The tools are separate but connected, and aim to support young designers by providing representations of the narrative under creation. The overarching narrative model is that of the storyline being driven by a series of events or encounters, some of which involve a choice on the player's behalf, whilst the connections between these always involve choices. These events are based around characters, objects or scripted events.

Each tool was designed in an iterative way with input from theory and existing work, and participatory design activities involving various forms of lo-fidelity prototyping. Design activities are described in the following subsections, and final design decisions are explained in the system description in the next section.

3.4 Character and Object Wizards with Associated Visual Representations

Theoretical Background. Norman distinguishes between experiential and reflective cognition [29], where experiential cognition does not require deep thought and is reactive and event driven, with automatic reactions following from input. Reflective cognition tends to be slower and more laborious, and requires much deeper thought.

Choice of representation and means of interaction can completely alter the mode of cognition used in a task. Svendsen [40] concluded that whilst direct manipulation interfaces can be very user-friendly, they can hinder problem solving if they are supportive of unreflective action.

Adopted Approach. Being able to drag a generic character or object into the game world encourages a reactive approach to adding characters and objects, and is often used merely as a way of testing out what different readymade characters look like. To address this issue we decided to create a set of wizard tools which guide the user through the creation processes, uniting the previously separate activities of adding an object and editing its properties. In line with the design model and underlining theory, the new creator tools should encourage reflective cognition when users are creating characters and objects which are important to the story line.

Participatory Design. Two girls and two boys, aged 11-12, who had been using Adventure Author with their class as part of a creative writing project, were asked to build a paper prototype of a new tool which would help them to create more interesting characters for their stories. They were given an example paper prototype of a software tool they had previously used to help them understand what a paper prototype was, and shown some very simple examples of what a character creation tool might look like. Care was taken to provide a range of designs to avoid ideas simply being parroted back. The design sessions were audio recorded, observation notes were made and photographs were taken.

The prototypes (an example of which is shown in Fig. 2), along with transcripts of the activities and additional interviews with the children, were analysed. A number of key themes were identified, which gave suggestions for important design characteristics.

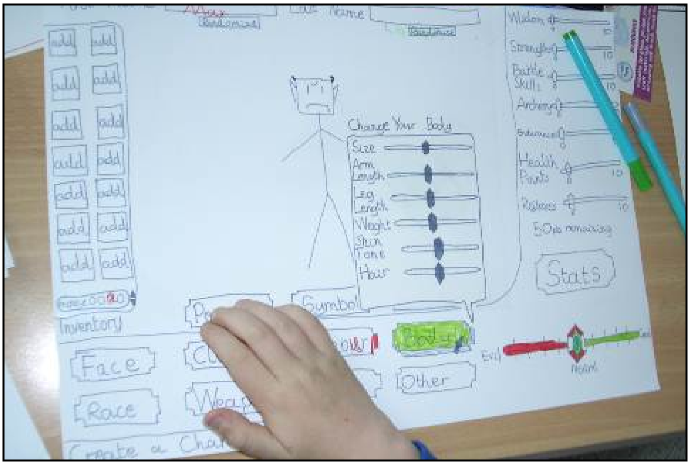


Fig. 2. A participant's paper prototype designs for a character creator tool

The designs created by the children were mainly based around physical appearances, with options for customising characters in fine detail. For the two girls, this involved numerous noses and other facial features to choose between, while for the two boys, this tended to revolve around combat settings such as strength, weapons carried, and for one boy, setting the amount of body hair and length of forearms!

Personality and the back story of characters were mentioned as important in interviews, but did not feature strongly in the designs created. It appeared that target users were not so interested in the personality of the characters, because typing a description of the character's personality did not have any effect on their game (visible or otherwise). When it was not obvious how an element would make a difference to the game, participants reported that they skipped straight past it, and both boys and girls comments on the importance of seeing the effects of their choices in a creator tool. The girls explained that they just picked 'any' for character settings which did not seem to make a difference. The boys also said that character-related settings should 'make a difference to how you play'.

Another aspect which caused confusion was the dungeons and dragons genre specific terminology used to describe some of the character traits; 'dexterity' was held up as a particular example of something which seemed meaningless to the participants.

The boys liked the idea of having the whole tool on a single view, and explained that it was hard to remember where options were if they had to switch between screens using ‘next’ and ‘back’ buttons.

3.5 Augmented 3D Map View

Theoretical Background. The match-mismatch hypothesis [12] states that where a representation highlights a certain type of information, tasks using that type of information will be easier to perform than those requiring other types of information. Where required information is implicit in a representation and needs to be inferred, the task will be harder than if the information were presented explicitly.

Adopted Approach. The task of creating an interactive digital story in the form of a game is not currently well supported because one aspect of the task, the design of the 3D areas, is fully represented while other aspects important to the story, such as how a character will behave towards the player, or whether an object can be interacted with meaningfully, are invisible. To tackle this problem, the decision was made to augment the existing 3D representation. This avoided adding an additional representation and had the further benefit of ensuring that users were more likely to use the story view map, as it would be integrated seamlessly into an existing essential display. The approach allows upfront debugging of story elements which could help to avoid the awkward feedback loop involved in testing the game under creation and making revisions

Participatory Design. Ten participants aged 12-14, nine boys and one girl, attended a half-term four-day game-making workshop where they learnt how to build their own simple games using the Adventure Author software. The study aim was to gather further information about the requirements for the augmented map view through targeted interviews and paper prototype activities with the participants.

A series of icons were designed to represent different game objects which were likely to have relevance to the plot of a game. There were icons for hostile characters, friendly characters, important items, conversations and transitions to other areas. These were used in conjunction with a sheet of acetate with a cardboard surround which allowed participants to place the icons on top of their 3D area views without risking damage to the laptop screens!

Participants were introduced to the paper prototype, asked to pick an area of their game and place the icons in the appropriate locations. Video recordings were made of the activity and photographs taken at key moments, and the videos were transcribed. The participants were able to place the icons on to their areas in the correct positions, as illustrated in Fig. 3, and found the representation reasonably easy to understand. In some cases they understood exactly what the icons represented and were able to interrupt and finish explanations as the researcher introduced them, but in other cases the icons did not seem to be intuitive.

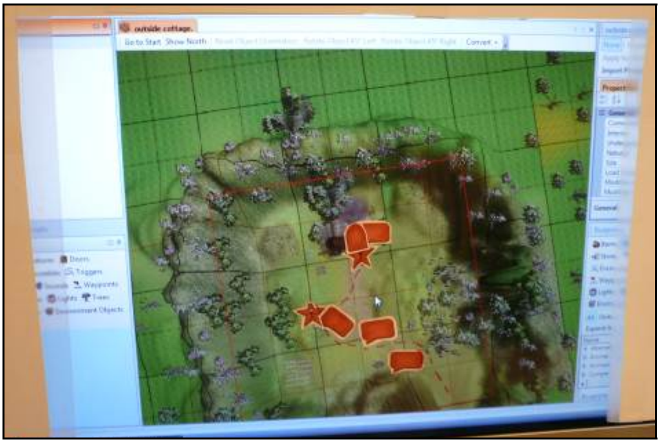


Fig. 3. Participant using paper prototype to show important story events in her game

In a second school study twelve children aged 11-12, six boys and six girls, selected from two classes who were undertaking a game making project, were asked to help with the design of icons for the augmented map view representation. Pupils individually designed icons which they thought best represented the key character and object types. They then took part in a group discussion about why particular icons were easy to understand, until a consensus was reached about the most appropriate icons for each category. A set of icon designs from this study is shown in Fig. 4.

Fig. 4. A participant's icon designs

3.6 Branching Narrative Diagram

Theoretical Background. Holding complex mental representations, such as a branching plot line, in working memory can be problematic as it can place a high cognitive load on the user [27]. Reflective cognition requires the ability to store temporary results and use those results in further thought processes. For this reason external representations can facilitate reflective cognition by allowing more complex chains of reasoning to be built up [29].

Approach Adopted. Creating a branching interactive plot with multiple modes of expression is a hard task, and keeping this constantly in working memory is not feasible, necessitating a visual representation of the plot under creation. Previous work explored young people's ability to understand branching plot diagrams in the form of a simplified Augmented Transition Network (ATN) [15]. Here the researchers found that children aged 10 were able to follow an interactive story represented in the form of such a diagram and correctly answer questions about what would happen if different choices were made in the story. They were also able to use a hi-fidelity prototype storytelling tool and create some simple stories which included branching between scenes. We chose an ATN-like diagram style because of the evidence from this previous work that children can use diagrams of this type.

Participatory Design. As part of the second school study described above, the same twelve children were also asked to draw branching narrative diagrams, loosely based on an ATN model, to represent the story of their game. They were shown two examples of games mapped out in diagrams of different sorts. Design activities were audio recorded and photographs were taken of the designs. After checking that participants were able to understand the diagrams and felt able to draw their own diagrams, they were instructed to draw a similar diagram in any way they chose. They were told that they did not have to use the same style as any of the example diagrams, so long as it was possible to see what happened in their games if the player made different choices.

Fig. 5. A participant's branching narrative diagram

The children were able to create diagrams of their own which represented the plots they were in the process of creating; an example of this is shown in Fig. 5. Most participants reported that they found the task easy and created diagrams of some complexity, but some struggled with the task and created only basic diagrams. Participants did not adopt a consistent approach to representing different elements, using a slightly different node design each time they referred to an element of a certain type. Most diagram nodes featured objects or characters around which significant story events revolved, but in some cases ‘travelling nodes’ were included, which described a movement the player would make, such as ‘player walks to house’.

In this situation participants were asked to draw the diagrams as a one-off activity mid-way through the game creation project. However, the branching narrative diagram should serve not only as a planning tool, but also as a representation of the plot as it develops. In order to design a tool which could be used throughout the game-making process, it was necessary to explore the use of such diagrams over a longer period.

At a five-day summer holiday workshop 12 young people aged 11-15 took part in a game-making activity. Early in the week participants were introduced to branching narrative diagrams as outlined above and asked to work on their own diagrams on large public displays by each of their work stations. Fig. 6 shows a diagram drawn by a participant.

In line with the findings from the previous study all participants could understand and follow the ATN style diagrams. Additionally, in this setting all participants managed to create their own diagrams of reasonable complexity. This difference may be due to the increased interest and ability of the young people who had elected to attend a workshop with an educational element during their school holidays. Again, most diagram nodes were based around significant characters or objects, with a few ‘travelling nodes’ included.

Participants were encouraged to go back to their diagrams throughout the week and edit them as they made changes. Most participants did this at least once, but as the week progressed some of them found other representations more helpful, such as “to do” lists. Some participants updated their diagrams throughout the project but others left theirs at an early stage and did not return to them.

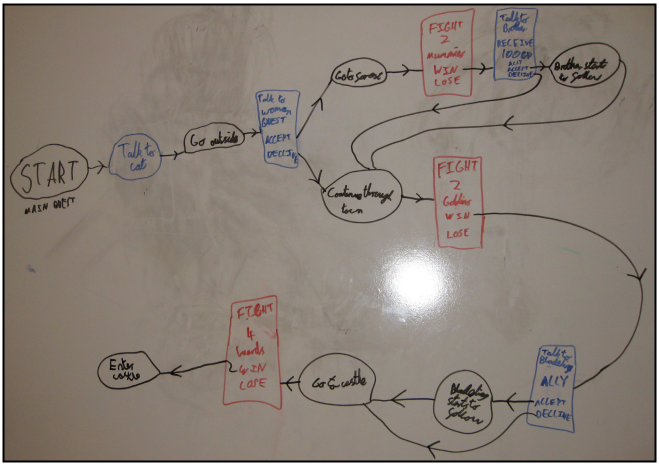


Fig. 6. A diagram drawn by a participant on a large whiteboard

4 System Description

In this section the completed system is described, and we explain how key features relate back to the design process findings.

4.1 Character and Object Creator Tools and Story Elements Panel

Main characters and plot relevant objects are now created using a wizard (less important characters/objects, or can still be added in the usual way). The wizards are loaded from the new Story Elements panel (shown in Fig. 7) which displays the characters and objects created using the wizards, and allows users to create new elements and add them to game-areas. Design activities indicated that target users like to configure characters in fine detail, but mainly focus on appearance-related properties. Evidence from interviews suggested that editing these properties is motivating because users can see a clear outcome from their effort when configuring appearance-related items; the visual feedback is strong and the impact on their game is obvious. Typing descriptions about a character's personality and back-story were seen as less appealing because there is no clear pay-off for such an activity.

Fig. 7. Story Elements panel

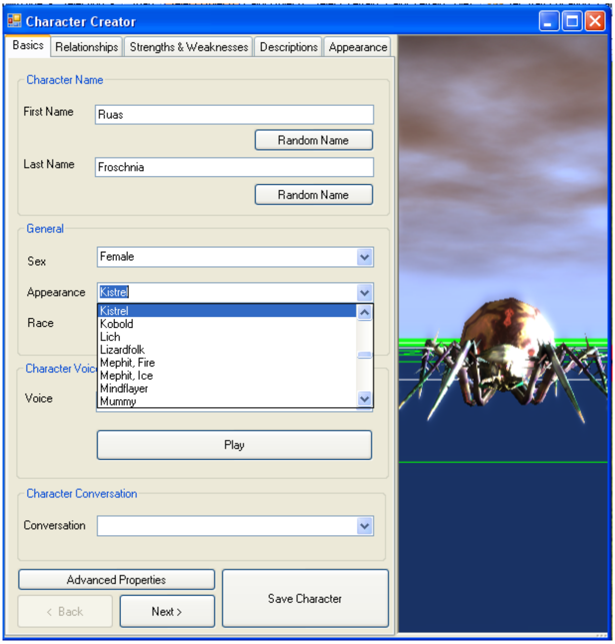


Fig. 8. Setting appearance on Basics Screen

To ensure that activities which are important to storytelling are seen as important by users, the Narrative Threads wizards give clear feedback for these activities and ensure that there are obvious outcomes for the game under creation. A persistent visual portrayal of the character was added alongside all screens so that users could see the effects of their changes and get immediate feedback as to the implications of those changes, effectively closing the loop. The character wizard is navigated using labelled buttons, in addition to 'next' and 'back' buttons to make it easier for users to find the option they want to change. The Basics screen is used to configure properties which are important for the in game mechanics, but not of great interest in the process of creating a character, including details such as name, gender and basic appearance, as shown in Fig. 8. The 3D window shows feedback from changes in appearance settings and an audio file can be played to support users' choice of the character voice.

The next screen is Relationships, which allows the user to choose whether the character they are creating will be the player, an enemy of the player or friendly/neutral towards the player. Because of feedback from users in design sessions about confusion due to the complexity of genre specific language, this screen translates the in-game terminology of 'commoner', 'hostile' and 'defender' into short sentences which describe the way such characters will behave towards the player. The 3D window gives visual feedback on the choices made by animating the character model in a way which reflects the chosen relationship type. Fig. 9 shows an example of the animation which results from choosing the friendly/ neutral relationship option.

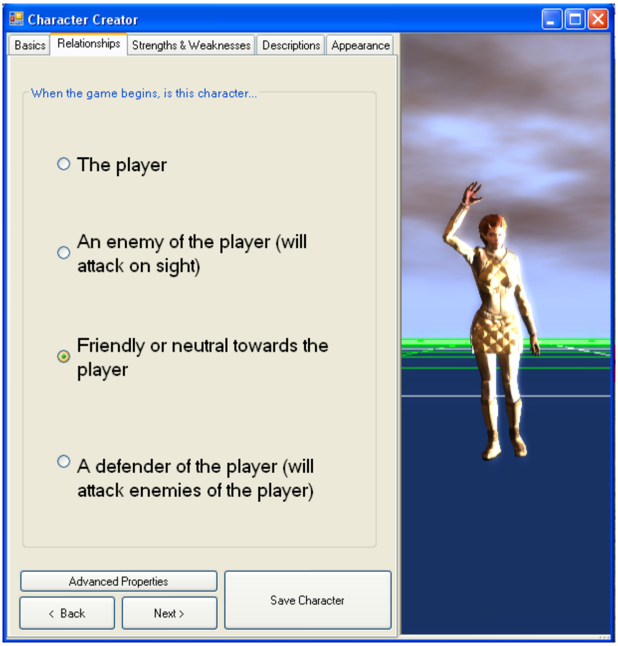


Fig. 9. Visual feedback from changing relationship setting to friendly

The third screen, Strengths and Weaknesses (Fig. 10), allows the user to set character traits by dragging and dropping descriptive phrases. This screen aims to encourage reflective thought about a character's significance in the story.

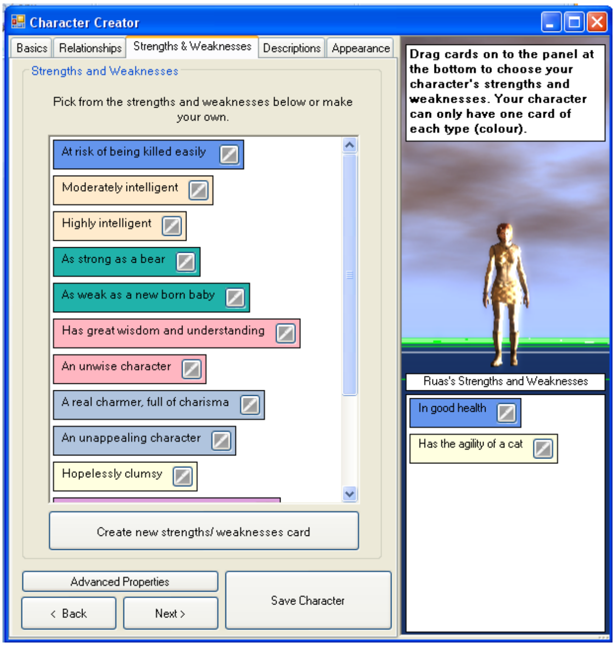


Fig. 10. Strengths and Weaknesses screen

Within the game characters have ability scores across five measures: Charisma, Constitution, Dexterity, Intelligence and Strength. On the Strengths and Weaknesses page users configure these score, as well as the health points the character will have, using descriptive phrases which explain these terms in everyday language. For example, a low charisma score is marked by the description 'An unappealing character'.

This design unites input from teachers about the potential for improving descriptive language through the activity and input from target users about confusion caused by the in-game terminology. Users can also define their own descriptive terms through a pop-up window which allows them to type in a new description and pick the associated trait and score. It was not possible to show feedback for character strengths and weakness, as appropriate animations were not available.

The next screen, Descriptions (shown in Fig. 11), invites users to enter two different character descriptions. Participatory design sessions suggested that boxes such as these would be skipped or completed with little thought if there was no clear in-game benefit to completing them. However, input from domain experts suggested that writing descriptive passages would help users think more deeply about the character under creation, as well as giving them more general practice in writing. As a result, descriptions were included, but the tool aims to show clear benefits for typing one of the descriptions.

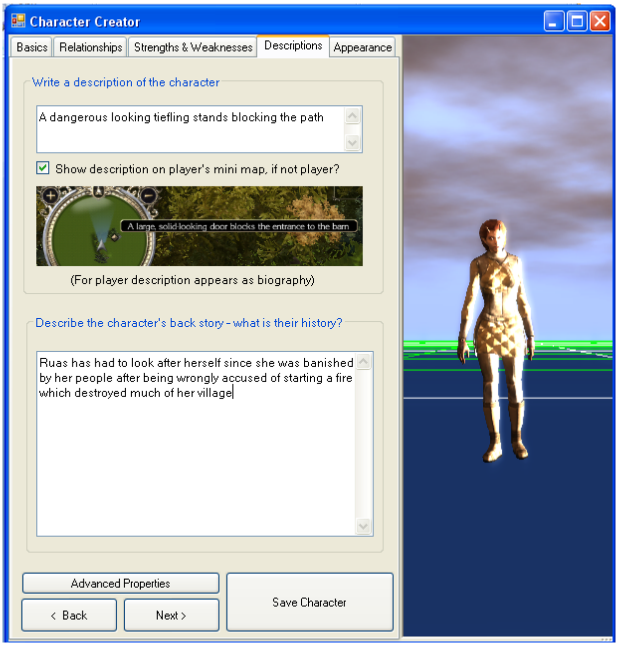


Fig. 11. Descriptions screen

The first description entered is tied to the in-game description of the character and can be made to show on the in-game map, and crucially, this is made clear to the users at the point of writing through the inclusion of an image showing where such a description will appear. The second description is deliberately left without a clear relevance to the in-game world to allow investigation of the extent to which this will affect what users type in to the different boxes.

The final screen allows the user to customise details of the characters' appearance using the existing functionality for changing things such as eye colour and skin tone. This page comes last in an attempt to ensure that the young users do not expend all of their time and energy on this part of the activity. However, users can navigate to screens in a different order to the one suggested by simply clicking on the button for the corresponding page.

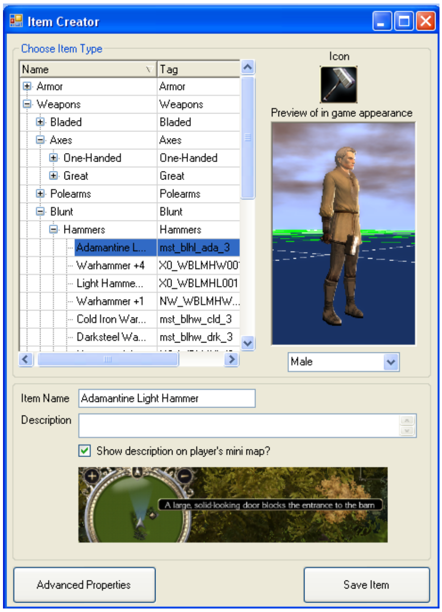


Fig. 12. Item creation wizard

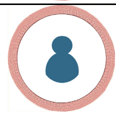
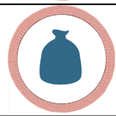
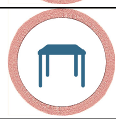
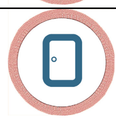
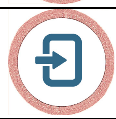
The character creation process now requires careful reflection and cannot be carried out thoughtlessly. Crucially however, the users are not asked to carry out activities which do not have a noticeable effect on the finished game. The same principles are applied to the design of wizards for creation of other in-game objects which have relevance to the plot. These make use of the same ideas, but in a greatly simplified form, as illustrated in Fig. 12, which shows the item creation wizard.

4.2 Augmented Map View

The augmented map view is a modified version of the existing toolset area view. It shows where key story objects are located, and indicates through different icons which type of story event can happen at that location.

Users can switch off the icons, which are turned on by default. Participatory design sessions indicated that target users can understand representations of this sort, and are even able to create their own correct representations when icons are provided,

Table 1. Rules for icon generation based on important objects

Object	**Conditions**		**Icon created**
Character	Hostile		
	Friendly	No conversation	
		Conversation	
Item	None		
Placeable Object	None		
Door	Without transition		
	With transition		

showing a reasonably deep level of comprehension. The icon appearances are based on designs by target users. Table 1 shows the icons and how they are automatically generated from the story elements in the game areas.

This spatially linked mode of representation cannot show all potential states or behaviours of a character or object, given that a single icon needs to be chosen. For example, it is possible to ascertain whether a friendly character has potential to turn hostile depending on the player's choices during the game, but the story icon will only represent the character's hostility or friendliness at the start of the game. One approach would be to attempt to represent all possible interactions within a single icon, but given the size of the icons this was not practical. The branching narrative diagram, as presented in the following subsection, is greatly superior in its representative power for interactivity.

Icons are turned on and off by a checkbox in the Story Elements panel, and update instantly when the corresponding object is moved. When the user clicks to turn on the icons, the area view is shifted to a zoomed-out, top-down camera angle, as shown in Fig. 13. This story icons view gives the user an overview of their area augmented with an indication of the location of key story events.

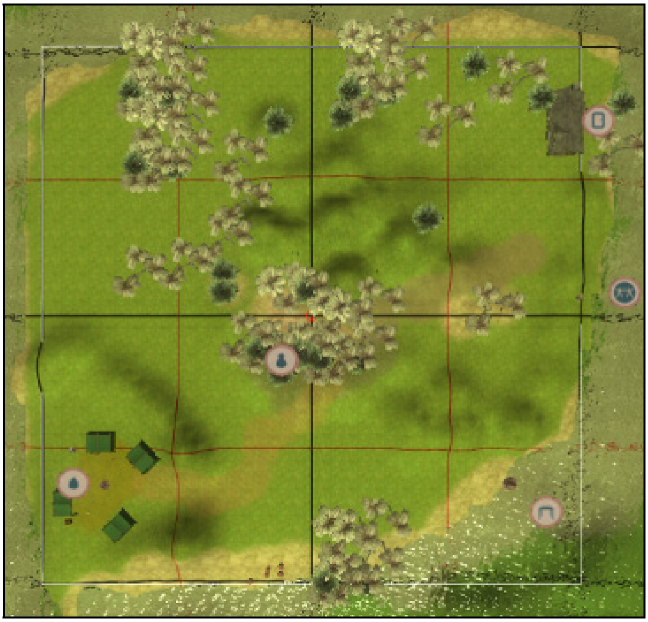


Fig. 13. Augmented 3D map view

4.3 Branching Narrative Diagram

The branching narrative diagram serves not only as a planning tool, but also as a representation of the plot as it develops. It is designed to provide visual feedback to the user within the toolset about how their interactive narrative will play out in the game.

A fully automated ATN diagram creation process was ruled out due to the computational complexity of such a task. It was also felt that an automatically created diagram would be less likely to encourage the user to reflect on the plot under creation. However, findings from the participatory design process suggested that it would be beneficial for some aspects of the diagramming task to be automated. The lack of consistency in node representations in diagrams created by target users suggested that automatically creating nodes to a standardised design would be beneficial. Additionally, findings from diagram use over a prolonged period showed that some target users were likely to forget or otherwise choose not to make updates to their diagrams as they made alterations in game, suggesting that it would be beneficial for nodes to update as changes were made. As a result of these design decisions the branching narrative diagram provides users with the building blocks to create the diagrams, but they compose the diagrams themselves. There is also a facility for custom blocks to be created to account for the ‘travelling nodes’ seen in participatory design sessions which cannot be automatically generated, and also to allow users to plan for future developments where characters or objects have not yet been implemented.

The diagram tool is launched from the story elements panel. On loading, the user is initially presented with a blank diagram space with only start and end nodes in place. At the bottom of the screen is a panel which contains all the plot events so far created by the user, presented as scenes. These include events generated from important objects, and scripted events. Table 2 shows the rules by which the scenes are automatically generated from important story elements.

Table 2. Rules for scene generation based on important objects

Object	**Conditions**				**Scene(s) created**
Character	Hostile				Fight Scene
	Friendly	No conversation			Meet Scene
		Conversation	With script	Non-attack script	Branching Talk Scene
				Attack script	Branching Talk Scene + Fight Scene
			Without script		Simple Talk Scene
Item	None				Get Item Scene
Placeable Object	None				Use Placeable Scene
Door	None				User Door Scene
Flip script	None				Script Scene (with description of script functionality)

This representation has much more power to show interactivity than the augmented map view, although it is much harder to understand in-game spatial relationships in this view. The majority of the interactivity in the diagram is represented through diverging paths between scenes, but one category of scene has branch points within it. The item and object scenes have a single outcome; the picking up of an item or the using of an object. The alternative (not picking up and not using) are represented by the scene not being included in a given path through the diagram. There are more subtle encounters with items or placeable objects, such as seeing them but not interacting with them, but in the interest of keeping the diagrams to a manageable level of complexity, these scenes are not included by default. However, custom scenes allow events of this sort to be added to the diagram.

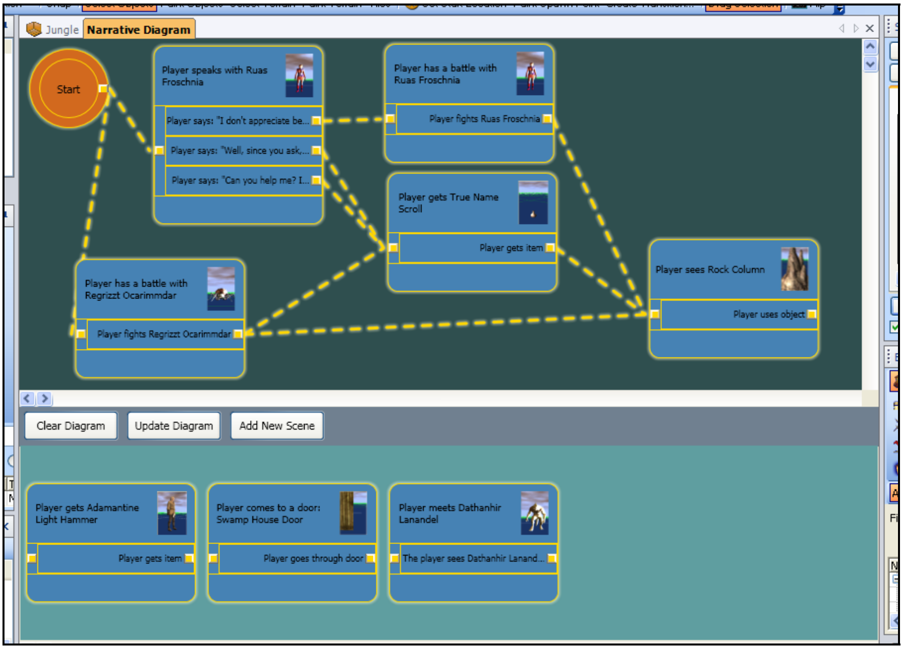


Fig. 14. Branching narrative diagram tool

Diagrams are built up by dragging scenes from the bottom panel on to the canvas, and drawing connections between scenes by clicking on the scene's connection point and dragging to draw a line to another scene's connection point. Start and end nodes are distinct, and connections can only go in one direction; from an end node of one scene to a start node of another scene. Once a user has started creating a diagram for their game, their progress is saved and when they return to the diagram tool later, they see the diagram they were previously working on. When a diagram is loaded, the tool checks for changes to elements involved in the diagram, and the corresponding scenes are updated with the alterations. In the case of an object being deleted, the related scene is removed from the diagram. This update process can also be carried out manually by the user clicking update within the tool (as the diagram can be left open whilst changes are made in other windows). Fig. 14 shows a diagram under creation.

Custom scenes are created by the user clicking ‘Add New Scene’. This brings up an editor which allows the user to add a scene title as well as a list of potential branch points, as shown in Fig. 15.

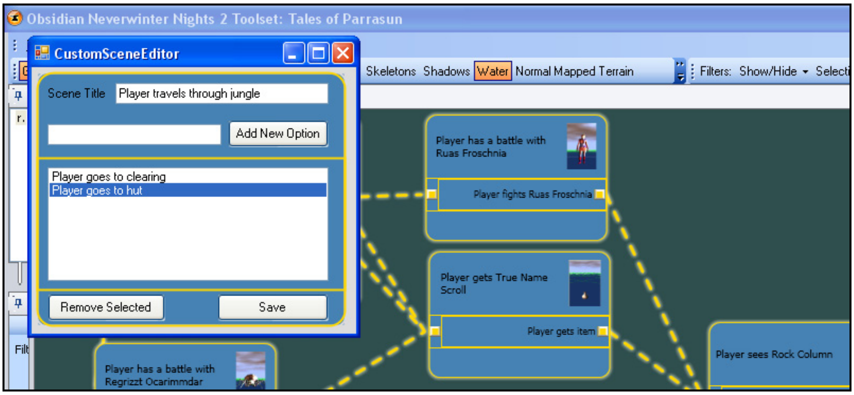


Fig. 15. Creating a custom scene for use in the Branching Narrative Diagram

5 Evaluation

An initial evaluation was carried out to explore the potential benefits of Narrative Threads. Data analysis is currently underway, but some early findings which indicate differences between games created with and without the tool are presented here.

5.1 Procedure

Fourteen young people aged 11-15 took part in a game creation project as part of a four day half-term holiday workshop. The participants were recruited through an advert on a university website and email list, and assigned to different groups before arriving at the workshop so that the groups were evenly matched according to age. One group (1 female, 6 male) used the NWN2 toolset with the Narrative Threads plugins (referred to as ‘Toolset NT’). The other group (7 male) used the toolset without Narrative Threads (referred to as ‘Toolset Basic’).

Participants spent approximately 21 hours on the game creation project. Both groups were given video demonstrations of the basic toolset functionality, and the Toolset NT group received additional instruction in using these tools. The first and second authors each led a workshop group and provided guidance to participants, along with two additional workshop helpers.

The games created by the young people were blind-marked by a secondary school teacher with experience of running game creation projects using a rating scale which is described fully in [17]. The scale was developed in conjunction with an expert literacy educator and has subsequently been used by another researcher in a different context [34]. The scale guides a marker to assign a score for nine different factors:

storyline, visual interest of areas, player guidance, player purpose/ goals, player choice, characters, dialogues, imagination and challenge.

5.2 Results

The Toolset NT group received higher ratings on their games, as shown in Fig.17 (box plot shows minimum and maximum scores for each group through the whiskers, with the top and bottom of the boxes indicating the 75th and 25th percentile and the central line indicating the median).

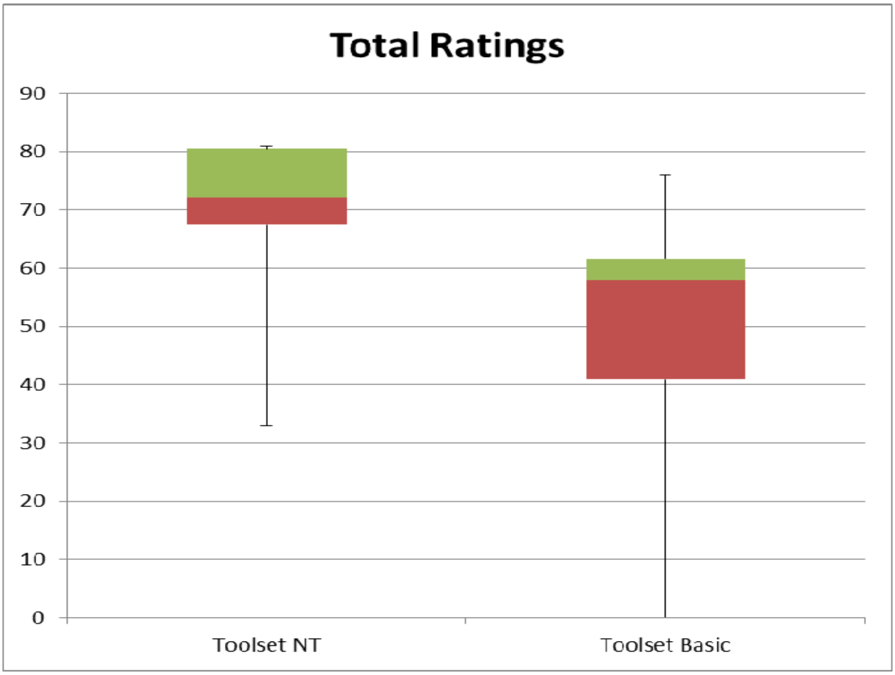


Fig. 16. Total Game Ratings by Group

As the data did not meet the requirements for a parametric test, a Mann-Whitney U test was used to examine the significance of the difference between the groups. The results indicated that there was a significance difference between the groups' ratings ($Z= -2.111$, $p < .05$).

5.3 Discussion

These preliminary result indicate that the additional support provided by Narrative Threads may make a positive difference to the quality of the games created as assessed by a teacher with reference to storyline and other factors of importance in a narrative-based game. Further data gathered from this workshop, including transcriptions of interviews with participants, logs of tool usage and observation notes, are currently being analysed to allow closer examination of these findings. Additionally, a multimodal analysis of the games created is underway with a view to exploring their narrative features in more detail.

6 Conclusion

Narrative Threads is a suite of tools designed to encourage young people to approach game creation as a storytelling exercise. It was designed in accordance with the principles of an associated design model, with reference to established theory and with extensive input from users through a participatory design process. The participatory methods used gave invaluable input to the design process, from insight about the importance of all tasks having a clear impact on the game being created, to specific design decisions such as the choice of representational icons.

Data analysis is ongoing, but initial results suggest that the tools have a positive impact on the story elements of young people's games. Early findings from use in a workshop setting indicates that the tools have promise, and can help young designers to produce games which are rated more highly by a teacher without knowledge of the conditions under which they were created. Future work will explore in more detail the extent to which the tools help users to create games with stronger narratives, analyse the multimodal meaning-making taking place and examine the skills developed through the activity.

Acknowledgments. Many thanks to Judy Robertson and Cathrin Howells from the Adventure Author project, and Keiron Nicholson from the Adventure Author and Flip projects, who all contributed a range of useful suggestions and ideas. Thanks are also due to the anonymous reviewers who made some very helpful suggestions. This work was funded through an EPSRC Doctoral Training Account.

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UpStage: An Online Tool for Real-Time Storytelling

Helen Varley Jamieson and Vicki Smith

Abstract. UpStage is an online platform for real-time interactive performances; in this article two of the originators of the project outline its history and contextualise UpStage within the wider field of digital storytelling. Examples from performances illustrate how UpStage has been used as a collaborative storytelling tool, including two specific examples of the use of UpStage in educational contexts. Techniques for devising and sharing real-time online stories are discussed, and the notion of an "intermedial audience" proposed, recognising the new relationship between remote performers and the online audience. In conclusion the authors suggest that online storytelling has a vital role to play in the shaping of geographically dispersed communities and the ownership of new digital tools and spaces.

Keywords: UpStage, cyberformance, online storytelling, elearning, networked performance, online performance, digital story telling, desktop theatre, remote collaboration, Avatar Body *Collision.*

Introduction

The term "interactive storytelling" encompasses a broad range of styles, techniques and approaches to storytelling in the digital age, and a growing range of tools is available to artists working in this field. This article looks at one particular tool that has been purpose-built for online performative storytelling: UpStage (http://www.upstage.org.nz[1]) is an accessible web-based platform that facilitates real-time collaboration between artists and audiences, enabling creative dialogue across geographic, cultural, social, artistic and educational circles without demanding high-end hardware and proprietary systems.

UpStage opens up exciting opportunities for cross-cultural collaborations without requiring access to high-end technology, or being constrained by institutional agendas. It offers an innovative and participatory approach to interactive storytelling, experimenting with the creative potential of domestically accessible digital communication technologies. The authors, Helen Varley Jamieson and Vicki Smith, are two of the originators of this platform and write from their personal experiences about the evolution of cyberformance[2] as a live art form, the development of UpStage,

[1] All Internet addresses referenced in this paper were last visited in August 2012.

[2] Cyberformance describes "live theatrical performances in which remote participants are enabled to work together in real-time through the medium of the internet, employing technologies such as chat applications or purpose-built, multiuser, real-time collaborative software" `http://en.wikipedia.org/wiki/Cyberformance`

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and techniques for real-time interactive storytelling in the online environment, drawing on examples of UpStage performances and its use within the classroom.

UpStage is one site in cyberspace where explorers can gather around the “digital campfire” to share their own stories and construct new stories that imagine the digital future.

Around the Digital Campfire

Back in the mists of time, the earliest storytellers likely had little more than words and voice with which to share stories. At some point they probably began to use gestures, sounds, objects – but with very little assistance they conjured up epic scenes in the imaginations of their listeners. Sometimes less is more: the imagination has always been technicolour and three-dimensional, capable of generating all the special effects a story might need and utterly customisable to individual preferences. The compelling concept of oral storytelling stays with us today in many forms – children's bedtime stories, holiday-makers sharing tales round the campfire, spinning a yarn over a beer at the pub, stand-up comedy and so on. And now we have a tempting array of new technologies with which to augment our stories – special effects, surround sound, digital animations – and new environments in which to situate these stories – virtual worlds, computer games and social media platforms. Today, when people say “interactive storytelling” they are most often talking about computer games or entertainment where the reader (or player) takes on a role within a story to solve a problem or puzzle, or creates their own narrative from a series of options. Interactive narrative development, intelligent agents and the creation of believable characters and immersive environments are all areas where significant research and development has been invested over the last several decades.

Contemporary “interactive storytelling” can trace its roots back to the emergence of role-playing games in the IRC channels and text-based chat rooms of the late 1980s [1, pp. 15-16]. This has evolved into the highly sophisticated computer games, online role-playing games and immersive environments that we have today. Another form that branched out from the same source in the early 1990s was the live staging of theatre texts in online chat environments – the first documented being *Hamnet*, an 80-line version of *Hamlet*, by the Hamnet Players in 1993 [2]. The same group followed this up with *PCBeth* in 1994. When graphical chat applications appeared, this concept was expanded into these new spaces by Desktop Theatre, who presented *waitingforgodot.com* at the 1997 Digital Storytelling Conference [3]. These and other performances signalled a new variant on digital storytelling, bringing improvisational and participatory street theatre techniques into publicly accessible online spaces. Often these early cyberformance works used recognisable theatre texts, providing audiences with a familiar framework from which to read the work. Other artists, such as ParkBench (Nina Sobell and Emily Hartzell) and Motherboard (Amanda Steggel) began to experiment with the use of webcams and online video conferencing. Around the same time the term “digital campfire” began to be used as a metaphor for computer-assisted storytelling, notably by storyteller Dana Atchley [4, 5].

As the end of the century drew near, many artists and researchers turned their focus to the high-end technology of digital theatre including 3D scenography, intelligent agents as actors and motion-sensor interactions. Such technologies were less compatible with live online events, except within universities or other institutions with access to high-speed networks. For independent artists, the Internet remained a playground for low-tech experimentation; lack of bandwidth and other resources was an environmental feature, not a limitation. It was in this context that we began our experimentations in cyberformance – online theatrical performance where the performers are geographically distributed and audiences can be anywhere in the world. Our performative research project, *the[abc]experiment* (2001), explored the intersection of theatre and the Internet over domestically-accessible networks, and from this project we formed the globally dispersed cyberformance troupe Avatar Body *Collision* along with Karla Ptacek and Leena Saarinen[3]. At first working with free online chat applications such as iVisit and the Palace, Avatar Body *Collision* soon felt the need for a purpose-built platform and conceived of the idea for UpStage – web-based, collaborative, open source, accessible and artist-led low-tech wizardry. The first version was launched in January 2004; as well as becoming Avatar Body *Collision's* primary rehearsal and performance venue, UpStage was immediately employed within the school environment in the *World X* project (discussed later in this article). Today it is used by artists and students around the world and a large body of work has been created, largely in the context of the UpStage festival, held annually since 2007.

A Cyberformance Platform

Prior to the development of UpStage, we worked with freely available online chat applications, primarily the Palace and iVisit but also investigating other platforms such as Active Worlds and Habbo Hotel (this was before the existence of applications such as Second Life and Skype). While all of these platforms offered interesting possibilities for live collaborative storytelling, they also came with limitations. For example, platforms developed primarily for chat and social networking were naturally concerned with authentic identity, which is very restrictive for the cyberformance artist who wishes to appear as multiple characters. Furthermore, at this time such applications tended to be closed-source proprietary developments, so while they may have been free to download and use, they were not free to be adapted and developed in ways beyond their initial, social, concept. As artists, we wanted to do things that the software hadn't been designed to do, and we found ourselves becoming frustrated in our creative goals; we dreamt of a purpose-built application for cyberformance that could combine our favourite features from existing applications into a single platform. When a funding opportunity through the New Zealand government emerged in 2003, we were able to develop the first version of UpStage.

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[3] Avatar Body *Collision*, `http://www.avatarbodycollision.org`, was formed in 2002 by Vicki Smith, Leena Saarinen, Karla Ptacek and Helen Varley Jamieson.

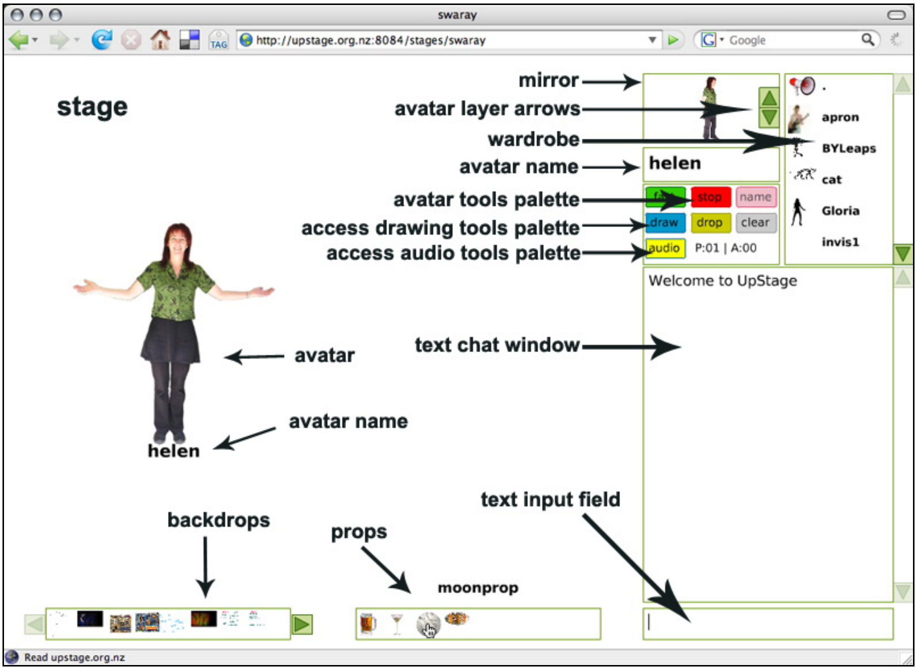

Fig. 1. The UpStage player interface, showing on-stage tools and media

UpStage allows artists to create real-time performance events in collaboration with online audiences. Originally developed by artist/programmer Douglas Bagnall and Avatar Body *Collision*, UpStage is today maintained and developed by computing students at the Auckland University of Technology and an international community of volunteer open source programmers and artists. The tools that UpStage "players" have at their disposal to compile performances include graphical avatars, props and backdrops (which are pre-loaded and can include animations), pre-recorded audio clips, real-time drawing, and live webcam image feeds. Avatars are graphical objects that players can "hold" and move about the "stage", rather like a live(ly) comic book. They can also "speak" – their words are spoken by a text-to-speech programme and appear in speech bubbles by the avatar, as well as in the text chat window. A drawing tool can be used for real-time illustration or to add coloured overlays or "curtains", highlighting or hiding areas of the screen. Pre-recorded music, sound-effects and voices can be played and mixed in real-time, and webcam images are presented as motion jpeg – a series of still images from a live feed[4].

UpStage is a server-side application, with all of the elements and interaction taking place within the artist or audience member's web browser. This avoids the need for

[4] Full audio-visual streaming is being investigated for the next version of UpStage, as until recently technical and bandwidth considerations meant it was not worthwhile implementing and it has not been necessary.

players or audience to install additional software[5], making the environment highly accessible. For artists, it is as portable as a username – they can log in from any Internet connected computer. Audience members do not log in, but simply click on a link in an email or web page to enter a “stage”.

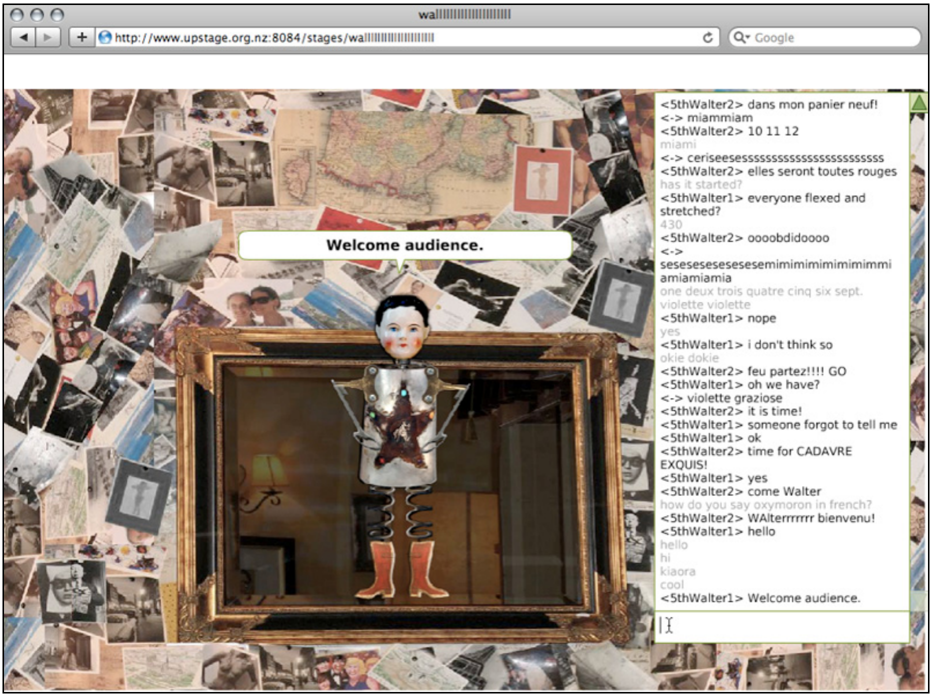

Fig. 2. *4th Wall* (2009) by Tara Rebele, Miljana Peric & Suzon Fuks, showing the audience view of the UpStage interface and the mix of player and audience text in the chat window

The text chat window serves as a deceptively simple shared space for player and audience dialogue. The audience can respond and comment anonymously, embellishing the performance and frequently talking amongst themselves as well. The chat enables even new audience members to easily contribute to the dialogue at the same time as allowing whatever textual expression the audience's imagination produces. Audience input is distinguished from that of the avatars by being slightly smaller in size, light grey and silent. This means that avatar text (input by players and spoken by a text-to-speech synthesiser) is prioritised visually and audibly over audience text, but the audience text is clearly there and is often integral to the progress of the narrative. In a performance with a particularly vocal audience, the speed at which the text chat moves up the screen adds to the lively atmosphere. Normally, there is inter-audience banter which generates a strong sense of temporary

[5] The server application is available to download from `https://sourceforge.net/projects/upstage/` for anyone who has access to a web server and wishes to establish their own UpStage site.

online community between the globally dispersed audience members. Experienced UpStage audience members may become more active and visible within the text chat – for example adding their name or an identifier to their text, giving advice to newcomers and contributing at a more sophisticated level to the performance, be it embellishing a narrative, creating visual poetry, jamming in response to the players' texts or providing a humorous or subversive commentary. Unlike most other real-time platforms, UpStage audience members cannot be silenced or ejected from the space but are empowered to construct community and story at will.

Other platforms similar to UpStage have been developed, such as Visitors Studio[6], (which has a less narrative, more cinematic approach) and webcam platforms such as Panoplie[7] and Selfworld[8]. Each one has a slightly different approach, but the common aim is a means by which artists can create and present real-time performances for and with online audiences. This emphasis on real-time interaction harks back to the campfire concept and the powerful connection generated through sharing space, time and story.

Performances may be narrative or conceptual, with greater or lesser degrees of audience involvement, incorporating other technologies and addressing any themes (often current global issues are discussed). The diverse and growing body of work created in UpStage has been largely fostered through its festival, held annually since 2007[9]. The 101010 UpStage Festival (2010) featured 17 performances by more than 50 artists from around the world, and as well as online audiences there were gathered audiences at 13 “real life access nodes”, physical venues located in ten countries. The 101010 artists ranged from 12-year-old school children to established digital artists, and artists from other disciplines experimenting for the first time with digital performance technologies. Some UpStage artists have now presented work at each festival for four years, and their familiarity with the tool is evident. Performances such as *Aquifer Fountain*[10]*, S/Zports: A Training for the Possible Wor(l)ds*[11] and *Mass-Mess*[12] from the 101010 festival demonstrate – in quite different ways – a high level of sophistication in the creation and presentation of cyberformance in UpStage. *Aquifer Fountain* created a visually rich and meditative space within which the audience poetically embellished the narrative; one audience member asked, “How can you see tears or hear crying in a waterfall?” and a little later someone wrote, “a wave of emotion, a constant sense of falling, crashing and flowing away, losing.” *S/Zports: A Training for the Possible Wor(l)ds* built a different energy, speaking directly to the audience to engage them in an “ambitious training programme” and layering a driving

[6] Visitors Studio, `http://www.visitorsstudio.org`, developed by Furtherfield and Neil Jenkins.

[7] Panoplie, `http://panoplie.emakimono.org`, developed by Annie Abrahams, Elisabeth Klimoff & Clément Charmet; no longer available.

[8] Selfworld, `http://www.selfworld.net`, developed by Ivan Chabanaud and Guillaume Dobbels.

[9] More information about UpStage Festivals including documentation is available online at `http://upstage.org.nz/blog/?page_id=1958`

[10] *Aquifer Fountain* (2010) by ActiveLayers.

[11] *S/Zports: A Training for the Possible Wor(l)ds* (2010) by Miljana Peric, Julijana Protic, Jelena Milosavljevic-Rubil, Goran Rubil, Andrea Aß and Suzon Fuks.

[12] *MASS-MESS* (2010) by Katarina DJ. Urosevic and Jelena Lalic.

musical soundtrack, multiple languages and theoretical statements. This layering of media was also employed by *Mass-Mess*, building to an apocalyptical crescendo where everything literally went down the digital plughole. UpStage festival programmes have always included artists at every level of development and highly experimental work, and there is normally a high level of exchange and support between the artists during the development of work for the festival; this contributes to a strong sense of community and cumulative knowledge amongst UpStage artists.

The Intermedial Audience

Unlike most computer games and virtual world role-playing, cyberformance does not place the audience in a "player" position but maintains a deliberate distinction between the artist/storyteller and the audience/listener [6, 7]. However, the relationship is very different to traditional situations where a passive audience sits in a darkened auditorium to experience a performance, or stands before a finished art work in a gallery long after the artist has left. In cyberformance, artist and audience are co-present in a dialogic relationship, and while the audience has less agency than the players, they are far from passive. UpStage audiences (also known as "chatters") are evolving new codes of behaviour for the environment, making choices about how anonymous to be and how they want to interact with a performance (as discussed above in the description of the text chat tool). The simple fact of being in front of a keyboard, along with the increasing ubiquity of the Internet and general confidence in online interaction, means that online audiences expect to be able to assert (or insert) themselves as active participants in a cyberformance.

The idea of the convergence of artist and audience has been explored in many forms since (and before) Prampolini's 1915 proposition of an "actor-gas" that would replace actors and "fill the audience with joy or terror, and the audience will perhaps become an actor itself as well" [8, p. 87]. Through the Fluxus Happenings of the 1960s, various forms of psychodrama and improvised theatre such as Playback, we have come to concepts such as "user-generated content" and "produsage" [9] in "social media" platforms such as YouTube and Facebook that promote the idea that everyone can and should be a creative producer. Particularly in digital and online media, the distinction between artist and audience has all but disappeared. Cyberformance is slightly different, however, in that it maintains a degree of distinction between artists and audience at the same time as empowering and involving the audience; this is one sense in which the cyberformance audience can be said to be intermedial – it is situated in a liminal space outside of traditional codes and yet not entirely within the new (and fluid) boundaries. Intermedial is described by Chappel and Kattenbelt as "a space where the boundaries soften – and we are in-between and within a mixing of spaces, media and realities", and intermediality is "a process of transformation of thoughts and processes where something different is formed" [10, p. 12]. This concept of intermediality is highly applicable to live online performance, as a transformative process situated in the liminal space of the Internet and employing multiple media. The cyberformance audience is also intermedial in both its situation and its materiality: the temporary community formed between individual members, and each individual's presence in the performance, is achieved with keystrokes, telecommunications technology, electronic writing and a haptic sense of connection through active engagement in the work.

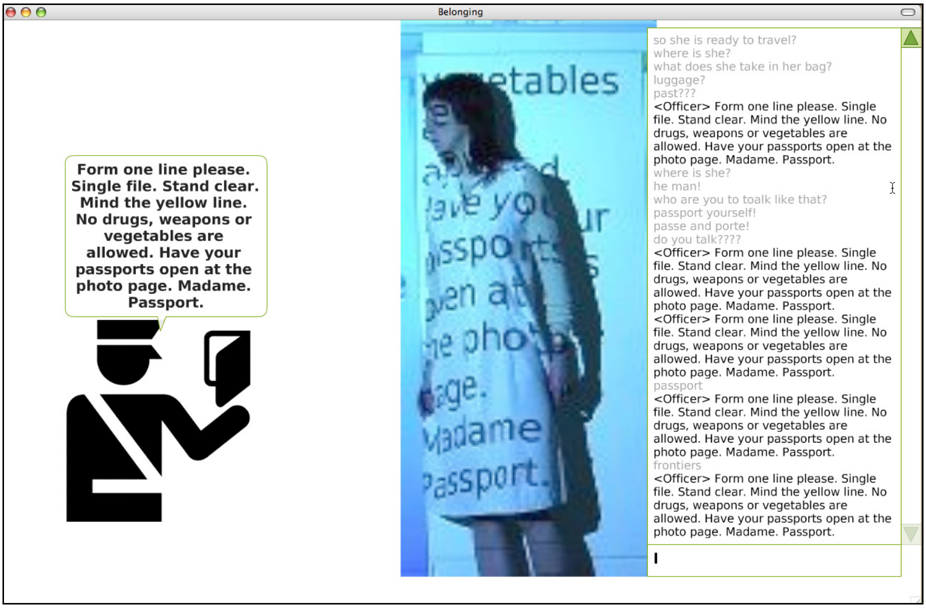

Fig. 3. Audience view of *Belonging* (2007) by Avatar Body *Collision*, showing the remediation of audience text chat through a webcam avatar

Some UpStage performances have inserted the intermedial audience into the visual scene through the remediation of the text chat. In *Belonging* (2007)[13] one of the performers stood in a large projection of the text chat and used a live webcam feed to re-present the collaged image. Audience members later commented that seeing their own words in the webcam image was a powerful reinforcement of the liveness of the event. In performances such as *make-shift* (2010)[14] and *Strings Attached II* (2011)[15] audience text has been copied and spoken aloud within the performance by the avatars. *Strings Attached II* explicitly asked the audience for their words, while *make-shift* initially confused some audience members who asked how the character repeating their words knew what they were saying, and wondered whether the character was in fact a scripted programme. Cleverly reversing this, in *Plaice or Sole* (2010)[16] the performers "appeared" in the text chat as anonymous audience members,

[13] *Belonging* (2007) by Avatar Body *Collision*.
[14] *make-shift* (2010) by Paula Crutchlow and Helen Varley Jamieson.
[15] *Strings Attached II* (2011) by Cindi L'Abbe and collaborators.
[16] *Plaice or Sole* (2010) by Francesco Buonaiuto, Mario Ferrigno and Simona Cipollaro.

further troubling player/audience boundaries and subverting the potential for the audience to use the chat for risqué or even offensive conversation.

Direct conversation with the audience is a common feature of UpStage performances: *Rejection: freeze, fight or flight* (2007)[17], *Fisk is Norwegian for Fish* (2009)[18], *West Side's Story* (2010)[19] and other shows have posed questions to the audience, inviting responses and procuring material that is then used in the performance. When the audience is not directly addressed, their input can range from quietly listening and observing to providing a running commentary or embellished narrative, and there can also be tangential discussions between audience members inspired by the content of the performance or arising from technical issues. Different performances of the same show can have hugely different audience input and the text logs saved after each performance make for interesting and often hilarious reading. Like theatre, cyberformance is incomplete without the audience, and in UpStage the intermedial audience contributes its unique voice via the text chat to generate a shared sense of those gathered and the collective "holding of breath" that completes the work.

Real-Time Techniques for Interactive Storytelling

Even in complex digital environments, interactivity is often limited to a series of set choices within a finite toolset or database of possibilities. Performing in real-time interactive environments alters some of those limitations – for example, players can choose to deviate from a script if the audience proposes an alternate route, or performances can be structured to respond to whatever input the audience gives, similar to improvised theatre forms such as Playback or Forum Theatre. Of course, these models are not without their own limitations. For example, in UpStage adding additional media to a stage requires reloading the stage for everyone currently on that stage, which is not normally desirable to do during a performance (although it has been done for deliberate effect, such as in *Merznet*[20]); therefore, if the audience suggests a dinosaur and the players do not have a dinosaur graphic, such as an avatar or a prop, already on the stage, creative solutions must be found to add one. A dinosaur can be drawn with the drawing tool; held up to a webcam; or performed by an avatar changing its name and inviting the audience to imagine it as a dinosaur. The low-tech wizardry of UpStage creates open spaces where imagination can flourish, and the lack of a dinosaur ceases to be a limitation: your dinosaur may be a fierce Tyrannosaurus Rex while mine is a graceful soaring Pteradactyl and someone else's is a pink fluffy toy, in a collective suspension of disbelief.

UpStage artists often collaborate remotely and use UpStage as their primary shared workspace; this means that meetings, improvising, devising and performing also become a form of training in the use of the software. The more time one spends

[17] *Rejection: freeze, fight or flight* (2007) by Suzon Fuks and James Cunningham.
[18] *Fisk is Norwegian for Fish* (2009) by Kjelsas 12.
[19] *West Side's Story* (2010) by Ellen, Joanne and Hannah.
[20] *Merznet* (2008) by Ben Unterman, Daniel Silverman, Maya Jarvis and Inouk Touzin.

in the environment, the more familiar one is with its operation, with the physical gestures and movements involved in using the software and with the sensitivity, positioning, tone of voice and other subtleties. Regular open sessions are held, to introduce newcomers to the environment and as opportunities for artists to jam together; these playful sessions spark connections between participants, with newcomers readily engaging with more experienced "UpStagers". The open ethos invites everyone to participate in lively co-construction of story, contributing spontaneously from their own experiences and ideas – sharing, borrowing and transforming in a collective experience that is also a form of cyberformance training and that may provide the basis for a performance. This is a practical exploration of the idea of stories as collaborative experience [11, 12], where the technology facilitates both a repository for experiences and the creative state of "inter-being" [13, p. 15] which then enables the transformation of material into story, and player into storyteller.

The structures of UpStage performances are usually progressive but not always strictly narrative, and frequently juxtapose multiple and diverse stories and characters within a single performance to enable a dense intertextuality. For example, three performances from the 101010 festival did this in different ways: *Theatre of Exchange*[21] evoked archetypes from dreams and mythology; *Sprinkler Fountain*[22] combined an Indonesian legend with scientific facts about water usage globally; and the contemporary cultural politics of Germany and Aotearoa/New Zealand, tourism and art, were spliced together in *Die Totezone*[23]. This layering of diverse material and media creates a degree of Brechtian "Verfremdungseffekt" at the same time as allowing multiple entry points and readings of the performance. Some audiences more comfortable with traditional story structures may find this confusing, but experimentation is vital for the development of emerging forms such as cyberformance and interactive storytelling. Generally, UpStage audiences appreciate this and value the opportunity to participate in the evolution of a new form – "assisting" the performance, to borrow from the French, who do not "watch" a performance, rather "j'assiste" [14, p. 262].

Examples of performances employing more overtly narrative structures include *Murder 2.0*[24], *West Side's Story* and *Snow White and the Seven Chihuahuas*[25]. These performances have adapted familiar structures and stories for the online environment, devising specific ways for audiences to interact. A film noir interactive comic, *Murder 2.0* used Flash and ActionScript in UpStage to give the audience clickable clues leading to multiple paths through the story. Although the audience were watching simultaneously and commenting together in the chat in real-time, they were not all seeing and hearing the same version of events. *West Side's Story* was a classic whodunnit created by a group of school pupils; the audience were invited to

[21] *Theatre of Exchange* (2010) by Nathalie Fougeras and Malin Ståhl.
[22] *Sprinkler Fountain* (2010) by Suzon Fuks, Miljana Peric, Marischka Klinkhamer and Tara Rebele.
[23] *Die Totezone* (2010) by Cat Ruka and Alexa Wilson.
[24] *Murder 2.0* (2010) by Virtual Theatre.
[25] *Snow White and the Seven Chihuahuas* (2009) by Kristen Carlson and Sheila Page.

co-interrogate suspects in a quest to solve a murder together. In *Snow White and the Seven Chihuahuas* the audience were asked multi-choice questions at turning points in the narrative to create a new variation on an old story. This real-time interaction within familiar structures fosters the sense of connection and “inter-being” between remote performers and audience.

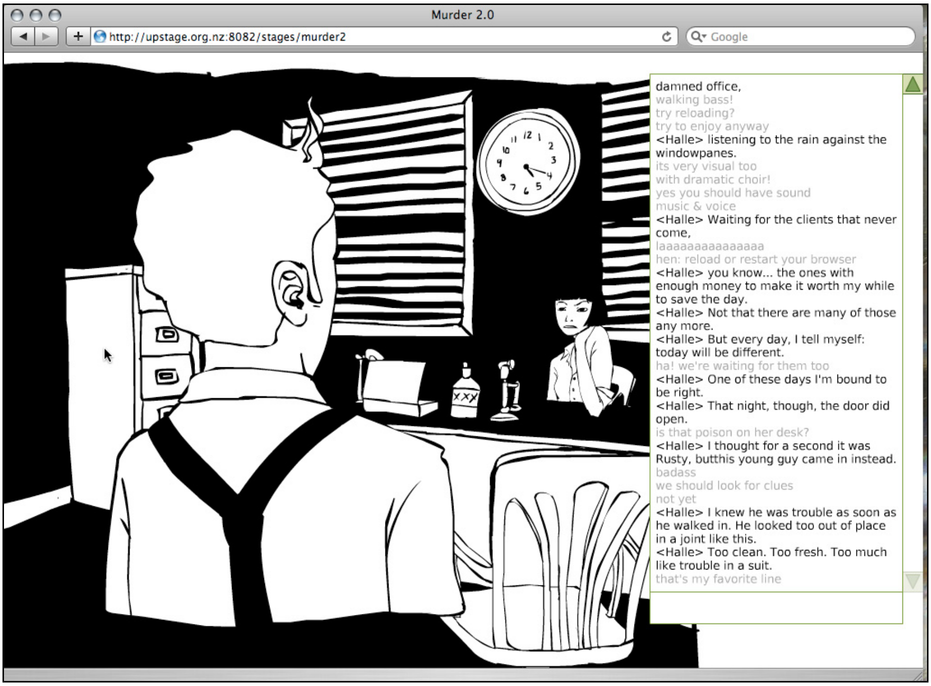

Fig. 4. Audience view of *Murder 2.0* (2010) by Virtual Theatre

The centrality of text – within the UpStage environment as well as within storytelling – means that all performances have poetic potential, whether they be tightly scripted (such as Avatar Body *Collision's* rendition of Beckett's short stage play *Come and Go*[26] and the cyberformance staging of a poem, *User Profile*[27]) or improvised (such as *Strings Attached II* and *Rejection: freeze, flight or fight*). As well as the text appearing in the chat window and the speech balloons of avatars on the stage, invisible avatars can be used to “float” words around the screen in a form of dynamic visual poetry. Some performances (such as *Noxiterra*[28] and *The Best Air Guitar Album in the World Vol. II*[29]) use comparatively little player text, instead offering visual provocations that inspire textual improvisation by the audience; this

[26] *Come and Go* (2007) by Samuel Beckett, performed in UpStage by Avatar Body *Collision*.
[27] *User Profile* (2009) by Meliors Simms.
[28] *Noxiterra* (2008) by Antoinette LaFarge and Marlena Corcoran.
[29] *The Best Air Guitar Album in the World Vol. II* (2007) by Anaesthesia Associates.

plays with the balance of focus between the text chat window and the stage area where the visual elements of the performance are presented. *Plaice or Sole* further disrupted this split focus by faking a technical problem on the stage and then situating most of the performance within the text chat window, where the player text became indistinguishable from "real" audience text.

Real-time audience interaction in UpStage is currently mainly textual input, however planned enhancements to the software aim to expand the possibilities and those with programming skills are already experimenting in this area. In 2007, before it was possible to play pre-recorded audio files in UpStage, *The Best Air Guitar Album in the World Vol. II* used animated Flash avatars that the audience could click on to trigger audio tracks. Two years later, *Lines*[30] used Actionscript to enable the audience to draw lines directly onto the stage which were then multiplied and animated by the players to generate a unique rotating mandala for each audience member. The same group were responsible for *Murder 2.0* in 2010, with clickable clues resulting in divergent plot-lines. UpStage has also been used in combination with other online platforms including blogs, streaming media interfaces, collaborative writing tools and websites to generate material and create a context outside of the moment of the performance, as well as within the performance itself, providing an additional dimension and tools that are not yet available within the UpStage interface (for example *Calling Home*[31]*, make-shift, A Little Online Communion*[32] and *4th Wall*).

UpStage in Educational Contexts

When used in educational contexts, UpStage offers the exciting possibility of direct creative interaction between students across cultures and/or geographies. In the first year of its release UpStage became an integral technology within W*orld X*, an educational project facilitated by Vicki Smith and Karla Ptacek. *World X* connected a group of school students from a rural community on the West Coast of Aotearoa/New Zealand with teenagers in a central London school in an extra-curricular programme exploring race and identity. The participants explored their local context and imagined a future world through asynchronous communication in the virtual learning environment Interact[33], and by performing family herstory, popular local recipes and alternative endings to current blockbuster films in UpStage. The process of sharing and co-creating story was encouraged and interfered with by HeRMiTT, a cantankerous cyberbeing who dwelt within UpStage – "... always in the matrix, an omnipresent intelligence, anarcho cyber terrorist acting as a virus of the new world disorder"[34] [15, p. 59]. Its unpredictable interactions with the students and the

[30] *Lines* (2009) by Ben Unterman & Daniel Silverman.

[31] *Calling Home* (2008) by ActiveLayers.

[32] *A Little Online Communion* (2010) by Sheila Bishop, Josh Cajinarobleto & Mitzi Mize.

[33] Interact is an open source learner management application which includes file sharing, discussion, blogging and chat technologies (`http://sourceforge.net/projects/cce-interact/`).

[34] Plant's description of the character All New Gen from the proto game *Bad Code* by VNS Matrix.

ambiguity about what or who HeRMiTT was[35] gave the two remote groups the parameters within which their imagined world could develop in cyberspace. Collectively, the students envisaged a world where their common interests as teenagers were contextualised by vastly different environmental realities, and where the physical possibilities and limitations of the real space were transposed with substances and actions given effect in the shared virtual space of UpStage.

Following the six months of the project, the students' improved social development in other areas was remarked upon by their teachers. Their concept of the future of education and learning as an ubiquitous process that happens how and when the learner is ready remains visionary within curriculum-driven education environments. The ability of the students to complement the asynchronous work they were doing in Interact with the performances in UpStage gave the project a focal point to work around as well as the playground to act out their collective understanding of how they negotiated the online space. The portability of UpStage meant that for one of the performance events, when the local school network was damaged by an electrical storm, the students could regroup and perform from the local Internet café.

A new educational project initiated in 2011 by Vicki Smith will use UpStage in conjunction with another open source online environment, Moodle[36], to explore narrative as a tool for remembering in physical and online performance. *How Haka Tells a Story* aims to engage artists, Maori[37] storytellers, teachers, kapa haka[38] performers and a dispersed group of students with tikanga Maori[39] in their local contexts. This project uses the process of learning physical sequences as a kinesthetic understanding of performing narrative within the creation and performance of haka[40]. The next stage will invite the students to apply that socially constructed knowledge to physical performance in UpStage. The students will work with local iwi (Maori) to be informed and guided in the creation and interpretation of their own story and performances. In both environments the lines between learner and teacher are blurred as students help teachers and other students negotiate their virtual classrooms. In closing the circle of narrative through art, story, carving[41] and performance, *How Haka Tells a Story* situates the participants in an "electric wananga"[42] - an expanded learning space that employs digital technologies to connect students in different physical locations. The intended culmination of the project is that the students deliver an online performance, physically performed from their local marae[43] – a positive

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[35] In fact HeRMiTT was a character/avatar, played in real-time alternately by Karla Ptacek and Vicki Smith.

[36] Moodle `http://moodle.org/`

[37] Tangata Whenua/Maori are the first nation people of Aotearoa/New Zealand.

[38] Kapa haka is Maori performing arts.

[39] Tikanga Maori is the way of Maori as a people, collective memory and cultural practices.

[40] Haka literally means performance or dance, and has many forms.

[41] Whakairo, carving, is a sculptural form of storytelling.

[42] Wananga means learning space or workshop.

[43] The marae is a shared communal space – technically the open space in front of a wharenui (Maori meeting house) but colloquially used to refer to the whole complex of buildings and open space.

response to concerns expressed by theorists such as Wade Davis about the potential threat posed by new technologies to ancient cultures and traditions [16].

Conclusion/Future

The sharing of stories and experience is fundamental to the development of community, as expressed in Lambert's description of “story as a map of our existence” [17, p. 17] and in the concept of the storytelling neighbourhood, where storytelling becomes the process of constructing identity as a neighbourhood [18]. In online communities, where individuals are commonly geographically disparate as well as separated by cultural and linguistic differences and may have never physically met, storytelling can provide a crucial bridge. This bridge may transport audiences into unfamiliar territories: *Amazigh Storyteller*[44] employed direct storytelling and real-time translation to share the storyteller's experience of desert life and interpretations of ethnic identity, while *x marks the spot*[45] took audiences to the high seas and brought the genre of a ship's log to cyberformance, combining poetic text with strong visual images; “... time, light and the sea imposing their narrative order … and character as yet unformed awaiting the sequence of events to define ...” [19]. In projects such as *How Haka Tells a* Story a bridge is created between past and present. At the meta-level, all of the stories shared in UpStage have together woven a strong and unique community between the many individuals around the world who have participated as artists and audience.

UpStage is one of a number of available platforms for experimenting with live online collaborative storytelling, and it is evolving along with the ideas of both artists and audience. At the same time, cyberformance artists are also experimenting with storytelling in other tools – both purpose-built and existing real-time environments from SelfWorld to Skype. Increasing accessibility of telecommunications technology, including mobile phones and Internet, means that more people are able to engage in participatory real-time storytelling forms and other digital arts practices. The annual UpStage festival continues to attract new artists and audiences every year, and its regular open sessions provide hands-on opportunities for newcomers to learn about the environment and get involved. Information about these sessions can be found on the UpStage web site, and interested people can join the mailing list. Those wishing to experiment with UpStage, especially open source developers, are also always welcome to get involved (see the web site, http://www.upstage.org.nz, for further information).

Storytelling is, at its heart, about communication between people: wherever people gather, stories are shared. As communication technologies open up new spaces for people to gather, stories are exchanged at digital campfires. UpStage is one beacon burning in the new landscape, attracting stories and tellers and listeners to its warmth, providing an opportunity for us all to interact with and influence the evolution of our communities through story.

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[44] *Amazigh Storyteller* (2008) by Nadia Oufrid delivered 'en Francais' and concurrently translated into English.

[45] *x marks the spot* (2010) by Vicki Smith.

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Comprehensive Blended Learning Concept for Teaching Micro Controller Technology Utilising HomeLab Kits and Remote Labs in a Virtual Web Environment

Sven Seiler[1] and Raivo Sell[2]

[1] Bochum University of Applied Sciences, Institute of Computer Science, Lennershofstr. 140, 44801 Bochum, Germany
sven.seiler@hs-bochum.de
[2] Tallinn University of Technology, Department of Mechatronics, Ehitajate tee 5 19086 Tallinn, Estonia
raivo.sell@ttu.ee

Abstract. This article introduces a comprehensive toolkit for the teaching of Mechatronics and Computer Science (especially micro controller technology and embedded programming). The approach is based upon a full set of materials, tools and products for internet-assisted distance learning. The concept presented here utilises remote labs, home labs and face-to-face teaching in classes. In detail, the learning concept is composed of a special DistanceLab solution, HomeLab kits and a Virtual Micro Controller Unit, assisted by supportive material which will be introduced in this paper and put into coherence with the didactic concept. Intended further steps in Remote Lab development are also presented by the authors.

Keywords: Virtual Micro Controller Unit, VMCU, Virtual Lab, Distance Lab, Remote Lab, Blended Learning, Learning Concept.

1 Introduction

The teaching of Computer Science and Mechatronics has received a lot of attention in the last decade and its importance is still increasing. This seems to be a logical process as these fields have entered into everyday life and smart products spread more and more into homes. Most of these devices are mechatronic in their nature, which means they consist of software in addition to mechanical and electrical parts. Therefore, a good education in these fields, especially in microcontroller and embedded programming, is necessary to assure quality and a continuous advancement in the future. It is quite a challenge for educational institutions to keep up with the high pace of technological innovation in industry. The availability of (often expensive) ICT based learning material for learners, a lack of functional qualified teaching staff and insufficient space in classes for bulky equipment are the main problems identified in the frame of projects analysis of target sector needs[1].

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The best way to fulfil the current and, more importantly, the future high demand for professionals in the fields mentioned above is to start at a quite early stage to delight young people with this technology. In the authors' opinion this can ensured by exploiting modern ICT based content, beginning in school and also covering vocational and university educational levels. Another point the projects were dealing with was to exploit modern Internet technology for education in these fields to make them more attractive for young engineers and keep them interested[2].

Within the following sections the different parts of the overall concept, which have been developed in the frame of joint EU projects [3,4,5] since 2007, are introduced and followed by detailed descriptions of each subpart where the concept was developed further [6,7,8] from one project to another. The current project *Virtual Academy Platform for Vocational Schools* (VAPVoS) [9], which will extend the whole framework by additional modules for the Virtual Micro Controller (VMCU) and integrate the results from former projects, has been accepted for funding.

2 Remote, Online, Virtual, Simulation and Distance Labs

In the literature, various terminologies are used for describing remote accessible or virtual online experiments. To avoid confusion this article discusses these terms before the principal section. The terms are used according to their definitions in [10,11,12], mainly taking the virtualisation component into account.

2.1 Distance Labs

A Distance Lab is a web platform offering any kind of online accessible experiment. This can be a remote or a virtual lab. These two kinds of labs are described next. In the case of the research consortium to which the authors belong, the term DistanceLab is used for a web platform including several labs accompanied by booking and user management modules.

2.2 Remote Labs

A remote lab (or online lab) enables actors (such as students or employees) to carry out experiments over the Internet which are normally performed in real-time physical studies in educational laboratories. Compared to a normal laboratory, additional equipment is needed to prepare traditional labs for online access. The fig. 1 illustrates these necessary changes. In a conventional laboratory environment, the actor uses the equipment with his or her own hands, getting direct feedback to any actions performed. When pressing a button the actor will see what the "reaction" of the lab is, without any delay. In a remote lab, the actor is connected by a personal computer (or any other device, like a smart phone or tablet pc) to the Internet. The actor is performing by utilising specific software or just by accessing a web application running in any common web

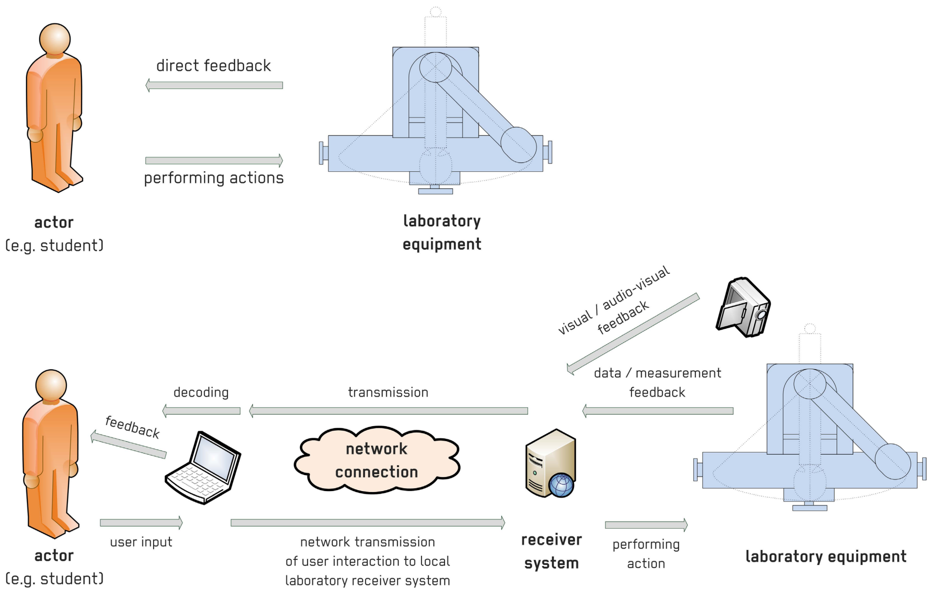

Fig. 1. A common vs. a remote laboratory

browser. The user's actions are transmitted to a receiver system (in most cases a computer system) with a public IP address. Naturally this receiver system is preceded by a user/laboratory management system, dealing with access rights and booking issues. This case is not illustrated here. The receiver system is directly connected to the laboratory equipment, enabling the actor to perform those standard actions to the hardware which are common for that specific kind of experiment.

Advantages of Remote Labs Compared to Traditional Ones. In a common lab course, mostly during practical work sessions as defined in the engineering curriculum, learners are encouraged to perform their exercises at a specific time, usually in a group of students, during the opening hours of their institution. There is often no consideration for disabled learners or for individual time constraints of the participants. Another problem is the availability of sufficient lab places. Especially, poor institutions may not offer costly experiments. Due to the nature of remote labs there is the possibility of sharing equipment, not only between students at the home institution but also between institutions themselves.

2.3 Virtual and Simulation Labs

The integration of virtual labs (see fig. 2) into a lab management system is generally easier than integrating remote hardware based labs. Some of the literature

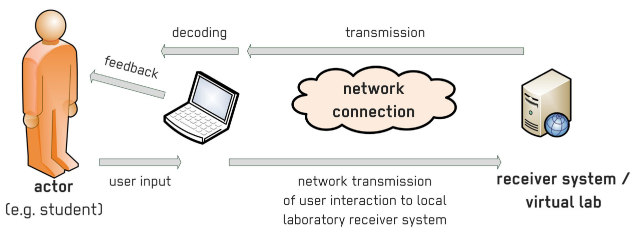

Fig. 2. A virtual or simulation laboratory

uses the terms "remote lab", "online lab", "cyber-enabled lab" and "virtual lab" synonymously but, while the first three are the same, "virtual lab" may not be used interchangeably. A virtual lab is a "laboratory" consisting of a specific piece of software. This software may be a proprietary one but also can be a web service or simulated hardware. The common case for all virtual labs is that real experiments are virtualised or simulated in this software, in most cases dealing with a challenge close to reality. A virtual lab can be accessed like a real hardware lab. The actor is performing his actions from a distance by using an ordinary computer system sending his input over a network (in most cases involving Internet transmission) to a receiver system which will be in most cases linked directly to the virtual lab. In specific cases a virtual lab may involve different virtual machines (as in a network experiment, where students have to set-up a network infrastructure from a distance) or additional server systems (database systems among others) which are necessary for the virtual lab. The system itself directly sends the feedback over the communication channel back to the actor's personal computer. All computations are done in the virtual lab and only feedback to the user input is sent back.

Advantages and Disadvantages of Virtual Labs. Virtual labs have some advantages compared to real hardware labs. If the virtual lab is a software service then once the lab is set up it can be used by many students simultaneously, restricted only by the computational power of the host computer. It is also more robust than real equipment; a student cannot destroy the hardware whilst adjusting some settings or failures in programming. Another benefit is monetary. The system can be easily duplicated without paying additional costs. Of course, virtual labs also have disadvantages in comparison to real (remote) ones. A virtual lab can never perform exactly the same as real hardware in all cases. As it is impossible to include all environmental parameters in the virtualisation, a virtual lab will sometimes react differently to a real one. The best solution seems to be a combination of virtual and remote labs to get benefits from both of them. A general approach, also used in our consortium, is to use the virtual devices for basic education to teach basic system thinking and to get familiar with the hardware. In later steps the learners switch to real hardware.

3 Overview of the Blended Learning Concept

During the above-mentioned projects a consortium of European partners[1] developed a comprehensive concept for teaching microcontroller technology based on several results, drawn up in fig. 3, which will be described in separate sections in this article. The concept consists of the following parts:

- *DistanceLab* - The DistanceLab concept [13] was initially developed during the Interstudy project and developed further in the follow-up projects. In its current state it is a web platform for accessing real hardware (labs) and virtual labs which can be programmed or controlled directly over the Internet. The concept is being continuously developed further and currently applied into study processes in Estonia and Germany.

- *HomeLab kits* - These are cases with micro controller hardware, for the self-educating of learners at home or for utilising them in classes in the context of face-to-face education. The kits are combined with specific modules for different domains (e.g. Automotive or Mechatronic).

- *Virtual Microcontroller System* (VMCU) - A virtual version of the HomeLab kit hardware simulating the microcontroller's behaviour but acting like the real hardware.

- *Robotic Applications* - These applications are based on combined parts of the HomeLab kit. So, after teaching basics with the kits, it is possible to use more complex scenarios for further education and for inseminating the more interesting side of microcontroller programming in the form of robotics. These robots can be existing ones provided by the course supervisor or self-built by student teams. In the summer semester of 2011 this was run as a robotic competition in an Estonian undergraduate class.

- *Supporting Material* - The strength of the concept is the provided material in the form of a wiki based webpage, named Network of Excellence, where broad information about microcontroller programming and the basics of mechatronic principles is provided. In addition, corresponding hands-on material and teaching books were developed. The material incorporates practical examples, theory, exercises, questions, discussions and project examples.

All modules are integrated into one package as a microcontroller blended learning concept. The main idea of this concept is to integrate and emphasise e-learning

[1] Since 2007, the following partners were involved in the concept development: Tallinn Technical Unversity (Estonia) Bochum University Of Applied Sciences (Germany), Helsinki University of Technology (now Aalto University) (Finland), Kaunas University of Technology (Lithuania), Royal Institute of Technology (Sweden), Universit de Technologie de Belfort-Montbliard (UTBM), Estonian Qualification Authority and several SMEs and schools.

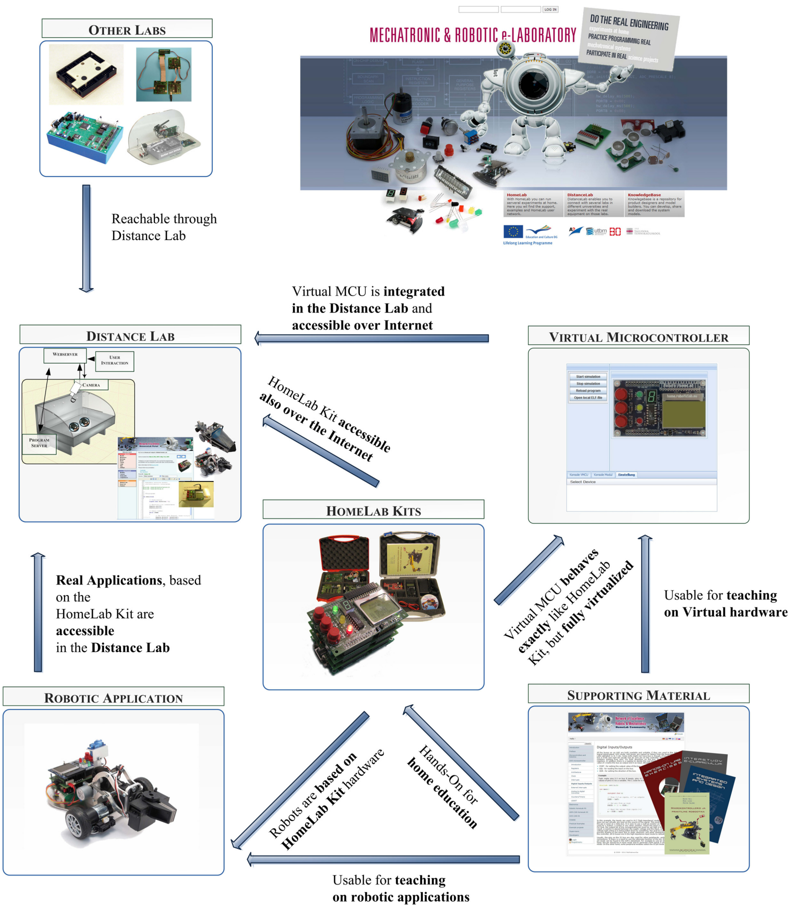

Fig. 3. Blended Learning Concept overview

possibilities into the normal learning process (face-to-face and self-education at home as well as collaborative work over the internet in student teams) to create a successful symbiosis of all three worlds in the form of blended learning. As illustrated in fig. 3 the connection of three different approaches in teaching microcontroller technology are used. Initially, the concept was based only on the HomeLab kit hardware.

As part of the Interstudy project a web platform was developed to integrate HomeLab kit into an e-environment and to make the same hardware as formerly used offline in classes and labs accessible and programmable over the Internet. The next step, undertaken in project MoRobE, was to virtualise the microcontroller and all of its associated modules as a supplement to real physical tangible labs. From January 2011 onward, a stable version of this virtualised controller can be accessed by the DistanceLab.

The didactic link between the above-mentioned project results is demonstrated by the fact that most integrated labs in the DistanceLab are using HomeLab kit hardware components or are compatible to it (like VMCU). The mobile robot solution, for example, is completely realised by hardware from the kit. Therefore, it is possible to learn at home and have more expensive experiments (more motors and sensors in one lab) together with the distance aspect overview of the hardware, overview of the software, etc. in different languages.

In addition to this self-developed content, the consortium's approach was also to integrate further external labs into the DistanceLab. The application into the learning process and the course set-up [14] is not covered by this paper. The next sections introduce the tools and products utilised by the concept in more detail.

4 DistanceLab

4.1 The First Version

The developed DistanceLab solution is intended for educational and professional use and was primarily developed in the context of life-long learning. It is composed of a Web 2.0 rich Internet platform, where different remote and virtual labs are integrated. In the first stage, the DistanceLab provided access to microcontroller based systems which can, but need not be, based upon the HomeLab kit hardware. In the current development stage external labs can also be integrated, so far as they can be interfaced using the consortium's defined standards.

The DistanceLab is designed for facilitating direct programming or controlling of the connected devices. In the case of programmable devices, this is realised by using a programming editor and an automatically invoked compiling process. This enables flashing programs directly to the connected devices over the internet. Some examples for interfaced labs are mobile robots, specific versions of HomeLab kits with add-on modules for a specific purpose (e.g. automotive study

Fig. 4. Distance Lab Environment

CAN-Module, LCD Display or a motor board) or the Virtual Micro Controller Unit with its various modules.

In the case of real hardware labs, the user can access cameras showing the lab in real time to monitor the behaviour of the robot and can control the compiled program written by the user. The programming interfaces, together with the images of robot in different configurations, are shown in fig. 4. In the case of virtualised labs, the user sees the behaviour in a virtual world (like a 3D robot arm, or the emulated HomeLab modules).

4.2 DistanceLab 2.0

As the first approach is somewhat limited because of decisions about the technology, the consortium is currently working on an advanced approach. It is intended to integrate the DistanceLab and Network of Excellence as well as further material into a Webdesktop system, which will be app-based and so easily extended with new functionality. Current conceptualisation of this system is illustrated in fig. 5. The system will use the same technology base as the VMCU and, therefore, our current results can be integrated in a convenient way. We intend to extend the Webdesktop system with new applications such as a virtual companion (the avatar in the lower right corner of fig. 5) based on knowledge assessment techniques which will provide useful hints for the users based on acquired information from the Network of Excellence and semantic analysis. It is the long-term goal to provide a virtual adaption of all real hardware labs. Using this approach, the first steps in a new lab can be undertaken in the virtual version and then,

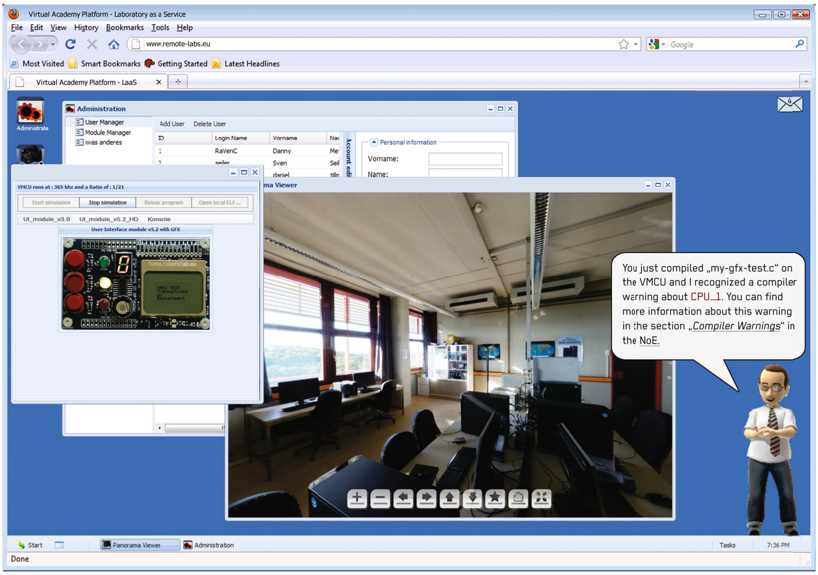

Fig. 5. Distance Lab 2.0 concept

as soon as the course instructor is satisfied with the student's learning outcome, change to using real hardware.

5 HomeLab Kits

The Robotic HomeLab kit (see fig. 6) was developed by the consortium with the participation of both authors. It is a mobile, ready to use small test stand packed into a case. It can be connected to a PC and operated in computer class, at home or in the workplace. The purpose of the kit is to provide practical and effective hands-on training. Students may combine various solutions with different levels of complexity and functionality, based on the modules belonging to the kit. The main feature of HomeLab kit is its mobility - the case is a small and compact box and all modules with the necessary tools are housed in that. Taking the current development status into account, the HomeLab kit offers, for example, hardware and exercises for 7-segment LED display, LCD (alphanumeric as well as a graphical one), sensors (potentiometer, infrared, ultrasonic, etc.), different motors (DC, servo, stepper), as well as a networking module (for Bluetooth, Ethernet and ZigBee), a CAN module and USB for direct connection to a PC (for example a student home computer). Simple and easy to install software is used to connect the main controller to the computer. This is particularly important because the student can start practical experiments in school and then continue with self-learning at home or even in the workplace.

The HomeLab kit is supplemented by a specific software library, enabling easy access to the modules and their functionality which is available as open source for all users. More experienced users may abandon using it but for beginners using the library makes it a lot easier to start with micro controller programming. This library is extended by implementing new modules or labs, so it can be used even for devices not consisting of HomeLab kit hardware, so long as they are micro controller based.

Fig. 6. HomeLab kits

In detail the following kits are available:

5.1 HomeLab Basic Kit

This basic kit features an *AVR ATmega2561 Development Board*, including Ethernet, SD card reader and integrated JTAG programmer. In addition the *User Interface Board*, composed of buttons, LEDs, Graphical LCD, 7-segment indicator is integrated to this kit.

In addition to the Controller and User Interface module, the kit consists of a multimeter for the basic measurements, a power supply and a USB cable. All needed software for Windows and Linux operating systems are included together with practical examples and different types of guides. The latest addition to the kit is a live Linux USB stick which has a preconfigured IDE and can be used in any computer able to boot from USB without affecting the main system. This is especially useful in cases where the kit is used in public computers, e.g. in a library. With the HomeLab Basic kit many exercises can be performed and this kit is usually enough for the introductory courses. For more advanced courses, such as Robotics or Embedded systems, the HomeLab Add-On kit may be necessary.

5.2 Sensor and Motor Add-On Kit

This add-on kit consists of a *Sensor module*, *Motor Module* and a *Communication Module*. The Robotic HomeLab Add-On kit provides the most common functionalities in robotics, which are sensing, actuating and communicating. Different types of this functionality can be studied and tested with the Add-On kit. The Add-On kit requires the HomeLab Basic kit as the main micro controller is included in the Basic kit but not in the Add-On kit. Also, the User Interface module is often needed when working with sensors, motors and communications. Together with the Basic kit this is a perfect set of hardware tools for many different practical courses, like Mechatronics, Embedded systems, Robotics, Practical Programming, Automation, among others.

The Sensor Module is equipped with an analogous sensor and low-pass filter combined board with on-board sensors (temperature sensor, light intensity sensor, potentiometer and mic), an ultrasonic distance sensor and an infrared distance sensor.

The Motor Module features DC motor (with gear and encoder), RC servo motor, Stepper motor (bipolar or unipolar stepper) and with an *motor driver board.*

The Communication Module module is based on a communication board, with 2xRS232 and a ZigBee or Bluetooth wireless unit.

5.3 HomeLab Additional Modules

Additional modules are not packed into the cases but can be directly connected with HomeLab Communication module. Practical examples and exercises are provided for these modules. For instance, the following add-on modules are available.

RFID Module, offering a high frequency RFID reader with several different RFID tags.

Machine Vision Module, a camera which can be used with CMUcam3[15], the Open Source Programmable Embedded Color Vision Platform.

6 Virtual Labs

6.1 Virtual Microcontroller System

The Virtual Microcontroller System (VMCU)[16] is the newest innovative result embedded into the blended learning concept. It is based on Avrora [17,18] with an Ext GWT [19] based GUI. It is a fully functional, but virtual, microcontroller running in any modern web browser[2], with JavaScript enabled, supporting the latest Java version (at least build 1.6.0.x). It can be used for educational purposes, as well as for prototyping. The system is illustrated in fig. 7 in the lower left corner, showing a virtualised LCD display and the Studyboard developed during the Interstudy project. The picture also shows the real hardware the VMCU is based upon, in the upper left corner.

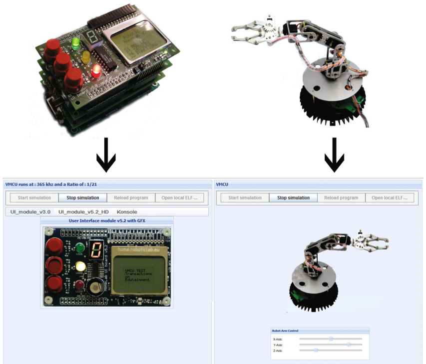

Fig. 7. Virtual Microcontroller System and Virtual Robot Arm Lab

The VMCU is a valuable and useful extension of the concept. Its main use is the education of beginners in micro controller programming but in fact it is possible to use it for any task that could be undertaken with the HomeLab kit basic modules. Compared to real hardware, it is easy to set up new instances of the VMCU without any extra costs (except server capacity). Many students may use the virtual solution, without any need to buy more expensive hardware for all workstations.

[2] Consortium tested so far: Chrome starting with version 11; FireFox starting with version 3; Internet Explorer starting with version 8.

Currently, the following add-on modules are available for the VMCU unit:

– User Interface Module version 3.0
– User Interface Module version 5.2 with a Graphical display
– User Interface Module version 5.2 with an attached LCD display.
– 7-Segment-Display Module
– GFX Display Module
– LCD Display Module

All User Interface modules feature a 7-segment-display, three buttons and three different-coloured LEDs, which enables working with the system for several weeks at tertiary level, or for half an year on lower educational levels[21,20]. The VMCU is embedded in a website, developed by utilising Ext JS 4[22] to build a fully dynamic Ajax-enabled web platform, as illustrated in fig. 8. The platform features an integrated development environment (IDE) a user can use for directly programming online. This JavaScript editor offers all necessary functionality (1), like *Select Files* (for loading files), *Save File* or *Save & Compile* what is needed for programming embedded devices, such as the VMCU. There was also a console feedback implemented (3), to give the user feedback when any errors occurred in the compiling process. Such errors are even highlighted in the editor, as is expected by users of an offline IDE. Each user has his/her own directory to store source code in (4). These are stored in the section *User Files*. To enhance working with the virtual controller, the course-supervisor can upload additional files, which will show up in the section *Example Files*. These files can only be loaded into the editor and saved to a new name, but not overwritten. So a supervisor may add hints or exercise solutions for the students.

The system also allows binary files to be loaded into the virtual controller (5), so any additional development environment may be used for development. As the Virtual Micro Controller Unit behaves like real hardware, it makes no difference.

Another goal we track was to make the internal behaviour of the micro controller or embedded system more transparent to the user. Therefore, we included a console output of the internal performance of the controller so it is easy to see which pins are connected and how they are addressed. Currently, new modules and extensions are being developed for the VMCU. In a version which will be complete in the near future there will be a *Physics Engine* implemented for the whole system, available for Virtual Lab users. This engine can be connected to virtual sensors, which are themselves interfaced to the VMCU. Currently, a PTC and a NTC sensor for temperature measuring are in test status. The data these sensors are reading are passed forward from the Physics Engine, which can simulate natural environmental values, like air pressure, humidity and light intensity amongst others. These data may be set up as values over time, or following a function over time. The general idea is to build a robotic 3D simulation environment based on the Virtual HomeLab kit hardware (for instance a moving robot) but with simulated environmental physical values in addition.

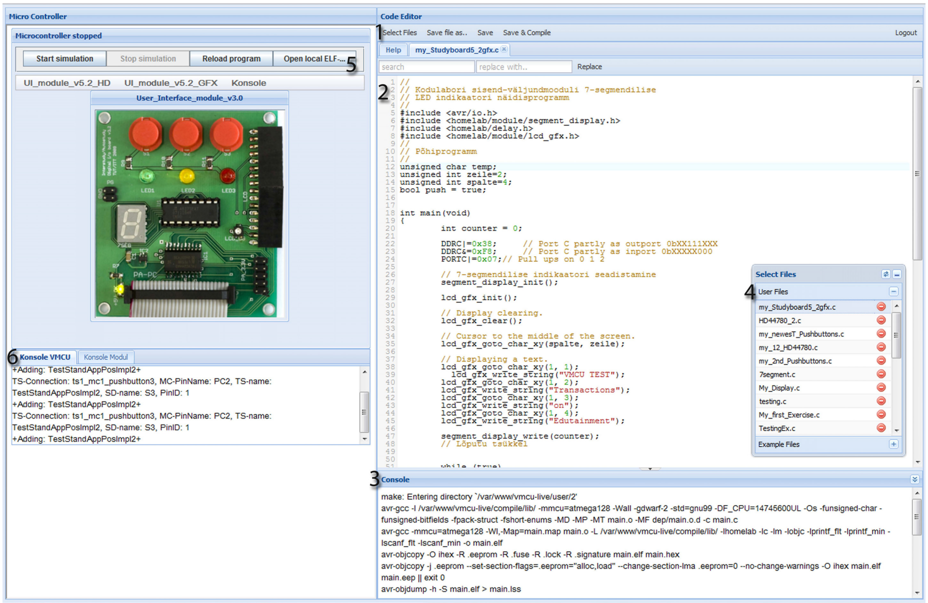

Fig. 8. Overview of VMCU environment

6.2 Virtual Robot Arm Lab

In addition, as illustrated on the right side of fig. 7 two Robot Arm Labs are currently in development. While the hardware robot arm (upper right corner) is already available online, the virtual version is currently being tested in-house before it is made publicly accessible in the DistanceLab. This lab also makes use of the VMCU technology approach. With this robot arm lab, students can train in real-life situations like *picking and deposit of pieces* or *swiveling*. It is not a substitute for working with professional robot devices and it is not intended to be. From the consortium's point of view, it is the right choice to introduce machine control to learners. When the virtual robot arm version is fully functional, the next step is to simulate the behaviour of real industry robot arms, followed by more complex devices.

7 Supporting Material

There are different kinds of supporting material currently in existence:

1. Network of Excellence (NoE) [23]
2. Hands-on-lab exercise book [24]
3. Learning situations for vocational education [20]
4. Textbook "Microcontroller & Mobile Robotics" [25]
5. Textbook "Integrated Systems & Design" [26], as a result of project Interstudy, covering current issues in Mechatronics. This book will not be described further in this paper.

7.1 Network of Excellence

The *Network of Excellence* consists of a forum for discussions and an encompassing wiki page. These collaborative tools have to be seen as the main educational material. The wiki page is a supportive environment for students and teachers using the Robotic HomeLab kit. Participating partners offer learning materials and a full set of methodologies for the teaching and self-education of AVR microcontroller technology (which the HomeLab kit consists of). Additionally, information about the ARM-CAN HomeLab kit or AVR-CAN kit can also be found there.

The page offers a versatile set of practical examples about e.g. digital input/output, indicators and displays, sensors and motor control. Additionally, the website has a special section for teachers which includes teacher training material and, most importantly, the exercise solutions and answers to revision questions. In the Robotic HomeLab Community the consortium intends to make all learning material and also the teaching methodologies directly accessible for interested learners and teachers, as well as ready-made examples about teaching courses for vocational schools to apply the developed solutions directly in school, which is the main strength of our approach. The overall page is designed as a multi-language website, with current translations to English, Estonian, German, French and Lithuanian, with English as the base language for all further translations. The next intended languages are Turkish and Russian. The strength of this website is the number of supporting teaching aids provided by teachers and developers in different European countries and, therefore, the influence of various cultures, level of knowledge or styles of teaching which leads to a (nearly) complete set of material.

7.2 Other Material

Learning Situations. During project MoRobE [5] a full didactic concept of the learning situation with full methodology was developed. This learning situation makes use of the HomeLabs as well as VMCU and integrates them in a real-world scenario of an injection moulding facility, where the HomeLab kit controller board with interfaces add-ons monitors the system behaviour.

"Microcontroller & Mobile Robotics". Based on content of the NoE a new textbook ("Microcontroller & Mobile Robotics" [25]) was provided to support students and self-learners in keeping their motivation to learn. The textbook is built with references to those fundamentals necessary to understand the topic discussed in a specific chapter. So a student may directly start with the chapter on writing to the LCD display, looking up necessary background information from other parts of the book. Currently, this textbook is available in Estonian and English. A German version will be published soon.

8 Robotic Applications

The whole concept designed as illustrated in fig. 3 intends to use the same hardware for even more complex programming tasks, like a moving robot. Building on the HomeLab kit hardware, the consortium developed robots using only modules which belong to other material we provide. Thus, students can train on the VMCU, after using specific modules from the HomeLab kit leading to complex programming, by including several modules attached to the micro controller. A prototype concept of the robots used in our concept is shown in fig. 9.

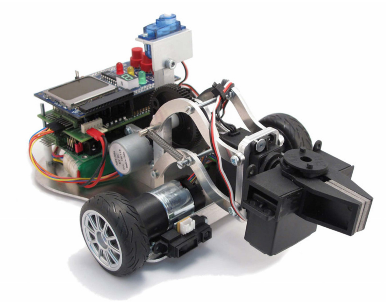

Fig. 9. Robotic Application

9 Conclusion

The paper has introduced all parts of the blended learning concept and gave a comprehensive overview about the project results of the latest European projects carried out by the research project consortium. Currently, project MoRobE has ended and we are starting a new project in a similar field working on enhancing the education of embedded systems. For further research, the consortium is currently planning to research and develop an open, standardised interface to easily plug-and-play remote laboratories into the educational process. This purpose should be realised by formulating a new architecture called "Laboratory as a Service" (LaaS), which will establish a generic method to integrate existing experiments and laboratories using a semantic description of devices and/or labs. This method also includes the research of user interfaces for the specific pedagogical contexts of our target groups, mediating the complexities of creation and usability of distance experiments. The concept includes developing virtual labs so students may gain knowledge of interactive experiments (virtual ones) before heading over to the real hardware. Of course this will be only carried out for a limited subset of labs.

The labs should be capable of being used on any target platform or medium (like mobile devices) supporting the new open standard. In addition to this research it is planned to interface widely-used e-learning platforms, like Moodle or Blackboard. On one hand it is intended to create the above-mentioned open standard which enables the integration of labs into any kind of "product" (e.g. mobile devices, any kind of software and websites); on the other hand there is also a need for one common platform which integrates all developed products. Thus, the generic platform for this project will be a wide-scale web platform, behaving like an ordinary Desktop system, but running in any modern web browser. This approach is similar to the one illustrated in fig. 5 but more advanced. This platform has to be seen as the over-spanning tool to access labs and also other included learning tools. In addition the platform is intended to be used for Europe-wide lab sharing between partner institutions offering, for example, a comprehensive booking system and user management for large-scale networks.

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Cooperative and Self-directed Learning with the Learning Scenario VideoLearn

Engineering Education Using Lecture Recordings

Marc Krüger and Gabi Diercks-O´Brien

eLearning Service Abteilung (elsa), Leibniz Universität Hannover, Hanover, Germany
{krueger,diercks-obrien}@elsa.uni-hannover.de

Abstract. Self-directed and cooperative learning through lectures? Is this not a contradiction, as lectures *per se* are instructional in nature? In this paper we will present the learning scenario VideoLearn and provide a differentiated response to this question. It will be demonstrated that it is possible to unite these two seemingly contrary concepts. We will give specific design recommendations to practitioners planning to use VideoLearn, as well as share with them our practical experience in employing this learning scenario at the Institute of Communications Technology at the Leibniz Universität Hannover.

Keywords: lecture recording, design-based research, self-directed learning, cooperative learning, VideoLearn, learning scenario, educasting.

1 Introduction

Lectures are a common teaching format in engineering education. The learning contents transmitted during a lecture constitute essential knowledge for future engineers. Without the declarative knowledge delivered in this particular format, engineers would not acquire the mathematical, scientific and subject knowledge required for the construction of cars, computers, airplanes, houses, mobile phones, robots and much other technical advancement. Sometimes up to 70% of all teaching in Engineering courses is therefore delivered in the format of lectures.

From a curricular point of view, however, the lecture is not without problems. Increasingly, the guidelines for Bachelor and Master degree programs stipulate learning objectives which in the past have rarely been documented. For instance, graduates should be able to "develop and maintain cooperative networks and working relationships with supervisors, colleagues and peers, within the institution and the wider research community"[1] or "demonstrate a willingness and ability to learn and acquire knowledge."[1] Learning goals like these are difficult to achieve by means of traditional lectures.

But how does one deliver teaching mindful of these guidelines in the Engineering Sciences, where a large body of declarative knowledge needs to be transmitted? How can self-directed learning and team-working skills be transmitted? And while we are on the topic of lectures, how can students be encouraged to discuss learning contents

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amongst themselves and with their lecturers in order to achieve more impactful learning?

These were the questions we asked ourselves at the Institute of Communications Technology at the Faculty of Electrical Engineering and Computer Science at Leibniz Universität Hannover before we had developed the learning scenario VideoLearn. The development was undertaken on the scientific basis of the Designed-Based Research (DBR) approach [2]. Our explorations provide evidence that VideoLearn can indeed answer the questions posed above.

How does VideoLearn work? In order to facilitate as much self-directed and cooperative learning as possible, students were put into groups of two or three. Instead of participating passively in a traditional lecture, they watched the lecture recording independently in their small groups and undertook exercises available to them in conjunction with the lecture recording. To assist the students in completing the exercises, they were also given subject-related literature, as well as access to the Internet. Also, the lecturer was on hand to help with difficult questions. This is precisely the benefit that VideoLearn is able to offer: Lecturers are freed from the task of presenting information to the students; they can use the contact time available to them to provide direct on-demand support to the students in their learning process at all times.

We will demonstrate in this paper that the learning scenario VideoLearn was developed on the basis of the DBR-approach. Referring to our results, we will describe in some detail how to go about constructing the learning scenario, so that other practitioners in the field can adopt our approach. VideoLearn will be described according to IMS Learning Designs. Thus, it is possible to give an insight into the individual learning phases and learning activities involved in this particular learning scenario, in order to comprehend the learning process that is taking place. Next, we will describe our experience with VideoLearn at the Institute of Communications Technology at the Faculty of Electrical Engineering and Computer Science and conclude with specific practical advice for lecturers based on our own findings. As a result, lecturers should be able to implement the learning scenario VideoLearn in their teaching.

2 Research Method

How was the learning scenario VideoLearn first developed? The reason for using the DBR approach as the basis for VideoLearn is that it enables us to develop a so-called “design framework” for the learning scenario [2] based on basic research as well as empirical field research. This provides fellow practitioners with recommendations for the design of the learning scenario and supports them directly in their teaching.

Thus, the DBR approach provides a solution to the theory-practice gap, which is much debated in pedagogical research [3]. Many findings from basic research are not being applied in practice due to the fact that experimental laboratory research normally is not tested in field research. Furthermore, there is no general interpretation of the research findings, all of which results in a lack of application in real-life teaching practice.

The supporters of the DBR approach therefore regard the results of basic research in a complex interchange with practical teaching. The starting point for the design of a learning scenario needs to be based in scientific research, which then has to be examined in practice. The DBR approach remains open to the different methodological approaches chosen for the research field in question. It is, however, an essential requirement that formative evaluation be carried out. This means that the design of the learning scenario should undergo an iterative process which takes place in the context of a design experiment. The design experiment is therefore the basic foundation of the DBR approach. Design cycles, evaluation and re-design lead to a critical examination of the learning design and to the identification of shortcomings in the design. Modification is then carried out to improve the design. With each iteration, the four steps of design, implementation, analysis and interpretation need to be gone through. The individual steps – or phases – can be described as follows [4, 5]:

- *Design phase:* The design of the learning scenario needs to be based on scientific evidence and theory. This is understood as didactical design. If the design cannot be based entirely on scientific evidence and theory, pre-scientific experience and the intuition of developers can be integrated into the design.
- *Implementation phase:* The implementation phase trials the didactical design in a real practice context. At this stage, it is important to systematically record the learning and teaching activities, including the interactions between learners, teachers and learning resources.
- *Analysis phase:* Data gathered in the implementation phase need to be analysed. The processes taking place during the learning and teaching activities need to be reconstructed and interpreted. The didactical design that was developed during the design phase will be re-evaluated. Lessons learnt can be included in a modified didactical design.
- *Interpretation phase:* Compared to the previous phase, in which the learning scenario is examined in a specific didactical context, the aim of the interpretation phase is generalise the results. In other words, the didactical design is reworked in order to be useful and applicable to other didactical contexts.

3 Studies

The development of the learning scenario VideoLearn was closely linked to several comprehensive studies. First of all, the learning scenario was theoretically researched and relevant findings from the research corpus available on learning and teaching were integrated into the didactical design for the learning scenario. We conducted four trials comprising a total of six teaching units in which we tested the didactical design in order to reveal any shortcomings. We carried out observations *in situ* during these trials and collected feedback from the students and the lecturer via open interview questions. There were two key questions:

1) Key question: Is it feasible to conduct the learning scenario VideoLearn on the basis of the didactical design employed?
2) Key question: What changes are required to improve the didactical design?

Analysis of the answers to the first key question was that VideoLearn is indeed a feasible learning scenario; but according to the second key question, it needed to be improved in two areas, as far as the didactical design is concerned. One of the suggested improvements was to provide more opportunities for cooperative learning: In our main studies we modified the exercises that we provided to the students and changed them in such a way that they attempted more clearly to foster cooperation among the students. The other suggestion for improvement was to provide headsets (see section D for further detail).

In total, during our main study, we introduced VideoLearn into twenty different learning units and three different teaching sessions. Our evaluation was based on the following data:

- The learning activity was recorded on a video camera.
- Experts marked the exercises which had been completed by the students.
- The student´s strategies for working, learning and controlling (independent learning competencies) were recorded.
- The students' motivational state in the context of the learning scenario was recorded.
- The amount of time needed for the students to complete the learning activity was recorded.
- Student and lecturer feedback was collected via open feedback session.

Processing the data recorded on video proved to be particularly time-consuming. An entire year of an assistant's time (0.5fte) was needed to code 75 hours of video recording. Both qualitative and quantitative processing of the data was carried out, and the results were triangulated. Finally, the results were incorporated into a design framework.

4 Design Framework

The design framework provides a detailed exploration of the learning scenario VideoLearn by discussing the results and value-added benefits, and also provides practical recommendations to lecturers. These recommendations will help lecturers to integrate the learning scenario into their teaching.

4.1 IMS Learning Design

Table 1. shows the didactical design of the learning scenario VideoLearn in the context of IMS Learning Designs [6]. Thus, we can provide an explicit semantic description of the didactical concept from multiple perspectives.

Table 1. VideoLearn according to IMS Learning Design

Item	**Description**
<learning objectives>	There are two main objectives for VideoLearn. On the one hand, the aim is to transmit declarative knowledge, and on the other, it is to provide opportunities for self-directed and cooperative learning.
<environment>	The lecture recording as a self-instructional learning tool is at the heart of the learning scenario. Functions, such as, a) to pause the lecture recording, b) to move backwards and forwards, c) to use additional learning resources, d) to be able to ask the lecturer for clarification, as well as, e) discussion within the group, all provide the students with a certain level of freedom within their learning.
<learning objects>	• Lecture recording: The lecture recording transmits declarative knowledge via lecture. • (Lecture) script: Learning contents that had been presented in the lecture recording is available as a printed copy of the (lecture) script so that students can take notes but also have a document that can be used to look up information. • Internet: Access to the Internet provides the opportunity to find further sources of subject knowledge. • Subject-specific literature: A selection of subject-specific literature enables the students to look up information.
<method>	Exercises are used to support students in their learning. The exercises provide a structured approach with the aim of achieving targeted and thorough engagement with the learning contents. The exercises assist the students in self-directed engagement with the learning contents. Moreover, they provide information as to which learning contents are important in order to achieve a basic understanding of the topics in question.
<roles> *<support activity>*	The students work in groups of two or three in order to make use of the positive effects of cooperative learning. The teacher is permanently available as a learning facilitator. The students decide when to involve him/her in their learning process or, alternatively, he/she reacts to obvious problems that the students have in their understanding and learning.
<act>	VideoLearn is a face-to-face teaching session, i.e. there are no virtual learning phases. The students meet at set times in a set location. A high level of personal interaction between lecturer and students and among students is achieved due to their presence in the same place at the same time.

4.2 Learning Phases and Learning Activities

Our studies showed that VideoLearn is separated into two phases between which the students switch constantly. These two phases are: learning phase I) Playback of lecture recording; and learning phase II) Exercises are worked on. Learning phase I) is the dominant phase of the two. Learning phase II) takes a proportionally smaller part of the duration of the teaching unit. A Didactic Process Map (DPM) [7] is used in figure 1 to describe the two learning phases, as well as the student and lecturer activities linked to these phases. These are discussed in more detail below:

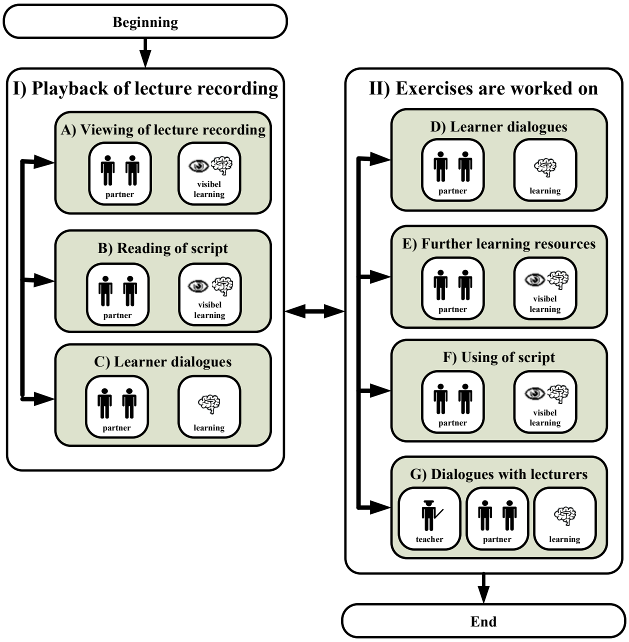

Fig. 1. VideoLearn according to Didactic Process Map (DPM)

The students begin the learning scenario VideoLearn with learning phase I) Viewing of lecture recording. They watch the recording (A); read the script alongside the recording and/or take notes (B); and discuss the contents of the video recording (C). During this learning phase the following activities dominate: viewing of the lecture recording (A); and reading of the script and/or note-taking (B). Dialogues among the learners (C) are rare during this phase.

At the point when the attention is turned towards answering specific questions posed in the context of the exercises, the students interrupt the lecture recording and enter learning phase II): Exercises are worked on. In this learning phase, they discuss the learning contents (D); use further learning resources to aid their completion of the exercises (E); use the script to check on certain information details (F); and ask the lecturer for assistance (G). Once they have completed an exercise, there are several options available to them:

- First, they re-enter learning phase I) and view the remaining minutes of the lecture recording. If this section of the recording contains further information that will help them complete further exercises, they enter learning phase II). VideoLearn oscillates between the two learning phases (about three to five times per teaching unit);
- Second, they work on further exercises or;
- Third, they complete the teaching unit. This is the case when the complete lecture recording has been viewed and all exercises have been completed.

4.3 Experiences with VideoLearn at the Institute of Communications Technology

VideoLearn was employed by Prof. Dr.-Ing. Klaus Jobmann at the Faculty for Electronics and Computer Science at the Leibniz Universität Hannover. He holds a chair at the Institute of Communications Technology, which focuses on communications networks both in research and teaching.

The students enrolled were predominantly students of the Diploma and Master courses in Electrical Engineering and are fairly advanced in their studies. In total, there were ten groups of two or three students involved in the VideoLearn learning scenario. The following observations were made by the scientific team supporting the learning scenario VideoLearn:

Fig. 2. Students participating in VideoLearn

Comparing VideoLearn to the traditional lecture format no changes in learner achievement could be discerned. The students engaged in the learning scenario VideoLearn produced the same subject-related results in their assessments as those before them who had not used VideoLearn. The main difference, however, was that students learned in a self-directed and cooperative manner in the context of

VideoLearn (about a quarter of the teaching session). As expected, the viewing of the lecture recordings took a high percentage of a teaching session (about three quarters). The average duration of a teaching session of 112 minutes indicates that the students require less time when viewing the lecture recording and completing the exercises as compared to the traditional lecture and practical session format previously employed at the Institute of Communications Technology (90-minute lecture + 15-minute break + 45-minute practical session with exercises = 150 minutes).

Most students answered the questions satisfactorily. While one half of the groups answered the exercises after they had finished the lecture recording, the other half answered them during the viewing. To this end, the latter students used the other learning resources available to them. For instance, they used the lecture recording script available as a print-out in order to look up certain passages but also to make notes. The students also made ample use of the Internet, read the available topic-related subject literature, and also used their own learning resources. The lattermost included lecture scripts from lectures on related topics, as well as their own subject literature.

It became apparent that the students made full use of the opportunities for cooperation during the learning scenario. The majority of dialogues were linked to the contents and were conducted with the aim of completing the exercises (on average twelve minutes per group). In addition, the students took the opportunity to discuss the contents with the lecturer (on average four minutes per group).

In summary, the experience of VideoLearn at the Institute of Communications Technology was very positive.

4.4 Instructional Design Recommendations and General Conditions for Future Application

Based on the findings from our investigations, we would like to make certain instructional design recommendations for those wishing to integrate VideoLearn into their own teaching. There are also a number of general conditions that lecturers need to be aware of and prepared for in order to guarantee a successful learning scenario with VideoLearn. With regard to the instructional design, the following recommendations should be noted:

- *Higher order questions:* Our observations showed that providing the right type of exercise had a considerable impact on the nature of student engagement and student activities during the learning scenario, as well as on the dialogues among students. Providing exercises that simply require the checking of factual knowledge led to superficial copying of the information from the various sources available to the students, rather than their discussing the learning contents in more depth. Only when higher order questions [8] were introduced, did students engage in a far more intense manner with the learning contents. The higher order question type demands a deeper engagement with subject knowledge, “which leads to considerably higher learning success in students” [9]. Following the concept of higher order questions, we developed two types of questions specific to the Engineering discipline: The "In-Depth" question type demanded that the students work in a self-directed manner with the lecture recording in order to comprehend the new topic introduced to them. For instance, they were left to their own devices to research the details of a communications technology protocol and present the findings. The "Engineer" question type entailed that the students had to apply the learning contents to a practical problem found in typical real-life engineering work contexts. As it is entirely possible to have different solutions to the problems described, this question type led to intense discussions among the students as to the various possibilities. This in turn led to a much deeper engagement with the learning contents. Based on our experience, we would therefore recommend that a pool of question types be developed, from which questions can be selected flexibly to serve different learning contents and learning goals.

- *Headsets are essential:* Flexible partition walls that had been set up to reduce noise levels did not manage to reduce the noise. Noise levels constantly increased (group 1 increased the volume on the lecture recording setting; group 2 responded by doing likewise; and then group 1 increased the level even further; and so on). Subsequently, the students disturbed each other. We therefore strongly recommend that headsets with which the students can listen to the lecture recordings be used. In our early trials, students seemed to be acoustically separated from one other, and this had a negative impact on their willingness to engage in dialogues. We therefore introduced headsets with microphones. Student commentaries are thus looped back to the headsets of the other students. We thus managed to find a solution to prevent acoustic separation among students working in the same group.

Certain general conditions need to be considered for the learning scenario VideoLearn:

- If a student cohort contains more than 15 groups, a second learning facilitator needs to be available to assist the lecturer. This means that in the case of larger teaching contexts there will be a higher staff-student ratio. VideoLearn is thus more suitable for medium-sized or small-group cohorts.
- Due to the need to record the lecture, there will be a one-off increase in workload for the lecturer compared to the traditional format of lecture followed by practical class. If the recording occurs in a lecture that is taking place with students present, then the additional workload is limited to the technical requirement to undertake the recording. Ideally, the recording should be undertaken by a service department responsible for lecture recordings in a higher education institution (e.g. computing services department or media department).
- The required technical infrastructure has to be available: this includes equipment for the production of the lecture recording; computers with which the students can watch the recordings; and a room for the viewing appropriate for up to 15 small groups with the lecturer walking around acting as facilitator.

4.5 Benefits

VideoLearn makes it possible to teach groups homogenously thus leading to similar knowledge levels among the students. The lecture recording allows lecturers to select how they present the learning contents. These contents can then be distributed in the same way to all students. Declarative knowledge is particularly suitable for transmission via VideoLearn.

It can therefore be concluded that the lecture recording in conjunction with other learning resources can facilitate self-directed learning. This is due to the fact that learning contents are made available to the student to be used as and when required, instead of being presented solely by the lecturer in a linear format and as a one-off activity which forces the student into the role of passive listener and note-taker. Students are provided with the means to access the various knowledge sources available to them independently. The lecturer no longer needs to act out the role of knowledge transmitter but can serve as coach to the students. Thus, a more intensive level of support can be provided than is the case in the traditional format of lectures and practical sessions.

Introducing an instructional aspect within the lecture recording context can help reduce the burden of having to work completely independently, which can be problematic for those students who are not ready for such a level of independence. The lecture recording facilitates the learning process for the students so that they can concentrate on listening to the contents rather than on coordinating their own, or the shared learning process. Open learning scenarios which provide a maximum level of self-direction can thus be enhanced by lecture recordings in conjunction with a certain level of structured guidance. In particular, learners who lack experience of self-directed learning can in this way be gradually prepared for increasingly more independent learning formats.

Discussing and cooperating in groups requires the skill to elaborate on, and defend, one’s own viewpoint, which can help to achieve a deeper understanding. Compared to the traditional lecture, the opportunities for active engagement can be increased and thus active learning time augmented in order to avoid a lack of variety in instructional learning formats. A further advantage of cooperative learning with VideoLearn is that the students’ responsibility for their own learning is increased and the dependence on external providers as unique knowledge sources is decreased. The students are therefore forced to act more independently and to rely less on their lecturers. In a time of permanent demands for more cooperation and team competence, VideoLearn provides opportunities to promote social interaction and interpersonal skills.

Finally, we would like to draw attention to the impact that VideoLearn can have on learner motivation: VideoLearn enables the student to have a learning experience which is free from sanctions. If, for instance, part of the lecture needs to be repeated, this can be done without the lecturer noticing it. Furthermore, students’ ability to judge their own achievements can be improved: cooperative learning can increase students’ sense of self, due to the fact that within the group working process the importance of one’s own actions is noticed.

5 VideoLern Requires Technical Equipment

In order to be able to use VideoLearn in teaching, it is necessary to provide appropriate equipment. This equipment needs to allow for the recording of the lectures on the one hand and, on the other, enable the students (working in small groups) to view the lecture recordings on the computer. We will present the required equipment separately:

- Lecture recording equipment: The minimum requirement is a video camera, combined with a tripod and a wireless microphone. Once recorded, the videos need to be uploaded to a (streaming) server, burnt on CD/DVD or copied to the student computers. In many cases, it may also be necessary to record the slides which are presented during the lecture, as well as handwritten notes on the board. There are different technical solutions available for this. The international project Opencast Matterhorn gives a good overview of options, see http://www.opencastproject.org/ for further details. The website also includes open source software for lecture recordings.
- Student computers: Each student group needs a multimedia computer with Internet access. In order to be able to listen to the lecture recording without disturbing the other student groups, it is necessary to provide a headset for each student. A splitter needs to be installed to ensure that the headsets of students working in the same group are connected to the same loudspeaker output. It has been shown that it is useful if the students can communicate with each other via headsets. This requires that the students' comments which are spoken into the headset's microphone need to be fed back into the sound stream of the lecture recording. Consequently, another splitter is needed to connect the microphones to each other. This will then have to be connected to the computer's microphone input. The soundcards of most currently available operating systems can be configured in such a way that both audio signals (lecture recording audio and recording of the student speech) can be mixed together and sent back to the headset earphones. Finally, as the number of students owning a notebook increases, it may soon not be necessary any more to provide computers. In this case, only the headsets with the described switches are required. VideoLearn could thus be used in many lecture and seminar rooms.

6 Similar Approaches

Similar approaches to VideoLearn can be found in [10] and [11]. These two examples show that lecture recordings have the potential for new teaching approaches. The primary goal of the learning scenario eTEACH [10] is not to assist the students in moving towards an increasingly independent learning process but to take advantage of the benefits offered by the medium of lecture recordings so that students can access the lectures at home. eTEACH is therefore comparable to VideoLearn to some extent only.

[11] alone is similar to VideoLearn in that it functions as a self-directed and cooperative face-to-face learning activity. The publication by Demetriadis and Pombortsis describes the following learning scenario: The students view the lecture recordings in pairs in a computer room but without the presence of a lecturer *in situ* and opportunities for *ad hoc* interaction with the lecturer. Once they have finished their viewing of the lecture recording, students go into a seminar room and have the opportunity to discuss the learning contents with the lecturer.

VideoLearn can provide a direct solution to a problem that has been noted in the study by Demetriadis and Pombortsis, namely that there are few dialogical exchanges between the learners and the lecturer. The authors hypothesize that the students would prefer to ask their questions whilst watching the lecture recording, which is not possible in the learning scenario as described by them. Instead, students have to wait until they have seen the complete lecture recording before they can have a discussion with the lecturer about specific issues. In the context of the VideoLearn scenario, questions can be asked just-in-time and feedback provided immediately by the lecturer.

7 Future Works

So far, VideoLearn has only been employed in a small number of teaching contexts and this study is limited to the context of the Institute of Communications Technology. This begs the questions whether VideoLearn can be successfully transferred to other teaching contexts. Furthermore, there is at present no information available as to whether VideoLearn can lead to enhanced learning outcomes. While the results show that VideoLearn leads to the same achievements in the assessment tasks, there is evidence also that students require less time to learn the same learning contents. It is also not clear whether the self-directed and cooperative learning approach really has a sustainable effect on related student competences. Further research on this would therefore be necessary. As the complex studies require a considerable level of effort, appropriate funding would be required in this area.

With regard to current eLearning trends, there is scope to complement the learning scenario VideoLearn with new media. For instance, the Web 2.0. technology makes it possible for different learners to work collectively on the same document. The answers to learning exercises could be posted onto a WikiWiki-Web and annotated by the lecturer. This begs the question as to whether the quality of the answers to the exercises could be improved. Moreover, students could put questions to the lecturer via audio conference, as the students already wear headsets whilst working on the lecture recording. Could the dialogues with the lecturer thus be intensified? Further funding support in this area would help identify the additional benefits of VideoLearn in the context of new digital media.

8 Conclusion

Summarizing the above, we can conclude that VideoLearn can easily be implemented. The following effects can be observed when using VideoLearn:

- Higher rates of interaction between lecturers and students as well as among students.
- A more intense student engagement with learning contents.
- Self-directed and cooperative learning in a particular context (about a quarter of the duration of the teaching unit).

It can also be said that our decision to develop the learning scenario based on the DBR approach has been successful. In comparison to other learning scenarios, it also shows that basic didactical design mistakes can be avoided through a reflective approach of this kind.

Acknowledgment. In particular, we would like to thank Prof. Dr. phil. Gabi Reinmann for the support provided for this work. Her advice, openness and trust have been of great value. We would also like to thank Prof. Dr.-Ing. Klaus Jobmann, who gave us permission to conduct our studies in his teaching sessions.

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Applying Computer-Aided Intelligent Assessment in the Context of Mathematical Induction

Sandra Rebholz[1] and Marc Zimmermann[2]

[1] University of Education Weingarten, Media Education and Visualization, Weingarten, Germany
rebholz@md-phw.de
[2] University of Education Ludwigsburg, Institute of Mathematics and Computer Science, Ludwigsburg, Germany
zimmermann01@ph-ludwigsburg.de

Abstract. Intelligent Assessment represents a novel approach in the field of Computer-Aided Assessment (CAA). In Intelligent Assessment, the student's performance is not only assessed by the solution but also by the individual steps leading to the solution. The web-based exercise tool *ComIn-M* uses Intelligent Assessment in the context of mathematical induction. In this article we describe the basic principles of Intelligent Assessment and highlight its prototypical implementation using the tool *ComIn-M* as an example. In the evaluation we investigate the practicality of Intelligent Assessment with the tool in two recitation sections at the Universities of Education in Weingarten and Ludwigsburg.

Keywords: Computer-aided Assessment, Intelligent Assessment, Semi-Automatic Feedback, Formative Feedback.

1 Introduction

In many countries lectures in beginning courses at universities have a large number of students, especially in mathematics and computer science. Because of that, the lectures are mostly non-interactive [1, 2]. Already the weekly recitation lessons have too many participants. As a result, the lecturer or graduate student is limited to only presenting the solution [1], and thus students only learn receptively.

Feedback for the students is mostly provided by grades or points on weekly exercises or weekly submitted tasks. Getting individual feedback is nearly impossible for them. Individual, formative feedback is a main key of constructivist learning theory [3]. Learning should be accompanied by formative feedback and assessment that is provided while the learner is working on the problem [4]. Such extensive support for students regularly exceeds the budget and cannot be accomplished by the assigned staff at the universities.

Especially students starting their studies experience similar difficulties with their exercises as previous students have done the years before. The same way teaching assistants have to restate the feedback to the students year after year. We propose that

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the computer should support the assistant in giving feedback to reduce tiring and time-consuming repetition.

In this article we describe how computer programs have to be designed to provide formative feedback. The implementation of such computer-aided feedback and the concept of Intelligent Assessment [5, 6] will be illustrated by the e-learning tool ComIn-M for mathematical proofs by complete induction. The focus is on technical requirements and development. Finally, we evaluate the practicality of Intelligent Assessment with ComIn-M in two recitation sections at the Universities of Education in Weingarten and Ludwigsburg. Our main goal is to investigate how students use the automatic feedback of Intelligent Assessment to correct mistakes on their own.

2 Intelligent Assessment

Formative feedback provided by a human is still the best form of support for learning [7]. A human can react individually to the needs of every learner, e.g. by giving non-verbal feedback like a gesture [8, 9] or he can provide help as less as the learner needs to continue with the exercise. However, giving formative feedback on an individual basis to each student would either lead to an overload of the tutors or would require to increasing the number of staff, which is inacceptable due to financial constraints. To resolve this conflict, the computer can support the tutors in assessing the student work and giving feedback to the student automatically.

A possible method of assessing and giving feedback during the learning process is to offer computer-based exercises. If an exercise is submitted in an electronic way a program can then assess the solution or parts of it [10, 11] and can provide feedback on the assessment results. Existing e-learning tools can already assess many solutions, but, especially in mathematics, there are often non-standard solutions which are still correct. These solutions can probably not be assessed by a computer program and, hence, will be judged as incorrect. In this case the students get incorrect feedback on their solution and learning process.

For that, Bescherer et al. [5, 6] developed the model of Intelligent Assessment. This model combines computer-based assessment with human assessment. First, a computer program automatically assesses an exercise in order to detect standard problems and mistakes as well as standard solutions. These set of standard mistakes and solutions can be defined when the program is written. Based on these standard solutions and mistakes, the computer can then provide feedback to the user, which is also implemented in the program. Unclassified mistakes, non-standard solutions or solutions which cannot be assessed by the program automatically will be forwarded to a human tutor. Then the tutor assesses the solution manually and gives the feedback needed by the student. As a consequence, tutors do not need to concentrate on all possible solutions and can spend more time on providing feedback on unusual solutions or weak students. More individual and more intensive assessment and formative feedback can be given by the tutor.

The feedback provided by computers should emulate human feedback as well as possible [10]. For this reason, Herding et al. [10] developed the framework *Feedback-M*, which considers two main aspects of good tutorial feedback [8, p. 3]: autonomy and approval. The framework also includes the possibility to email a human tutor with the current state of the solution. If the feedback provided by the computer is not clear to the students or they do not know how to continue, they can simply contact their tutor. Aspects of the framework Feedback-M are also implemented in ComIn-M.

3 The Mathematical Training Tool *ComIn-M*

The web-based tool ComIn-M provides students with an electronic exercise sheet for learning mathematical proofs based on the method of complete induction (Fig. 1). At any time, students can check their current solution and request feedback. According to Intelligent Assessment every step of the students' solution is then analyzed and the result of this analysis is returned and presented to the learners. Using this feedback, students are guided gradually to a correct solution.

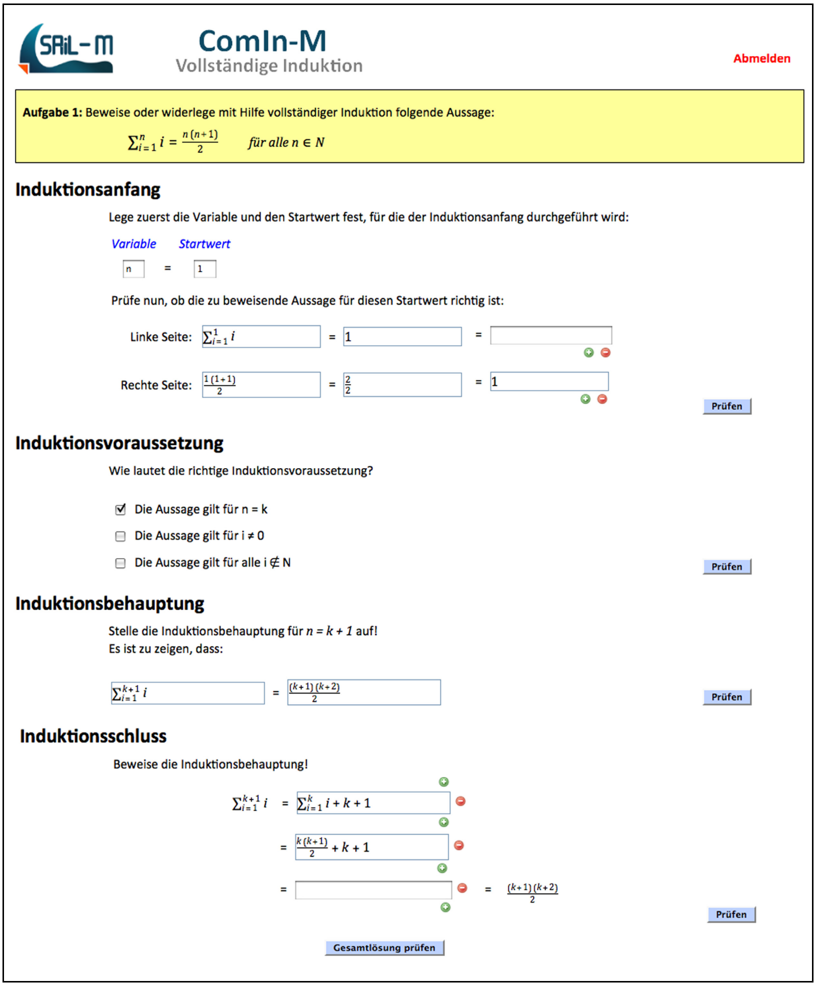

Fig. 1. ComIn-M user interface

3.1 User Interface

ComIn-M is implemented as an HTML page in a standard Internet browser. Using JavaScript, the web page dynamically changes its content depending on user input. As shown in Fig. 1, the user interface of ComIn-M is structured according to the four basic steps of a proof by mathematical induction: base case, assumption, statement, and proof. This interface mimics a pencil-and-paper solution, i.e. the users have the same options as if they were working on paper sheets. An important strategy for proving the equivalence of two terms is to transform both sides simultaneously. Equations can be transformed either “top-down” or “bottom-up” [12], i.e. you can transform the right or left side of the equation. Most mathematical tools only allow transformations of one term, e.g. transform the left side step by step into the right side. Hence, we implemented the possibility to add blank fields on each side of the transformation (see Fig. 1).

While working on a given exercise, students can request automatic feedback on their solution at any time (“Feedback On Demand”, [13]). This feedback is given immediately and describes all problems that were detected in the submitted solution. In addition to a textual description of the error, the input field containing the error is visually highlighted in the user interface. As a result the learner gets a clear indication on where to look for errors.

Fig. 2 shows the feedback area that is directly displayed under the erroneous part of the exercise. If multiple errors were detected within the same part of the proof, the user can navigate between them using the “forward” and “backward” arrows in the navigation bar of the feedback area. Moreover, ComIn-M offers a detailed hint on how to resolve the errors (“Hint on Demand”, [14]). The generation of automatic feedback is based on the mechanisms developed within the framework Feedback-M.

If both problem descriptions and hints are not sufficient to find a solution, the learners have the possibility to contact a tutor directly by email. Using the menu entry “Ask tutor”, they can forward a question along with the current solution to the responsible tutor. Then the tutor assesses the solution manually and can provide answers to all questions.

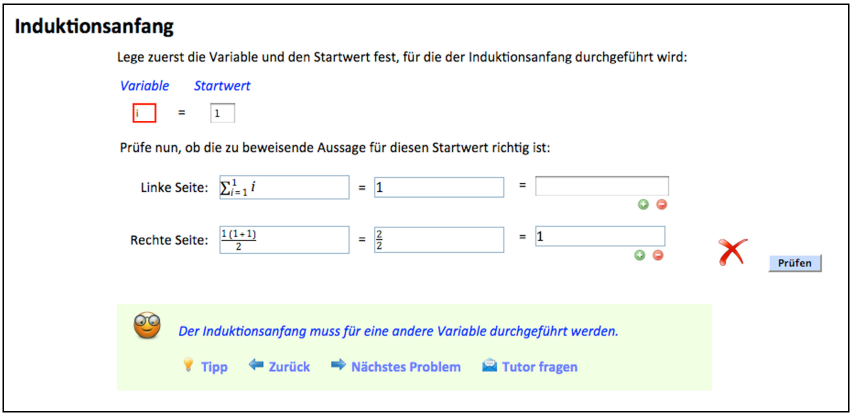

Fig. 2. Feedback presentation with requested hint

Entering mathematical formulae is a general problem in e-learning environments for mathematic. In ComIn-M, we currently expect mathematical formulae to be entered in the syntax of the computer algebra system (CAS) Maxima. As is the case with all CAS languages, the syntax is based purely on keyboard input and requires the user to be familiar with a set of predefined keywords, functions, and the rules for setting brackets and applying mathematical operators. However, ComIn-M uses the CAS syntax only for input. As soon as the focus leaves the input field, the formula is automatically transformed into the Mathematical Markup Language (MathML) and displays in classical notation (see Fig. 2). As a consequence, the solution can easily be read by students as well as a mathematical reader.

3.2 Web Service-Oriented Architecture

ComIn-M offers its services using a web service-oriented architecture based on the Simple Object Access Protocol (SOAP). Fig. 3 shows the ComIn-M architecture and gives an overview of the interaction between its components.

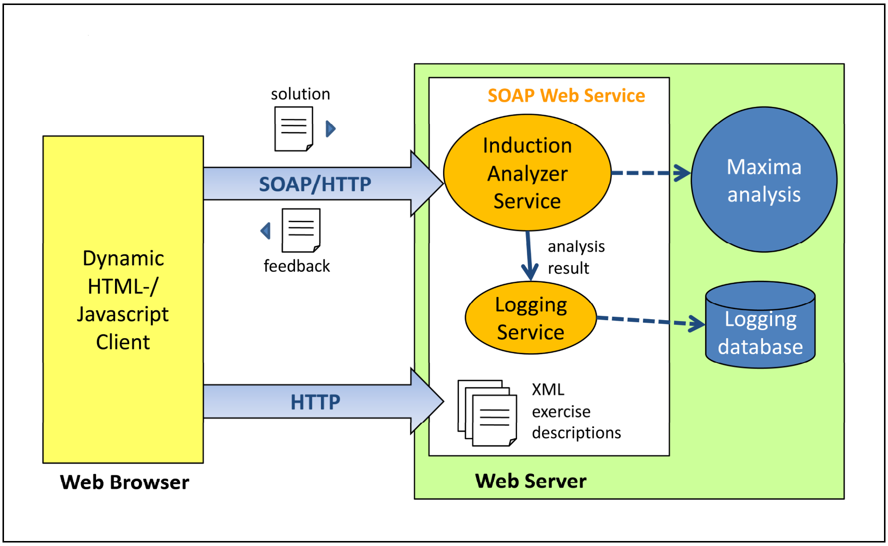

Fig. 3. Webservice-oriented architecture of *ComIn-M*

The Induction Analyzer Service is the core component that is responsible for assessing the students' solutions and for giving automatically generated feedback. All mathematical testing and verification procedures are delegated to the CAS Maxima, which is run as an external process and contacted via socket communication.

Users access the ComIn-M user interface in their web browser and download the selected exercise dynamically from the web server. Whenever the students request feedback on their current solution, all their input is converted into an equivalent XML structure and sent to the server for analysis. In the same way, the resulting feedback is returned in XML format, extracted on the client side and finally displayed as problem descriptions and hints on the ComIn-M web page.

A basic logging service is responsible for storing and retrieving all results from the analysis along with the corresponding solutions in a special database for logging data. Currently, this service is used when issuing and handling manual feedback requests. Using the service, the teachers can track and analyze the learning processes of enquiring students and give their feedback on an individual basis.

3.3 Assessment of Solutions

Based on the principles of Intelligent Assessment, incoming solutions are first checked against well-known standard solutions and standard errors. The categorization of a given solution as being correct or incorrect is not only determined by a limited set of preconceived solution steps, but also considers and accepts correct variants of the problem solving procedure.

In order to achieve this goal, the ComIn-M web service verifies the mathematical correctness of every single rewriting step. If an error is detected, it will be classified according to a set of predefined heuristics. Depending on the type of error, possible strategies for resolving the error are determined and reported to the user in the form of automatic feedback. Only in cases where the system fails to categorize a solution automatically, the system asks the student for permission to forward the solution to a teacher for "manual" assessment. This is where the semi-automatic aspect of Intelligent Assessment takes effect and the advantage of this approach becomes obvious: the integration of the human tutor in the assessment cycle ensures that learners are optimally supported even in highly individual and non-standard solution contexts.

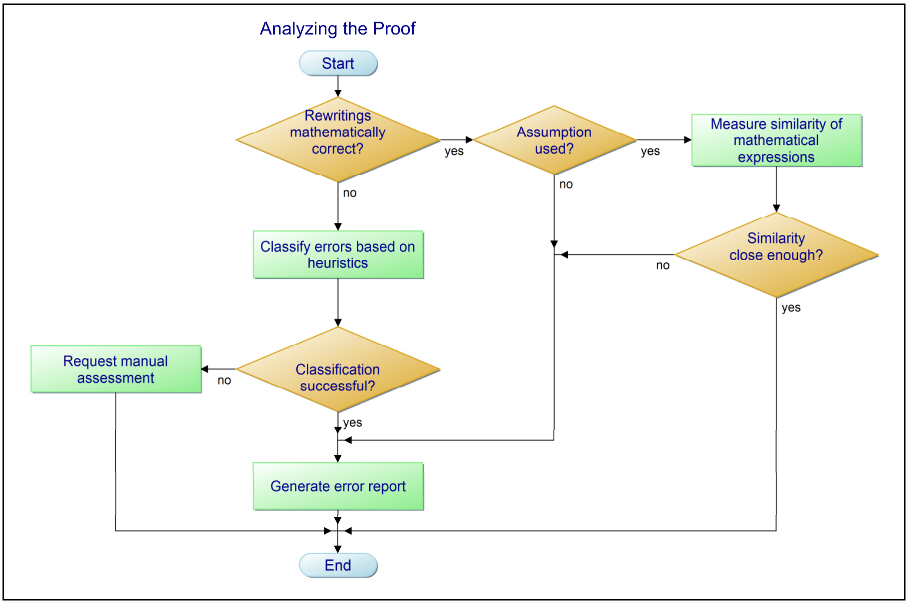

Fig. 4. Flow chart for proof analysis

In the same way as the system detects erroneous solutions, the system also has to find out whether the mathematical solution is formally correct (see Fig. 4). As a prerequisite to this step, the verification that all rewriting steps are mathematically correct has to be completed successfully. If this is the case, the system checks whether the assumption was used correctly in the inductive step. Ideally, the next analytical step would assess the similarity of the mathematical expressions and would determine that the similarity of the two formulas from an individual rewriting is close enough. This challenge has to be addressed in future versions of the Induction Analyzer Service. After having passed all analysis steps successfully, the solution is judged as being correct and appropriate feedback is returned to the learner.

4 Evaluation

In the winter term 2010/2011 the tool ComIn-M was evaluated regarding the usability and practicality of Intelligent Assessment as a method of Computer Aided Assessment. At the Universities of Education in Weingarten and Ludwigsburg, students used the tool ComIn-M in two recitation sections. The evaluation was performed on a voluntary basis and students used the tool independently and without any introducing guidance. In the following, the results of this first evaluation are described. The data is gathered from 26 usability questionnaires and from logging data of 13 user sessions.

4.1 Usability

As part of the tool evaluation, all participants were asked to fill out an online questionnaire containing questions and statements relating to the software tool ComIn-M. The main purpose of the questionnaire was to find out how well the participants perceived the tool ComIn-M in terms of usability and the quality of the automatic feedback features.

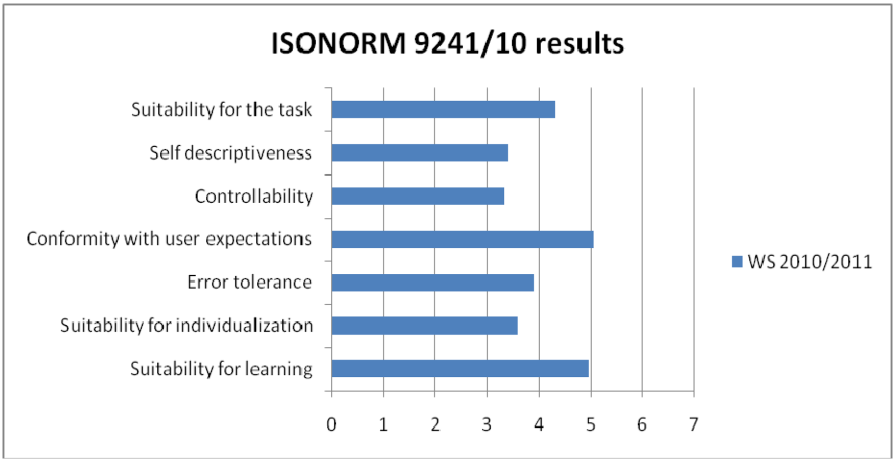

Fig. 5. Results from the usability questionnaire ISONORM 9241/10

Based on the standardized usability questionnaire ISONORM 9241/10 [15], various statements considering different aspects of software usability were presented to the participants and had to be rated on a scale from 1 to 7. The selected value should represent the extent to which the participants agree (value = 7) or disagree (value = 1) with the given statement. Fig. 5 shows a summary of the collected data grouped by the design principles as defined by ISONORM 9241/10. The overall mean across the scales is 4.1 which shows that there are no major problems in terms of usability. However, only the scale "Conformity with user expectations" reaches a mean of 5.1 which is an obvious positive rating [16].

Further analysis on the level of individual items, allowed us to identify both areas of usability in which the tool ComIn-M performs well, and areas of potential deficiencies. Table 1 lists selected items that were either positively rated (mean value greater than 5) or items that were negatively rated (mean value less than 3). While positive ratings can be stated in the fields of user interface design, predictable response times, and ease of learning, shortcomings were found in the self-descriptiveness of the software tool and the provided descriptions on how to resolve errors. These shortcomings were also evident in the suggestions for improvement that were proposed by the participants: 5 of 16 (31.25%) participants requested improved hints and more suitable terminology. Another three (18.75%) participants requested better support through dedicated help pages, practical examples and a glossary.

Table 1. Results of usability questionnaire

Item	n	Mean	Standard deviation
Positive ratings:			
The software is designed consistently, thus facilitating orientation within the user interface	10	6.40	0.699
It is easy to predict how long the software will take to perform a given task.	10	5.80	1.687
It does not take a long time to learn how to use the software.	10	5.50	1.581
There is no need to remember a lot of details in order to use the software properly.	9	5.67	4
Negative ratings:			
The software offers useful explanations on how to use the system.	12	2.92	1.782
The software does not require adhering to an unnecessarily fixed sequence of steps to perform a given task.	10	2.90	1.595
The software provides useful information on how to recover from errors	10	2.80	1.874

Additional feedback questions relating to the software tool in general revealed yet another shortcoming: 4 of 16 (25%) participants criticized the CAS-like syntax that has to be used for entering mathematical formulae into the system (see chapter 3.1 User interface). As positive feedback, 5 of 16 (31.25%) participants highlighted the simple and clear user interface design, and 4 of 16 (25%) participants emphasized the usefulness of working through the exercises step by step.

4.2 User Behavior

The analyses of the usage logs allowed us to draw several conclusions about the typical usage behavior of the learners and the perception of automatic feedback generated by ComIn-M. The usage logs showed that 90% of the participants worked step by step through the exercise and repeatedly made use of the button for checking the correctness of their solution. In average, the users requested feedback on intermediate solution states eight times per exercise. If the system reported an error, 63% of the users tried to correct the error and the majority of these users (67%) were even very insistent in trying to fix the error: they made at least three attempts to correct the error. However, if the feedback still remained unchanged and the users were not able to find a correct solution, they switched to another part of the exercise or stopped working with the system completely. In some cases, we could even observe that previously correct input was changed to wrong input. A possible explanation for this behavior could be the fact that the users wanted to evoke a changing feedback to see if the system was still working.

Although the students were supposed to use the system independently, the evaluation was conducted in a laboratory setting with a human tutor available to answer any questions regarding the usage of the tool. Due to this laboratory setting the semi-automatic features of ComIn-M were not used by the students, i.e. the tutor was never contacted from within the system. Future evaluations should focus on the semi-automatic aspects of the system and should be run in a realistic setting without direct contact to the tutor.

Moreover, our analysis of the logged data revealed that the system accepted solutions that contained mathematically correct rewritings, but did not represent valid proofs by complete induction as such. The technological implementation of the analysis needs to be refined in this respect, focusing not only on the correctness of individual rewriting steps but also on the validity of the proof as a whole. In this context, we also have to address the question of how many rewritings are mathematically necessary to reasonably proof the statement.

4.3 Conclusions

In summary, we found that the exercise tool ComIn-M was well perceived by users working through a mathematical proof by complete induction step by step. In doing so, the learners made use of the offered feedback and hints in order to identify errors and correct them independently. However, the evaluation results indicate that the feedback and the hints should be more fine grained and should be modified after several unsuccessful attempts of correction. With these improvements we expect to keep up the learners' motivation and prevent them from abandoning working with the system too early.

5 Future Developments

The learning tool ComIn-M is a prototypical implementation of the concept of Intelligent Assessment. As a web-based training tool, ComIn-M offers the ability to check individual solutions of proofs by complete induction and delivers semi-automatic feedback on every intermediate step of the submitted solution.

Future developments will target better usability of the system in terms of mathematical input. Additionally, a much more elaborate mechanism for logging and analyzing user interactions is under development. In this context, we are working on a general logging service that can be used by different learning tools. Our main focus will be on the automatic evaluation of the collected data logs to allow for a quick and simple overview over the user's learning performance over time.

Additional evaluations will investigate the usage and effectiveness of the semi-automatic features of Intelligent Assessment. Both technological aspects and acceptance among the users will be considered in these evaluations.

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Digital Inclusion: Zero to Deuterio Learning and the More Knowing Other

John Richard Walton

Department of Computing
Faculty of Arts Computing Engineering and Sciences
Sheffield Hallam University
Howard Street
Sheffield S1 1WG, UK
J.R.Walton@SHU.ac.uk

Abstract. This paper evaluates a situation where two organisations, in the field of encouraging digital inclusion, targeted the same population with the same intent, but with different modes of engagement. This entailed reaching outward, making contacts with those to whom the benefits of the digital realm could make a significant difference to their lives. Both involved the 'More Knowing Other' to engage the tacit knowledge of that part of the population that was considered 'hard to reach'. Success would be deemed to be the number of challenged individuals who by engaging with the proximal zone of development could acquire digital literacy as a consequence. The two ways in which this process was conducted is the subject of this paper.

Keywords: Problem based learning, Digital inclusion, Zone of Proximal Development.

1 Introduction

Historically, a large proportion of South Yorkshire's employment has been in the manufacturing and extractive industries. Industrial change has left a significant proportion of the workforce jobless, without key digital skills to engage with emerging creative and digital industries. South Yorkshire has had a low uptake of ICTs, and digital inclusion has been defined as a key sub regional priority for economic and social regeneration.

One response has been to use central government finance to provide the region with very high speed broadband via an infrastructure development programme known as *Digital Region*. At the time of writing, 96% of the population have access to this network; despite available access, significant groups are excluded from the benefits of this initiative.

The types of technologies we are concerned with in this case are those that generate information that is convenient to transmit, integrate, manipulate and duplicate at minimal cost [1].

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It has to be understood that information technologies will only make a positive difference to individuals if they are able to operate them. Digital developments which neglect the agency of the user, characterising the individual a subject or content, are unlikely to effect positive social or economic transformations [2]. Some groups of people are particularly hard to reach. These include those who are unemployed with skill-sets in manual or manufacturing work, and those from cultures that do not traditionally engage in life long learning.

Two organisations are examined in this paper; one a council, *Barnsley Metropolitan Borough Council* and secondly a 'third Sector' body *Access Space Network* Both have recognised that the most effective way to reach people is through their peers. Such local people, embedded in the community with similar backgrounds, experiences and culture as their own are most likely to be able to introduce the digital realm in such a way that the interest, utility and value are clear. Subsequently digital skills can be passed on to 'hard to reach' groups.

Although the structure and scale of these two providers are very different the super ordinate goals [3] of both organisations of increasing Intellectual Capital [4] and Social Capital [5] are highly congruent.

It is the conception of the path *towards* these shared values that is investigated here.

2 Learning, Knowledge and Intellectual Capital

That all our knowledge begins with experience there can be no doubt

Immanuel Kant, The Critique of pure reason

One of the features of economic depression in a region is that the activities which animate the economy of the area typically demands less and less labour which previously had been characterised by sheer physical strength and/or endless repetitive manual labour. Knowledge, emotional intelligence, and the ability to learn are amongst the attributes demanded by the new businesses that will create value in the region.

The ability to acquire knowledge comes through a variety of channels; traditional education, self instruction and experience. However just having experiences is not the same as learning from them.

Learning implies change, a change of thinking in terms of conceptualisation of the world often accompanied by changes in behaviour. The focus in this paper is on the learning by adults rather than children.

Knowledge is defined as justified true belief, [6] If an individual holds a belief about a phenomenon, that belief is held because it is considered true by some criterion, for example the correspondence of a proposition to the perceived evidence. However, an individual's belief only qualifies as knowledge against the criteria expounded by Boisot *if* it can be justified to *another* human being. Furthermore justification requires language as the *sine que non* for another person to agree or disagree with the knowledge claim.

Intellectual capital is a factor of production which in addition to land, labour and capital brings about the creation of wealth. A knowledge asset is knowledge that has an economic input and which has a tradable value in the market. Examples include but are not limited to, contraction of value chains, increased customer service and responsiveness, and the mass customisation of products.

2.1 From Experience to Learning

Humans have veridical experiences by which *a posteriori* view of the world is created in the mind. This view is developed to include the v term *sensibility* being the receptivity of the mind to these impressions [7]. The receptivity of these impressions is called intuition. On the other hand, the conception of such impressions spontaneously is termed understanding. The cognitive process then involves the perception of the 'world' and then the generation of concepts that can be manipulated in the mind by logic.

When Immanuel Kant was writing the Critique of Pure Reason in 1781, he could not have foreseen that for many of the world's population, their veridical experience (that of the senses) would be mediated not by what they could see directly *id est* an object, but as a representation of the object on a computer screen. He further asserted that the perception of an object was that of its form and not of its matter [7].

In the digital realm, the perceptions of human beings can be almost totally mediated by the computer screen and digitally generated sounds. The sense of touch comes from a mouse or joystick which gives motion to objects perceived by the eye. So the human perceives a representation of a representation. The development of the WIMP [1]interface at Paulo Alto, was designed to make the use of a computer more intuitive, that is the image and sound of the computer appear to represent the world with greater realism.

There are two issues that have to be addressed in the diffusion of information via the digital medium. The first is the acceptance of the legitimacy of using ICT as a primary contact with the world, and the second is the acquisition of digital literacy to enable individuals to interact with the manner in which information is presented.

These two considerations actually have a theoretical impact on the methodological and epistemological choices made by the implementers and the recipients of the services provided by the digital region. There are a number of vehicles that deliver these services, for example, face to face interaction, books, or web based applications. The question that arises is in how far is it possible to know that knowledge has actually been gained and internalised by the individual?

One example is the experience curve [8] this shows that, given a specific situation, and a task to perform then *ceteris paribus*, the resources to undertake the task will reduce overtime. This phenomenon is true for teams and organisations as well and gives rise to the notion of productivity.

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[1] WIMP is an acronym for Window, Icon, Mouse and Pointer.

2.2 From Learning to Knowledge

The knowledge that emanates from learning is dependant on the type of learning that has taken place. For example rote learning of a poem is unlikely to gives rise to appreciation of the use of language exhibited by the poet no matter how accurate the rendition.

Learning characterised by navigating a predetermined set of choices is single loop learning [9]. The type of learning can in fact be automated. Devices that use simple feedback mechanisms such as thermostats demonstrate how human learning can be reified into artefacts.

In contrast, double loop learning [9] questions the assumptions inherent in the loop of that learning. It is in questioning the pattern of contexts [10] from which the learner has to choose. It is often presented as *learning about the learning*. In this way, an individual can and will over time optimise the conditions for knowledge acquisition. This is also deutero learning [11].

There should then be a consideration about when learning ends and knowledge generation begins.

This has been elegantly answered by the notion of retroduction, sometimes called abduction which is the creation of a suggestion to an explanatory hypothesis [12].

2.3 From Knowledge to Intellectual Capital

The knowledge economy in contrast to the energy economy is based on the principle that data and information can be substituted for physical factors [13].

The data and information necessary for this substitution is enabled by human beings. The capital required for this is called intellectual capital, and can be considered to comprise two or possibly three elements.

Intellectual capital has been thought to comprise two elements: human capital (intellect and tacit knowledge) and structural capital (routines, non human storehouses of data) [14]. In the digital world the structural capital is advancing quickly. The so called internet 1.0 is autistic and mute. It is autistic because an internet is not sensitive to its environment, and it is mute because very few people publish material relative to the vast number of people viewing material on the websites [15].

Another definition of intellectual capital comprises three areas: human capital; structural capital and relational capital (knowledge embedded in relationships) [16]. Web 2.0, sometimes referred to as Enterprise 2.0, places much more emphasis on the discovery, enablement and development of relational capital and seeks to overcome the shortcomings of Web 1.0. The impact on the diffusion of intellectual capital in such networks is obvious; the invidious or negative aspects less so.

The key factor for our research programme was to investigate the *initiation* and *development of* the human capital so that there can be an active engagement with the structural capital. If an individual cannot meaningfully interact at all with the structural capital, they are as good as illiterate in a society dominated by the written word. That is why the term digital exclusion is used.

For those who *are* included, development of their intellectual capital is an ongoing process. When considering the population of an area or region, a complete spectrum of aptitudes and appetites for learning becomes apparent. These include but are not limited to Learning Style [17], divergent and convergent thinkers [18]. All these cognitive appetites can be catered for in the virtual digital world by the edutainment to optimise the learning of the individual.

Knowledge assets are assets capable of deriving a tangible economic benefit e.g. a knowledge of double entry book keeping, object oriented programming, web design, all of which require the individual to believe (understand) the subject, be capable of a true rendition of a problem when applying it, and being able to justify a solution or deliverable applying the discipline in question.

In so far as these activities give rise to processes which add economic value to a substrate [6] they are *knowledge assets.*

The problem with intellectual capital is that it can become stale. It can by the creative destruction as suggested by Joseph Schumpeter be disintermediated, overtaken or eliminated. Therefore for the economy as a whole as well as for the individual, an effective management of intellectual capital requires the securing of a continuing supply of knowledge assets. That is why digital literacy is so vital.

The possibilities for the maintenance and development of the intellectual capital are immense when the capabilities of edutainment are factored into the equation. However impressive the research and development of serious games has been to date, the impact for the future for those that embrace this approach can only be imagined.

The journey from individual experience to the acquisition of intellectual capital is underpinned by a vast number of theories indicating the complexity of the process. To navigate this space requires a guide to ensure those who travel this path arrive at their destination with the minimum of distress, with a sense of achievement and a positive frame of mind for the future. It is the role of this guide to which we now turn.

2.4 Socialisation and the More Knowing Other

As has been stated in the introduction, this paper has focused on the learning of adults, and in particular those who have not necessarily had a good educational foundation. This slant must be emphasised because there are important differences in the way children and adults approach the learning process. One significant difference is the way children develop and learn. Piaget discovered that development precedes learning. However, for adults who have already developed a role in society, the social role is crucial to an individual's learning capacity [19].

The second critical factor here is the *More Knowing Other* (MKO). The learner has rapport with the more knowing other such that the latter sets the next (proximal) step zone in such a way that it has the following characteristics:

it is realistic to achieve;
it is possible to partly achieve; and
it is possible to totally fail to achieve.

As a consequence of this the MKO can give feedback on the learning in a meaningful way. It is this that accelerates the progress of the individual.

If it transpires that the student has totally failed to achieve the step, the MKO must revise the next step so that it exhibits greater specificity with the learner's prior experience. It is to this aspect that we next turn.

2.5 The Proximal Zone of Development

Another powerful concept in this is the area is that of the proximal zone of development [19]. This is the difference (zone) of the ability to perform a task with the MKO and the ability to achieve the step independently. This, according to Vygotsky is where the learning is located.

As its name suggests, learning is a series of steps which in turn implies logical incrementalism. The question is how are these steps linked?

2.6 Hierarchies of Learning

Learning 0

Learning implies change [11]. In context in this work on digital inclusion, the most common reason for a minimal change is its response to a repeated item of sensory input. This can be the result of habituation or other factors. Thermostats and other devices that employ simple feedback mechanism show that learning 0 can be programmed into simple control devices with ease.

Learning I

This is the next 'level' above zero learning, is a 'change in the specificity of response' by the correction of errors within a choice of alternative' [10].

Learning II

This is characterised by a change in Learning one, often called the *learning about the learning* or *deuterio* learning [11].

3 Peer Learning and the More Knowledgeable Other

To address the situation of those unable or unwilling to engage with the opportunities presented by the digital region suggests an extremely large scale task of advocacy and learning which is neither financially or organisationally feasible to deliver through structured teaching.

Making IT Personal, Joining the DOTs is an initiative developed by Barnsley Metropolitan Council (BMBC). To address the challenges of peer learning as discussed above, BMBC has developed the concept of “Digital Outreach Trainers”, (DOTs). These are volunteers that pass on digital skills to local people. By recruiting and supporting DOTs who are located in deprived demographics and communities, this initiative aims to engage all members of the community so that they can benefit from the internet and the World Wide Web.

This research paper, based on a case study, examines the manner in which the effectiveness of the (DOTs) can be optimised in two distinct ways.

Firstly, the different ideations of *socialisation* that the distinct organisations embrace, which when combined in an appropriate manner, can enable a symbiotic relationship to optimise the capability of the DOTs

Secondly, through the use *of technology* which acts as a locus of information about the activities undertaken. Two examples from the case study are given; one a server that contains official documents and procedures as well as contacts for the DOTs, the other a Wiki which records the learning events in a less formal and codified manner.

The case study brings into sharp focus the qualitative and quantitative differences between tacit or informal learning and formal, explicit learning. The latter often leads to accreditation while the former does not. The discussion also illuminates the strategic dimensions of the relationship of a Public Sector body and a Third Sector institution. Interestingly in both cases it seemed appropriate to consider inclusion to be a stage process.

First, to convince an individual to enter the learner phase and hence become a member of the learner class and second to enable the transition from learner to learned by the acquisition of knowledge. From the above, it seems rational to propose the role of a mediator to enable this transition for certain groups.

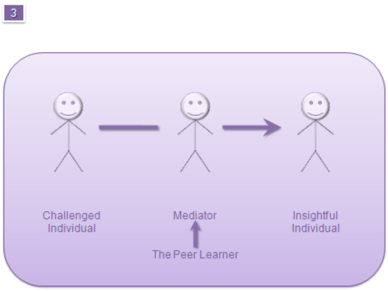

Fig. 1. The role of the mediator

The DOTS, being the mediator then engage with the 'challenged individual' that has been identified by outreach workers. The mediator is the *More Knowledgeable Other* who, being able to set proximal (subsequent) steps, is able to move from a state of zero learning to learning I [11].

To provide an insight into this we borrow a concept from chemistry. The mere observation that molecules of a particular species are present and in equilibrium and *could* react, does not mean that this will *actually* occur. In order for this to happen the energy levels of the molecules has to be increased. This increase in energy is termed the activation energy, given the term $\Delta F^{\ddagger}$ [20]. Without $\Delta F^{\ddagger}$, the reaction will not proceed and the new equilibrium will not be reached.

To follow the metaphor through, in order to move from a state of zero learning once a dialogue interaction has occurred, the new equilibrium position will cause a new proximal zone of development to provide a basis for learning I.

This “activation energy” is achieved by interpersonal interaction between the student and the DOT in the case of BMBC. In the case of Access Space it is the interrelationship between the student, the participants and the staff. This is the socialisation that is the precursor to the constructivist approach proposed by Vygotsky, in his theory of Proximal Zone of Development.

4 Strategies in Action

Given the economic climate in Europe, optimisation of all resources is essential especially for those most vulnerable in society. The five Ps of Plan, Pattern, Ploy, Perspective and Position have often been used as a way of conceptualising strategy [21].

It is the outcome of this work that the Third Sector institution's strategy emerges as a *pattern*. This is a consequence of an emphasis on learning from *knowing to doing*. There is a high degree of tacit knowledge in this.

The public sector body on the other hand embraces the concept of *plan.* This is characterised by a significant teleological commitment, together with an explicit knowledge [22]. This interplay was also manifest in the role of the information systems that both types of institution deployed.

The notion of *plan* has several ramifications. Firstly, it assumes that objectives or the future desired state can be specified prior to its attainment. Secondly, it has an appeal to rationalism which is of course highly congruent to Central Government thinking.

Thirdly, it separates those who formulate the plan from those who actually deliver it. Finally, plans need to be validated, and this occurs at two stages; when the plan is formulated *id est* when resources are allocated to it and then at the conclusion of the plan when an assessment is made as to the extent to which the objectives have been achieved.

Due to the separation of those who formulate the plan and those who execute it, a great deal of emphasis is placed on explicit knowledge represented by such artefacts as project milestones, the nature of the deliverable, job descriptions representing the division of labour, and budgets complete with variances and projections for the future. Individuals and organisations that espouse planning are prepared to commit physical and financial resources without an immediate benefit because they perceive that the plan itself will deliver delayed gratification. This approach is captured in the famous expressions "Failure to plan is planning to fail" or "Proper planning prevents poor performance".

The concept of pattern is different. Patterns in strategy emerge as the consequence of a complex interaction of behaviours which evolve over time to exhibit coherent and effective action. Since these behaviours are in part a response to the environment in which an organization is located they involve learning which is why they are said to evolve. In addition the response is mediated by all the individuals in the organisation not just those who are decision makers, therefore they are said to be effective albeit from a local, not a global perspective. Such patterns cannot be anticipated or predicted in advance. Clearly the pattern approach to achieving strategic dividend relies heavily on tacit knowledge. Individuals and organisations that consider strategy as a pattern are often very frugal with physical resources. This approach is often expressed as "this is the way we do things round here".

The contrast between pattern and plan is synthesised with the notion of the Generative Dance proposed by John Sealy Brown, the Chief Scientist of Xerox [23]. This is the difference between *knowledge in possession* and *knowledge in action*.

5 The Case Study

BMBC adopting as they did the strategy of plan had then to find ways in which the Digital Outreach Trainers status could be legitimatised. This entailed a relationship with another stakeholder, Sheffield College, which had the knowledge of the specification of learning and a competency in its assessment. In addition to which they had the power to confer awards. In this case they were the UK National Vocational Qualifications at level 2 and 3.

This further created the requirement of a bureaucracy to support it together with a dedicated IT system. Access Space Network (working with The Sheffield College, and directed by the MITP JtD Steering Group) developed the 'Join the DOTS' (JTD) server which recorded the application from an aspiring DOT through to them passing the approval process. Central to this procedure was the concept of Learning Outcomes. This states that it is possible to specify in advance what a learner will achieve, and to what extent this has actually been achieved.

A great deal of time and effort was expended in codifying the information the DOT would have to acquire in order to fulfil the role. The processes underpinning learning outcomes are that the knowledge that is derived from information is cumulative and successive so that it is quite authentic to consider that an individual is progressing towards an educational goal.

It is important to note that the knowledge here was considered to be explicit, that is capable of being captured and then externalised in written form without the *loss of the utility* of the knowledge.

In parallel with their development with the JTD[2] Server, Access Space Network also developed SOAP[3]wiki, an internal system to monitor and evaluate face to face peer learning at their centre. Comparing the operation of SOAPwiki and the JTD server they were able to contrast their concept of peer learning with that of BMBC.

The approach of Access Space Network is quite different. The organisations centre, Access Space is a physical space. It is the *context* where the learning together with the development of each individual takes place. It does not deploy prescriptive learning as typified by learning outcomes; rather it uses Problem Based Learning

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[2] JTD is an acronym for **J**oin **T**he **D**ots.

[3] SOAP is an acronym for **S**upported **O**pen **A**ccess **P**rogramme.

(PBL). This is exemplified by a large sign in the space above the computers upon which the following words are written: *Show me how to fix my computer. Please don't do it for me.* This encapsulates the pattern that the staff at Access Space follow. The motivation for engaging with the problem is internal to the participant, not imposed from outside. Therefore each individual will construe and articulate his or her own problem and then marshal the available resources to confront it. Socialisation is therefore essential as no one individual has the static capability to completely specify let alone solve a problem at the extreme end of his or her knowledge horizon.

Emanating from medical schools PBL has been embraced by a number of educational initiatives; the key characteristic being that the learning emerges for the problem situation and cannot be predicted in advance.

SOAPwiki seeks to record the encounters or 'touch points' that occur in the process of peer learning. It is therefore a way of codifying the socialisation so that it is externalised. The fact that there are a variety of routes to this e.g. texting, via twitter or direct entry means that there is the maximum opportunity for capture at the *moment of engagement*.

6 Discussion

Essentially the two case studies illustrate two approaches to education. One is where the objectives (learning outcomes) are specified in advance and the other where they are not. One relies heavily on explicit knowledge [22] and the other places more emphasis on tacit knowledge [24].

This paper does not champion one approach over another. For example, there were no controls over the population of the individuals who involved themselves (or are involved) in each of the approaches. It is hard to ignore that they were self selecting and whether other factors such as availability caused an individual to enter a specific route of learning.

What is possible though, is to compare the extent to which the individual directs his or her own learning. In the server/council example the student is placed on a highly structured path by virtue of a predefined proximal zone of development which the More Knowledgeable Other has to follow. In the SOAPwiki example, the path is open because the proximal zone can be negotiated with the More Knowledgeable Other.

The former places much more emphasis on convergent thinking whilst the latter offers opportunities for divergent conceptualisation.

Although the two approaches represent extremes of provision in this area it may be possible to synthesize aspects from each one. The propositions gleaned from the two examples allow a contrasting view of the learning process in the domain. It is hoped that this can inform subsequent initiatives. However, as Dick [25] points out, the ideal position is that of the sequence. This is because the *providers* of the educational experience are learning about the learning [11].

Given the austerity with which educational initiatives of this kind are faced, evidence is crucial, because without this any notion of progress cannot be assessed. As Konrad Adenauer, the first Chancellor of the Federal Republic of Germany famously pointed out 'it is vital not to confuse energy with strength'. It has to be acknowledged however, that some attributes and benefits of the acquired digital literacy and hence inclusion can be very difficult to appraise. Such characteristics include but are not limited to: increased self esteem; self actualisation and increased social mobility. In addition increased educational competence which in turn can lead to the acquisition of intellectual capital can be an elusive quality to determine.

It has been pointed out that the traditional approach to evidence based practice is shown in the sequence depicted below by Dick [26]:

Theory -> Evidence -> Practice

The evidence emanates from theory but also feeds back into it, which will in turn cause practice to be more effective and hence more 'evidenced' based. This approach is reminiscent of 'single loop learning' [9]. In this conceptualisation the theory itself is not challenged, the evidence 'fine tunes' the theory to increase its efficacy, and removes any non-value adding steps. To adopt a manufacturing analogy - the outcome will be smaller, faster, cheaper.

However, using a Grounded Theory approach, [26] the telescope is reversed. The practice is examined first and then this is used to generate the evidence of the outcome, from which emerges theory, as shown below

Practice -> Evidence -> Theory

This is because the approach suggested allows a retroductive commitment. In permitting the generation of both case and token, rather than the mere refutation of knowledge, new theories are created. Actually, this is the only way in which new knowledge can be created [12]. As far as the recipient of the educational experience is concerned the proposition is that learning *how it works* is much more significant than *how to work it*.

7 Further Research

There are five areas of further research that present themselves.

Firstly, the extent to which the *actual use* of the digital arena is experienced by those targeted by the initiative as detailed in this paper is still open to question. There could be a tendency to believe that in gaining the insights via the approaches discussed, such determinants can be codified. A full discussion of all the factors involved is beyond the scope of this paper. Indeed such factors can be counter intuitive. For example to select just one recent paper , in which some attributes are reported, Social Identity, Telepresence and Altruism are identified as the dependant variables that determine actual use [27]. This indicates that a wide variety of factors will condition an individual to a position of engagement with the digital world. There are a myriad of opportunities that are available on the WWW, opportunities that can provide a path to self actualisation [28] once the threshold of engagement has been crossed. The possibilities that are available may be limited by the individuals, if the digital world is then seen as something just to be exploited rather than explored.

Secondly, the very organisation of the Digital Outreach Trainers could give rise to a community of practice [29]. This would enable the *maturing and stewardship* phases [29] of development to make the maximum contribution to the local people. For many people, such as the retired or those interested in voluntary work, the attainment of an NVQ, is not in itself a motivation to engage in the programme. But being a member of a community of practice, with the possibility of steering and optimising the process of inclusion could be a strong motivator. Apart from this, building a CoP may combat the sense of isolation that many DOTs feel and also provide a forum for the inevitable experience of emotions of frustration and anxiety that many individuals in such situations encounter. Whichever model is used to address the issue of this paper, extensive demands are made on the tacit knowledge of the DoT. This can be exacting and arduous. In addition to which, it should be possible to abstract the characteristics that make the initiative replicable in other domains making the process more rewarding and life enhancing for all concerned.

Thirdly, for the information to become an asset, it is important to identify and codify the stakeholders in the domain. Initially this could involve the classification of salience of the stakeholders [30]. Once this has been achieved it should then be possible to instantiate the actants, to depict the region as an Actor Network, using the eponymous Actor Network Theory ANT [31]. This would further allow the actors to reflexively appreciate the position [32] in order to formulate a comprehension of the centre of gravity of initiatives that can lead to regeneration and the development of the whole community.

Fourthly, the notion of digital inclusion and the degree and extent of its associated literacy should be formalised into a framework. An event was held at Access Space entitled 'Questioning Digital Inclusion'. The objective was to generate a rich debate, which being recorded and transcribed could form a basis for a grounded theory based conceptualisation of the levels of digital inclusion. This work is currently in progress.

Finally, the potential of the context based approach of Access Space required further consideration. The modus operandi encompasses a number of theoretical approaches. Since it is situated in a social context, it provides a fertile ground for the socialisation, externalisation, combination and internalisation of knowledge [23]. The authors also assert that the knowledge spiral that is proposed will flourish in an environment they call Ba. Ba is a place where 'information is interpreted to be knowledge' [Nonaka *et al* 2000:14]. Ba is characterised by love, trust and commitment as a basis for reflection and action as a result of dialogue. The location that provides an institution with Ba is crucial to their work where they discuss the optimisation and promotion of the SECI spiral [23]. In addition to this, the Social Learning Cycle [13] is also in operation. The Social Learning Cycle (SLC) describing as it does the stages of scanning, problem solving, abstraction, absorption, impacting and adoption, should allow the optimal approach to learning.

The central question is can this be replicable? To this end an action research project could be initiated at relatively low cost to determine if this is the case, and if so what factors would influence such future duplication of the space that has served the city of its inception for a decade.

8 Conclusion

This paper has emphasised the significance of the More Knowledgeable Other. The contribution that is made can be considered to be focused on two roles; that of the disciple and that of an apostle. A disciple is a student; an apostle is a messenger.

In the first model of prescriptive learning the student can indeed welcome the apostle who has a valuable message from which he or she can learn from, benefit and develop. The disciple's perceptions and experiences can therefore be enhanced but they *cannot* surpass or exceed those of the messenger.

In the second model, the disciple encounters another disciple. With the meeting of minds, and in the creative rejection of ideas in the consciousness of them both a new world is brought into focus. In this case it is possible that the newcomer to the field may become a true peer to the one who is the teacher. A good and true teacher knows and believes that in giving the utmost for the highest to the disciple, the latter could *transcend* him or her. And that is what justifies and legitimises the role of the teacher.

Therefore it is posited that there are *two* learning cycles operating. These are firstly, that of the participant engaging with the domain, and secondly, that of the trainer as he or she become more competent at conveying the ability to engage with digital technologies.

Indeed the learning about the learning will have more impact than the learning itself. The *learning* is the signal; the *learning about the learning* is the amplifier.

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Human Computation in Mobile Cooperative Learning: A Museum Tour Case Study

Huber Flores[1] and Dennis Maciuszek[2]

[1] Institute of Computer Science, University of Tartu,
J. Liivi 2, Tartu, Estonia
huber@ut.ee

[2] Institute of Computer Science, University of Rostock,
Albert-Einstein-Str. 22, Rostock, Germany
dennis.maciuszek@uni-rostock.de

Abstract. The article presents an application scenario merging mobile and cooperative learning by taking advantage of human processing capabilities. We demonstrate our ideas by presenting as case study a museum tour application in which visitors collectively translate instructional texts on exhibits to foreign languages using their mobile phones. The case study covers the design and implementation of a prototype architecture and interface, as well as an early user study.

Keywords: Smart Environments, Mobile Computing, Mobile Learning, Pervasive Education, Computer-Supported Cooperative Learning, Human Computation.

1 Introduction

eLearning in its early days put the learner in front of a computer and removed the social context of the teacher and co-learners in a classroom, lab, or on an excursion. In its most basic form, this ignores the view of psychologists favoring situated learning theories, i.e. learning not as a purely cognitive process, but as "participation in a social practice" [9]. Many regard interaction between learners as a key factor, as individuals learn from the knowledge of one another, adjusting it to their own context and history [22]. Over the years, though, eLearning has yielded new forms of learning support such as Computer-Supported Cooperative Learning (CSCL) and, recently, Mobile Learning (mLearning).

CSCL uses social software to re-unite teachers with learners and learners with each other, especially when they are in different places – or in the same place at different times. In order to restrict the complexity of the topic, we will for the scope of this article restrict the idea of CSCL to the distance learning case, where there is no communication between teachers and learners or among learners going on in real life. That is, we exclude "blended learning" scenarios, keeping in mind that real-life communication in presence learning sessions might facilitate learning. In our case, "social practice" is mapped onto the communication technology or social software.

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mLearning (eLearning using mobile devices) can take physical context into account, i.e. the learner's current environment. In combination, CSCL and mLearning form "mobile cooperative learning", i.e. eLearning that seeks to enrich learning experiences with both, cooperation and context sensitivity. Section 2 provides background information and motivation for mobile cooperative learning. By falling back on the idea of Human Computation (Section 3) and presenting a case study within the context of a smart museum [15] (Sections 4–6), the article demonstrates one way of exploiting the mobile-cooperative combination. The main idea of Human Computation is that people perform tasks within a computer-based system in which they – as a group – are better than a machine. Note that the term "computation" in this field need not mean humans performing calculations. They would rather perform cognitive processing tasks such as recognising images or working on natural-language texts. Note further that we understand the term "case study" as studying a specific case (system) to gain insights on a wider range of similar systems. Here, this means collecting evidence for the utility of the concept of human processing in mobile CSCL. The focus is on the technology. A user study beyond the scope of a mock-up pilot experiment shall be discussed in Section 7, as a part of future work.

2 Problem Statement: CSCL and mLearning

Nowadays, in times of Web 2.0, much of the content on the Web is created using social software. Producing and presenting content in online communities has become a common way of sharing knowledge and spreading information. This process of content creation is a social learning activity itself, in which individuals learn by interacting with their peers [22]. Social software has become an enabling technology for CSCL. There are however drawbacks. Social communities are basically asynchronous and do not encourage active participation in real-time. Teachers and learners post educational material independently of location and time. The material is static and does not adapt to an environment context, as situated learning theorists would demand. This is where mobile technologies can improve CSCL in online communities and learning management systems. In fact, the mobility element has now spread to *Facebook*, *Buzz*, *Twitter* et al. [8], yet these applications only provide mobile access to and mobile generation of information – no sensors to collect context information, let alone ubiquitous context sensitivity.

On the other hand, there is the mLearning and Pervasive Education field that employs Pervasive Computing (or Ubiquitous Computing) technologies to enhance eLearning experiences. These include smart environments [11] that can react to the user's behaviour, e.g. a student in a lab, but also infrastructures that enable context-sensitive presentation of educational content on mobile devices. The device, e.g. a mobile phone, perceives the environment through sensors – GPS, camera, gyroscope (positioning and accelerometers) etc. – and the respective software adapts the content accordingly, e.g. the language of presented material. By this, mLearning may allow for authentic learning in that the educational application can choose or recommend lessons or examples related to real-world situations or problems relevant, interesting, and meaningful to the individual user. Interactive tasks may be built around data capture and location awareness. What this idea still lacks, though, is a level of proactiveness and intelligence beyond context sensitivity and adaptation. It cannot compete with a human co-learner that assists with content creation and knowledge construction.

3 The Human Computation Approach

A huge step forward would be to either integrate sensors and context sensitivity in learning communities, or to integrate human-like intelligence in mLearning scenarios.

The integration of micromechanical sensor technologies such as accelerometers, magnetic field and air pressure meters within the handset and/or located across the environment can enrich the usability experience of interacting with software applications like games or controlling handheld devices in a convenient way. Several prototypes and signal processing algorithms have been developed for human motion classification and recognition, allowing reliable, more than 90% accurate detection of basic movements [17].

The integration of artificial intelligence into eLearning systems is as old as research on Intelligent Tutoring Systems, which started as early as in the 1970s. Unfortunately, most prototypes have not become off-the-shelf products. Research continues, though, nowadys moving Intelligent Tutoring to mobile devices (e.g. [7]). Yet, whether mobile or not, ITS are mostly based on the cognitivist perspective on learning, i.e. modelling and assisting individual problem solving, not learning as social practice. There may only be one or a few fixed solutions that are taught, and assistance is restricted to previously anticipated difficulties. This is why some researchers (e.g. [1] or [18]) include communication with human experts as part of their (non-mobile) architectures for electronic learning and assistance. This may happen via chat, e-mail, some other form of tele-presence, or by individual or collaborative authoring.

Our perspective in this paper is to incorporate both, sensors and intelligence, by relying on the actual human learner. This is the central idea of the Human Computation movement: exploit the information processing capabilities of groups of human beings in tasks where they collectively beat any computer. "Crowdsourcing" is another term. Prominent examples include the *reCAPTCHA* technology [4], which is not only used for validating users as human beings (as in traditional CAPTCHAs), but also for digitizing texts at the same time, and the *Google Image Labeler* (aka *ESP Game* [2]), in which users are paired in a game to cooperatively tag images for Web searches. Yet, both examples are not in the context of education.

As pointed out above, involving other human beings in teaching and training systems is not new. Learners become authors of educational material in learning communities, or teachers appear by some form of tele-presence. However, exploiting the collective intelligence of larger groups as in the Human Computation idea is still uncommon in the educational sector. A recent project, *GuttenPlag* (de.guttenplag.wiki.com) did become famous in Germany. Using Wiki software, a larger group of users collectively reviewed the dissertation of then Minister of Defense zu Guttenberg, finding it largely plagiarized. On the research side, *Verbosity* [3] is a game in which players collectively document common-sense knowledge. Neither project is mobile, though, making use of users' perception of real life. Applications of human computation to mobile learning and knowledge construction tend to appear – as in the case of *Verbosity* – in the form of serious games (see [13] for an overview and a discussion of the game *Clandestine*). This does not surprise, as games are good at involving participants voluntarily.

When it comes to the tasks where humans excel, it seems that processing natural language is particularly interesting. Playing the game *Webpardy* [5], users collaborate on a Web-based natural language question answering system. *Actionary* and *TwinMinds* [21] are Human Computation games intended to improve the linguistic capabilities of an Interactive Fiction game. *MonoTrans2* [14] is a system used to translate children's books by employing crowds of users that need only speak one of the languages. Liu et al. [16] engage human users in translation efforts as well, focusing on complex Asian scripts that put high demands on image recognition. Yet, differently from the other works, they do address a mobile scenario. In a real-life situation, a foreigner would notice a sign in Asian script, take a photo with his or her mobile phone, and submit it to a crowd of human translators. The authors discuss a game approach as well.

The following section takes the idea of mobile, cooperative human translation to an educational setting.

4 Application Context

Advances in mobile technologies foster the emergence of smart and ubiquitous environments in which the user can access, create, and share information in any location with considerable ease. Mobile devices have become an essential part of distributed architectures. They can be used for infering context and behavior (e.g. location, situation, etc.) of the user with the purpose of enriching the centralized systems, improving the experience of interacting with the "everywhere" information. In particular, applications in the domains of social networks [19], location-based services and context-aware systems [20] benefit.

To investigate possibilities of exploiting the inherent languages skills of individual users within groups, the application to be presented is developed as an experimental extension of the SMARTMUSEUM project (www.smartmuseum.eu). This project was targeted at improving personalized on-site cultural heritage access with a strong focus on user preferences and context-based recommendations. The focus of the project was on textual and video content. SMARTMUSEUM solutions include mobile devices for access of multimedia content, user feedback acquisition, recommendations by processing user profiles and content metadata, and real content servers. Recommendations as the core component of the system are based on hybrid technology combining content, rule-based, and collaborative techniques.

5 Application Description

Museums are a classic testbed for Pervasive Education prototypes, such as those discussed in [6] or [12], although the notion of cooperating visitors is less common. We regard a visitor as a learner interested in a certain subject matter, trying to find out about the different exhibits. Exhibits in a museum are accompanied by instructional texts. However, these texts are often displayed only in the local language, while typical visitors are foreign tourists who do not speak that language (and might not be helped by English translations using domain-specific terminology, either). However, some visitors do know the local language and another one as well. The idea is that these provide their knowledge in order to help other learners. They would translate texts on a voluntary basis. One volunteer would only need to translate one or two text passages, but in the end the mass of contributions would make a difference and translate the whole body of texts collaboratively into many languages.

The proposed system is meant to be a client-server application running on a handheld mobile device (the client), in the least intrusive way as a social application on a visitor's own mobile phone. The client application provides all the tools to the user in order to capture his or her interpretation of the environment – technically speaking "sensor" readings of the exhibits and the accompanying texts. The user can receive and submit information from/to the system (the server) respectively as shown in Figure 1.

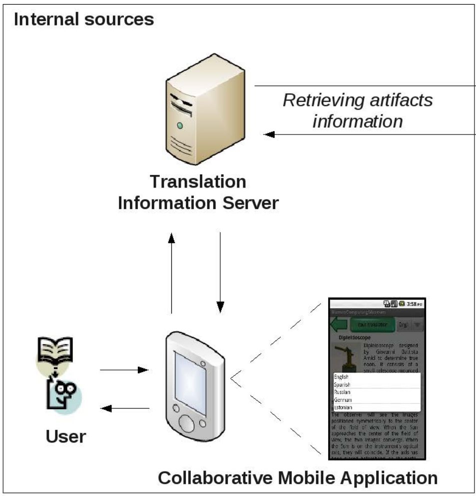

Fig. 1. Information flow in the human-client-server translation system

Along the tour, the user interacts with the exhibits in the museum. Each exhibit has a description (instructional text) which provides information about the object plus one unique identifier to locate the piece within the system (database). At the moment, the user would either type in the ID or browse the WAP site of the museum. Within the application, the user can request information about the piece in the available languages (read part) or submit translations (write part) using the identifier.

Figure 2 shows the flow of the application from the user's point of view. When the application is invoked in the handset at the beginning of the tour, it presents a login screen in which the user credentials must be introduced (bottom). Once the user identity has been validated, the application presents a list of categories in which the user can explore the artifacts available in the museum. By pressing one category, a list of artifacts is shown so that the user can select a specific artifact in order to retrieve its content (the instructional text). In the content screen, the user can (1) introduce a new translation (following the human computation approach) or (2) explore the list of available translations that exist in the system.

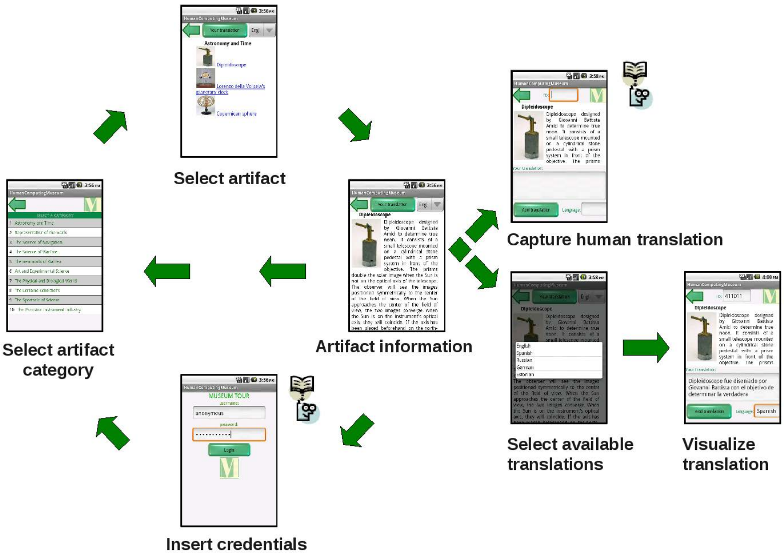

Fig. 2. Application flow for the museum case study

The application on the handheld device obtains information from the user via the translation button in the content screen (artifact information). Once the user presses the button, a list of already available translations of that particular content is shown. Here, the user can add an own translation. To perform the translation, the user must select in the content screen the part of text which he or she wants to translate. By this, the translation of the text is linked with that particular piece of the content. When the user has made the translation, the only step remaining is to specify the name of the language in which the new translation was performed and to submit the information: Figure 3.

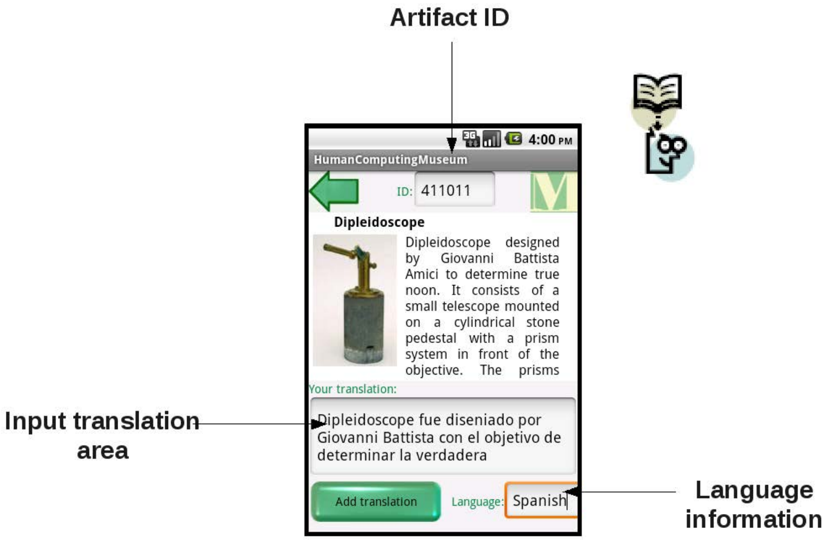

Fig. 3. Submitting information to the collaborative database

Since the application retrieves information from the server within the museum, it implements an HTTP mobile API developed for managing the requests to the information system. The server side consists of a Servlet implementation deployed on Tomcat and an SQLite database. The system provides special WAP content that fits the mobile screen. From the client perspective, the application was developed for mobile phone handsets with the Android platform, therefore the application was written in Java. As a hardware requirement in order for the application to run, the handset must have a touchscreen for sensing when the user has selected text.

6 Analysis and Results

The next step is to refine the design by testing the prototype system with users. So far, we have performed a small-scale pilot study, mostly to verify that the technology works. We set up an artificial environment in one room. Real museum content (instructional descriptions) was taken from the SMARTMUSEUM project, specifically the Brunelleschi Museum in Italy. Pictures of some of the artifacts were printed together with their respective information and distributed around the walls in the room. The server application managing the translation feature was deployed locally. Thus, retrieving information was from a remote site (the museum) and submitting information happened at the local site, i.e. the room (cf. Figure 1). The mobile application was tested using three different devices, one Samsung Galaxy 5, one LG GT540, and one HTC Desire, all three of them with the Android API 2.2.

Once the environment was set up, handsets were given to some users to test the application. All the text that was translated by the users was stored in the database. Due to each exhibit having a unique identifier, when one user requested to submit a new translation, the related content was retrieved depending on the language requested, and it was first shown to the user with the aim of having him or her improve it before adding a new one.

The experiments showed that different persons may translate the same text, in some cases leading to shorter or longer descriptions. In such cases, the system cannot merge everything into a single document. However, it can present to the author of a single translation all related translations. It might select the best translation depending on which of them has been read more often or more intensely. This is a ranking problem. In SMARTMUSEUM, an accelerometer feature can determine how a visitor moves and interacts with a physical exhibit in the space around it.

Each sentence that is translated to one specific language depends on the cultural background of the user. It can vary according to his or her criteria. In some cases, phrases are more elegant, and in others simpler, as there are different styles of writing the same sentence. On the other hand, from the point of view of the museum, content which is translated several times must be the one which is most interesting to the users. Content can thus be redefined to present clearer and more interesting facts for future visitors.

Another issue is related to the diversity of words from the same language in different countries. Colloquial words are used in some translations which can only be understood by people from the same region or country. For example, the phrase "this instrument allows you to determine true noon within 5–10 seconds" (from the experiment data) could be translated to common Spanish as "este instrumento le permite determinar medio dia dentro de 5–10 segundos". Another Spanish version, but from a person from Guatemala, might be "este instrumento te permite a vos determinar medio dia dentro de un margen de 5–10 segundos". Notice the inclusion of the word "vos" as colloquial language and the additional word "margen" as an extended version of the sentence to explain the meaning in a better way. The power of the Human Computation system relies not only on people's language skills, but also on personal criteria, accuracy of words, etc.

All in all, it seemed that human-translated sentences turn out to be well-structured and understandable. They would probably support visitors' thinking in a better manner than a machine translation would.

7 Conclusions and Future Work

The article presented an application scenario combining advantages of mLearning and CSCL while making use of the Human Computation vision. Humans become involved teaching other learners, providing their mental processing capabilities, as well as their eyes and ears as "sensors" in a Pervasive Education scenario. We have demonstrated this idea via a museum tour application in which visitors collectively translate exhibit descriptions to foreign languages using their own mobile phones. The application works, but is still very much in a proof-of-concept stage, opening up interesting directions for future research. We need to improve the mobile aspects, improve the cooperative aspects, and plan sophisticated user studies.

Making better use of the mobile scenario, we should implement new methods for identifying exhibits from the user's point of view. As in SMARTMUSEUM and other projects, obtaining the ID could be done, for instance, by scanning a bar code or via positioning sensors (further solutions are discussed e.g. in [12]).

Examining cooperation, the whole issue of concurrency needs to be dealt with. What happens when visitors work on the same text at the same time? In addition, what happens if a user disagrees with another user's previous work and replaces it with a very different translation? How can we assure quality, bearing in mind that we may be dealing with technical terminology or subtle descriptions of social conditions?

Approaches to these problems can probably learn a lot from the collective editing of Wiki sites on the Web. *MediaWiki*, the quasi-standard in Wiki software, offers features like versioning, rollbacks, and handling of read-write conflicts. Content and quality can be negotiated collaboratively on a discussion page.

Our application is already running on mobile phones, hence a new author might contact a previous author asynchronously via text messaging, or synchronously through a call – given that the respective user has given consent that he or she may be contacted (this raises privacy and security issues). It might even happen that two users meet in person in front of an exhibit. Suddenly, the situation turns into a blended-learning scenario. In fact, the pedagogical setup might encourage such discussions to take place, thus situating technology-enhanced learning in real-life, human-to-human encounters.

Human factors need to be examined in real-life user studies taking place in actual exhibitions. Following the ideas of participatory or user-led design, this could happen in an iterative fashion, where the design is continuously improved based on experiments and focus group discussions with users. Among the issues to be examined should be motivation and acceptance.

How can we motivate museum visitors to make the extra effort and provide a translation or two during their stay? Applying external motivational measures, one could reward dedicated contributors with free tickets or items from the merchandise shop. Stimulating intrinsic motivation, one could appeal to people's personal interest in the topic. After all, many visitors will be at the museum out of curiosity about the exhibition themes. Contributing a translation could be experienced as a way of becoming involved with an exhibit that has caught a visitor's special interest. Web users' dedication to contribute to Wiki pages may pose as a role model here as well.

Another alternative would be to turn the translation activity into a game. In Section 3, we noticed that much of the related work does come from serious games researchers. For example, museum staff could hand out a quiz at the entrance, asking foreign visitors to walk through the exhibition and answer questions about exhibits in their own languages.

Motivation to do the task would relate to the "perceived usefulness" aspect of technology acceptance (cf. the Technology Acceptance Model [10]). Another important factor is pedagogy and didactics: How does the scenario support learning?

The second aspect of technology acceptance, ease of use, needs to be studied as well. How can we improve the usability of human computation in mobile, cooperative scenarios? This will involve studies of software usage (screen design, design of cognitive tasks and collaborative processes, user-to-user communication), hardware usage (interaction between the mobile device and exhibits, support of typing on mobile devices), an analysis of the interconnected mixed-reality setting, and, last but not least, finding ways of providing easy access to the translation task as such. For instance, it may be worthwhile to provide a default translation, obtained via *Google Translate*.

Our scenario has examined the power of crowds of learners helping each other without meeting in the same space or at the same time. But even teachers might act in crwods, e.g. in a scenario where they would collectively review learner work. To assure quality in our museum application, a larger group of language teachers might collectively and collaboratively review the learner-produced texts. This might even include improving the writing style. Furthermore, content might be added by experts in the exhibition domain, by contemporary witnesses providing their own narratives, by artists, storytellers, etc. Crowds are not only knowledgeable, they can be creative as well, if we think of photographers posting and collaboratively tagging or commenting images on the Web, or the creative power of participants in a collaborative massively multiplayer online game.

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Touching Nametags with NFC Phones: A Playful Approach to Learning to Read

Jukka Riekki, Marta Cortés, Marja Hytönen, Iván Sánchez, and Riitta-Liisa Korkeamäki

University of Oulu, 90014 Oulu, Finland
firstname.familyname@oulu.fi

Abstract. Near Field Communication (NFC) technology was developed for mobile devices from RFID technology. It enables new kinds of learning applications that are based on touching objects with phones. When an object is touched, a phone reads data from the object's NFC tag. An application interprets the data and acts consequently. We report our first pilot study of an NFC-based learning application that supports children in their efforts in learning to read. We tested the application in one kindergarten with 23 three-to-five-year-old children with their two teachers. The results suggest that NFC is a suitable technology for learning applications and that the tested application had an effect on the children's emergent letter knowledge although the activity period lasted only for two weeks.

1 Introduction

Near Field Communication (NFC) technology is based on RFID and mainly targeted at mobile phones [1]. Phones are equipped with NFC readers and NFC tags are placed in the environment. NFC tags are stickers containing an antenna and a chip with writable memory. When a user places a phone near a tag, the phone reads the data stored in the tag and processes it. A phone application can, for example, store the data, present the data to the user, or perform some other operation the application designer specified for that type of data. Many applications suggested by researchers read just an identification number from a tag and use it as a keyword to fetch data from the network. Easy to use user interfaces can be built by placing each NFC tag under a graphical symbol advertising the action that a user can trigger by touching that point [2]. NFC technology is now mature for large scale usage.

NFC technology enables new kinds of learning applications based on touching objects with phones. For example, a language learning application can ask a user in a foreign language to touch a certain object. The applications can be brought to the everyday environment, that is, NFC enables location and context aware learning applications. This technology offers great potential, specifically for children, as it enables more natural learning by exploring and creating direct links between physical world and digital data [3]. Therefore, NFC could be a key technology in edutainment, as it facilitates the implementation of gamelike learning applications.

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However, to find out how NFC technology should be used in learning applications – to achieve good learning results and a good user experience – this new technology has to be studied in the context of learning. Specifically, concrete prototypes have to be implemented and tested in real environments, as an unfamiliar and artificial laboratory environment could cause unusual behaviors which would not apply to other settings. The environment should have social relevance for the users and offer opportunities for exploration in a playful way with the applications. Moreover, we agree with the statement given at the 2005 UbiApp Workshop: "Real-world deployment is the only way to investigate fully the complex three-way interactions between [ubiquitous computing] applications, their users, and the environment" [4].

In this paper, we report our first pilot study of an NFC-based learning application that supports children in their efforts in learning to recognize words. We tested the application in one kindergarten with 23 three-to-five-year-old children with their two teachers. This application was selected due to the importance of learning digital literacy in modern society [5]. With the application, children can practice associating the written names of their peers in a kindergarten with the pronunciation of the names – by touching nametags with NFC phones.

2 Background

2.1 NFC Technology and Physical Browsing

RFID tags are small and slim electronic components made of an antenna and a microchip. The microchip makes use of non-volatile memory to store data permanently. RFID technology has been used for several years in the field of pervasive computing since it permits creating links between the real world (the world surrounding us) and the digital world (applications and computer devices) [6]. Objects in the environment can be associated with a webpage, with online documentation, or with a data record. The necessary data to create those links, for example an identifier that uniquely determines a certain object, can be stored in an RFID tag attached to that object. An RFID reader can access this information and communicate it to an application.

NFC is a short range wireless technology for data transfer between two devices within five to ten centimeter distance from each other. NFC operates in the 13.56 MHz band and permits a data rate between 106 and 424 kbps. This technology is fully compatible with existing RFID tags working in the high frequency (HF) band. Actually, NFC technology can be viewed as an extension to RFID since it allows half-duplex communication between two NFC readers. NFC supports three different communication modes, namely, Reader/Writer mode, Peer-to-Peer mode and Card Emulation mode. In the Reader/Writer mode an NFC reader can read data stored in an NFC tag and write data to it. The Peer-to-Peer mode permits a bidirectional communication between two active NFC devices (i.e. readers, not NFC tags). This NFC mode is quite similar to Bluetooth technology. The main advantage over Bluetooth is that the handshake (initialization) process is much faster and easier, while the main disadvantage is the lower speed. Finally, the Card Emulation mode permits using an NFC device as a contactless card (e.g. a credit card). This mode enables payment and ticketing applications. For the experiments reported in this paper, we have used the Reader/Writer mode.

Although RFID has been available for several decades it has been mainly used either for research or for industrial applications; mainly for tracking of goods. RFID has not been integrated into daily use. One possible explanation is that there has not yet been any right technology catalyst to boost deployment of the technology. NFC might be such a technology [7]. Moreover, NFC readers can be integrated into mobile phones which have become everyday objects. A mobile phone has both computational and communication capabilities as well as a user interface – all that is required to build both stand alone and networked NFC applications. Thus, mobile phones have the potential to bring RFID and NFC to daily use, specifically as several phone manufacturers such as Samsung and Nokia already have NFC phones on the market and NFC phones are expected to mushroom in the next couple of years.

Classical graphical user interfaces (GUIs) present interactive elements such as icons and menus on a screen. Users utilize a keypad, a pointing device (mouse, joystick) or more recently their own fingers (to touch screens) to activate those interactive elements. Physical browsing [8], in contrast to classical GUIs, offers a different approach to user interfaces. Users interact with applications by pointing or touching objects in the environment instead of icons or menus on a screen. NFC is an enabler technology for building this kind of interfaces. NFC tags are attached to objects placed in the user environment. A phone with an NFC reader reads the data on a tag when brought near that tag. A user interacts with an application running on the phone by touching tagged objects. Touching an object triggers an action in the same way tapping an icon on the phone's touch screen does. Touching might start a specific application, open a web page, make a phone call, play a sound, or show a picture on the phone's display, for example. We advertise NFC tags to potential users by graphical symbols placed on top of the NFC tags. These symbols have two tasks. Firstly, they announce to users that they can interact with those objects using NFC technology. Secondly, they give information on the actions that are triggered when the tags are touched. Thus, an NFC tag and the corresponding symbol form a two-sided interface between the real and virtual worlds: the graphical symbol communicates an action to a user and the data in the tag defines a command triggering the application to perform that action.

Summarizing, NFC technology can be used to create user interfaces for mobile phone applications which are embedded in the user environment. Instead of interacting with a GUI on the mobile phone, a user interacts with objects in the environment.

2.2 The Theoretical Background for Learning to Decode Words

The theoretical background comes from the theory proposed by Ehri [9] that children progress in their reading development through phases. Children start their development by recognizing words by their visual characteristics instead of using letter-sound relationships. Often these words are logos which the children learn to recognize in their environment such as the names of the shops or labels of toys and food baggage. This type of reading is limited to the context where these words appear and children often don't recognize these words in standard print. Therefore, it is necessary for them to learn the symbol system of letters and their sounds required for conventional reading in alphabetic writing systems [9],[10]. The process of learning the alphabetic system is gradual. After the logographic phase described above the children reach the rudimentary alphabetic phase when they learn to recognize a few letters. Most often recognition is based on familiar letters either as an initial or final position in the word [9]. Because children's word recognition is rather random, they end up with faulty results in their recognition. For example, they may recognize the word house as home. However, the rudimentary alphabetic phase is useful for learning more letters and their sounds. In fact, Ehri [9] suggested that letter knowledge is the key for alphabetic coding and entering into the full alphabetic phase which is one of the main goals in reading instruction.

Similarly with commercial logos children learn to recognize their own names, as well as siblings', parents' and peers' names [11]. Indeed, children are able to recognize names although they don't know the letter names of the names. In doing so, they recognize the names as logos but they may pay attention to the initial letters which they often call my letter, mummy's letter, dad's letter etc. to demonstrate ownership. However, names may offer a pathway for children to learn letters and may help in learning the alphabetic principle especially when recognition is connected to printing the names [10], [11], [12].

Research and theory support the idea that names are useful in the process of learning the letter names and moving from the logographic phase to the alphabetic phase. In addition, activities with the names can be naturally integrated into daily routines in kindergarten. Furthermore, children seem to be motivated to use technology and play with it while learning to read [5]. Therefore, in this study NFC technology was used to afford opportunities for young children to use their names for their logographic reading and learning the letters.

3 Related Work

In the last decade, there has been an increasing interest in research named as m-education or m-learning. In most work, 'm' stands for "mobile" but the definitions of the complete terms vary [13], [14]. Laouris & Eteokoeous compiled and analyzed the definitions related to m-education [13]. From a simple expansion of e-learning towards mobile technologies to considering the mobile device as a pervasive tool, almost all the approaches agreed that this term involved the use of mobile devices. Lam et al. define m-learning as "a new type of learning which allows people to learn across context and without restriction of location", and studies its evolution jointly to mobile technologies [14]. Mobile phones are utilized in many projects in learning context. For example, [15] emphasizes the use of mobile phones over other mobile devices (PDA's) because of the price. In this work, mobile phones are utilized in teaching technical English vocabulary to first-year undergraduate students.

We are not aware of the use of NFC phones for learning literacy. However, there is a related research from the United States where three- and four-year-old children learnt letters and alphabet songs with cell phones [16]. In the application children had video clips where letters were introduced in alphabetical order, 3-4 letters a week for eight weeks. The application was drawn from Ready to Learn content, Sesame workshop, where a puppet introduced a letter of the day and several words beginning with that letter. The application also included music and alphabet songs. According to the parents' pre-post-test survey, the children's letter knowledge grew. However, statistically significant differences were found only with children living above the poverty line. The authors concluded that cell phones are a potential medium for delivering the program; similar programs have been seen earlier in TV programs in the United States. The survey also revealed that children liked the program and requested to view the video. But some parents found difficulties in using the phones according to the instructions. Therefore, it is important to test in this study how children learn to use the phones and how names work as a context in learning emerging literacy knowledge.

Applications utilizing the same interaction paradigm, touching, and NFC technology have been suggested for attendance supervision [17] and content collection [18]. Learning applications and toys presenting content about a topic related to a RFID tag's or 2D barcode's location have been suggested as well. All these applications are for older users.

The prototype built in the LAMBERT project [3] and the ShadowBox [19] are targeted to the same age group, three-to-five-year-old children. Both these systems consist of toys equipped with RFID tags and a computer equipped with an RFID reader. ShadowBox teaches children the representational relationship between words and their meanings. The toys are wooden blocks that children put in a box; the task is to find matches between shapes of items and written word equivalents. A correct pairing is rewarded with an animated video; an incorrect one triggers an audio feedback presenting the pronunciation and the spelling of the word. The LAMBERT project focused on helping deaf children acquire language and expand their scaffolding of concepts. When a child placed a toy near the reader, a short multimedia presentation about that object was shown on the computer display. The main differences from our work are the application area and our use of mobile phones that allows integrating the application to the children's environment using common devices instead of usage in a single place where a computer and an RFID reader are installed. Our application uses NFC technology for faster paced interaction more intertwined with the real environment and requiring less focusing on the devices' user interfaces.

4 Application

The application supports three-to-five-year-old children in their efforts to learn to read. The application is installed on NFC phones (Fig. 1). Children use the application by touching NFC tags with phones – a phone instructs a child about the tag to touch and gives feedback after a tag has been touched. As the application is based on touching objects with a handheld device, visual and audio capabilities of the device (screen size and resolution, audio quality) were not the primary concerns when we were selecting the handheld device. Individual words and simple animations are shown on the display and audio clips are played. We selected the Nokia 6131 NFC phone because it has sufficient capabilities to offer this functionality - and the phone fits in small children's hands.

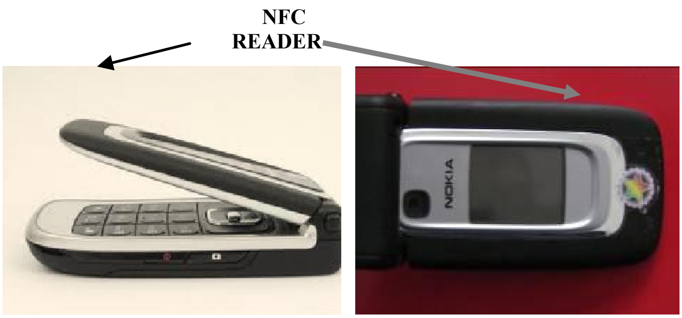

Fig. 1. The NFC phone used in the testing

Fig. 2. A nametag “JARNO” equipped with an NFC tag and a star icon. The tag is placed behind the star icon.

The staff in a kindergarten usually attach children's nametags to chairs, coat racks, beds, drawers, and so on. We equip these nametags with NFC tags; star icons identify tag locations. A tag and the corresponding star icon are placed at the right edge of each nametag (Figure 2). A small star icon is also attached to the position of the NFC reader (Figure 1, right), so the children can be instructed to touch the stars on the nametags with the stars on their phones.

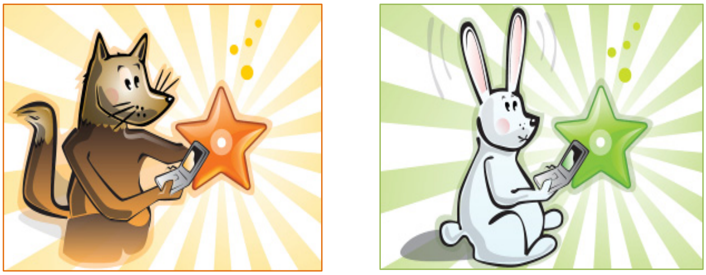

Fig. 3. The poster for starting the application in the two modes, exploring and practicing

The application is started by touching a star icon on a small poster placed on a wall in the kindergarten. The poster shows an animal touching a star with a mobile phone similar to the one used by the children. In other words, the animal instructs the children on how to start the application. The poster is shown in Figure 3.

The application has two modes. The first, exploring mode, is started by touching the star icon next to the fox character (Figure 3, left). Therefore, we also call it the "Fox game". In this mode, a simple animation is repeated on the phone display: a hand holding a phone touches a star icon (Figure 4). When a nametag is touched, the phone says the name aloud and also shows the name on the display for a while; then, it returns to the animation. The state diagram for the application in the exploring mode is shown in figure 5.

Fig. 4. The animation shown on the mobile phone's display

The second, practicing mode, is started by touching the star icon next to the rabbit character (Figure 3, right). Consequently, it is also called the "Rabbit game". In this mode, the phone shows a name and waits for a child to touch the corresponding nametag (i.e. the star icon on that nametag). If no nametag is touched within a period of time, the phone says the name aloud. If the correct nametag is touched, the phone says "Great" (in Finnish) and says and shows the next name. If a wrong nametag is touched, the phone says "Please try again" (in Finnish) and says and shows the same name again. The state diagram for the application in the practicing mode is shown in figure 6.

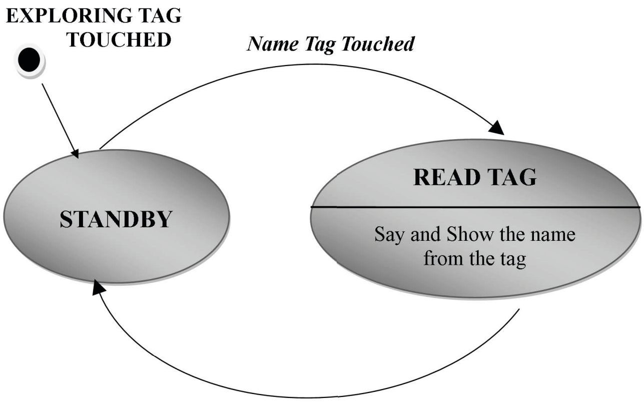

Fig. 5. State diagram for the mobile phone in the exploring mode

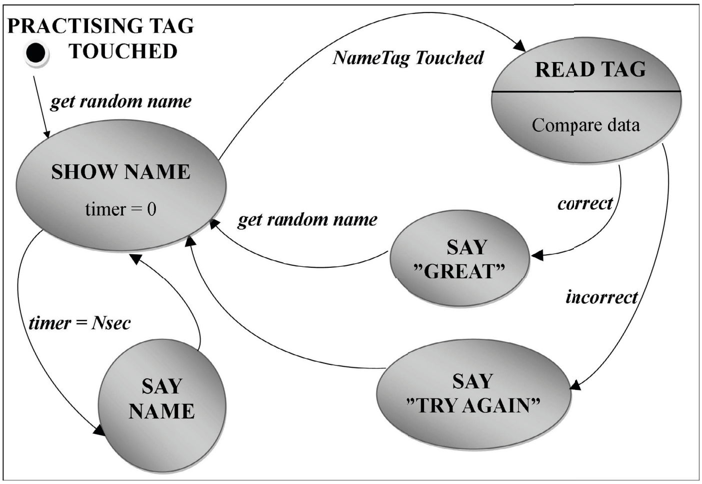

Fig. 6. State diagram for the phone in the practicing mode

5 Procedures in the Study

We selected one kindergarten for the pilot study. We tested the application with 23 three-to-five-year-old children with their two kindergarten teachers. The main objective was to study how the application worked in children's natural environment as described above. In other words, we investigated (a) how children learned to use the technology and how interested they were in using it, (b) how the names worked as a learning context in using their emergent literacy knowledge such as their letter knowledge and their ability to recognize familiar names and (c) how the children progressed in their emergent knowledge. This pilot study lasted for two weeks in the spring of 2010. Parents were informed about the project by the kindergarten teachers.

Both the parents and the teachers discussed the project with the participating children. All the parents gave a written consent which included permission to use the children's pictures for research purposes.

We tested all children individually, both before and at the end of the pilot. We were careful to use unobtrusive and sensitive research methods and doing research with children – not on children. Special emphasis was put on being sensitive to the children's development stages and reactions. Each child's development stage was considered in testing individually their knowledge: testing started from uppercase letters and proceeded to lowercase letters, to the child's own name, to other children's names, and to phonological awareness when a child was considered ready for such testing. The tests were developed to be playful [11] and children looked at one letter at a time through a "magnifying glass". Children's names were printed with capital letters on cards resembling playing a memory game typical of that age. Similarly, for testing phonological awareness the context was made playful by using stories and cards.

Apart from the abovementioned data of the pre- and post-tests, we were also interested to know how each child used the application on the mobile phone. Therefore, a log system for the application was implemented. We collected all the data related to the usage of the application by each child. When any of the two starting tags was touched with the phone, it recorded the mode name. If the exploring tag was touched, the phone recorded the subsequent touches. That is, the phone recorded which name tags the child was exploring. From timestamps included in the records, we were able to calculate how long the child played with the phone. Likewise, data was recorded for the practicing mode. The name proposed by the phone and the different attempts (if any) of the child to find the correct answer were recorded.

Besides the quantitative data we also videotaped and took pictures of some of the children's activities. A research assistant also made some observational notes. These data provided an important source in evaluating the feasibility of NFC phones and names as a context for learning.

The selected kindergarten had nametags in common use: all children had their nametags in chairs, coat racks, beds, drawers, and so on. We equipped the nametags with NFC tags and star icons and attached a poster on the wall, as described in the previous section. All in all, around 50 NFC tags were placed in the kindergarten. Moreover, we delivered 13 NFC phones to the kindergarten.

At the beginning, the children were instructed to first touch a star next to an animal character in the poster. In the exploring mode, the children were instructed to touch star icons on the nametags. In the practicing mode, the children were instructed to first listen to a name and then touch the corresponding nametag (Figure 7). Teachers had participated in developing innovative literacy activities in earlier research projects; therefore, they needed only a brief introduction to the technology. This was done in the course of one morning in the kindergarten by some of the authors of this paper.

Fig. 7. A child is touching the nametag "ANNIINA". The star icon is on the right, behind the phone.

6 Results

Although our main interest was not to investigate the progress in children's name and letter recognition, we present this data first to provide a background to the other results. The test results before (pre-test) and after using the application (post-test) are summarized in Table 1. In the pre-test, seven children recognized all of the children's names. But there were five children who recognized only their own name. One child did not recognize even his own name. The Finnish alphabet includes 28 letters but only 21 letters are needed to read original Finnish words. Five children were able to recognize 20 or more uppercase letters and three children recognized ten or more. Note that the playing time was recorded for the first, Fox game (i.e. the exploring mode) for reasons explained below.

Post-test results show that seven children recognized all of the children's names, and four children's name recognition improved by several names: one child recognized 15 names more in post-test than in the pre-test, three other children recognized about seven to nine names more after playing. But there were two children whose name recognition did not develop at all. On average, the children recognized about four names more in the post-test than in the pre-test. There were five children who recognized 20 letters or more in the pre-test, and after the two-week experiment seven children recognized 21 or more letters. Interestingly, most children's letter knowledge improved by one to four letters although letters were not focused in the play at all. Some children who did not learn the conventional letter names mentioned in the post test letters based on whose letter it was.

Table 1. The pre- and posttest results and the playing time in the Fox game. Both the number of recognized children's names and uppercase letters and the changes in the recognition are listed. 'A' indicates that all the names or letters were recognized.

Child	Names		Letters		Playtime		Child	Names		Letters		Playtime
	pre/post	+/-	pre/post	+/-	(min.)			pre/post	+/-	pre/post	+/-	(min.)
1	23/23	A	2/3	+1	43		13	1/3	+2	0/0	0	11
2	23/23	A	21/23	+2	10		14	11/20	+9	0/0	0	16
3	0/4	+4	3/7	+4	13		15	9/8	-1	0/1	+1	14
4	19/23	+4	17/21	+4	64		16	1/1	0	5/5	0	5
5	2/17	+15	1/2	+1	22		17	23/23	A	28/28	A	3
6	23/23	A	28/28	A	61		18	23/23	A	26/26	0	51
7	23/23	A	20/23	+3	45		19	23/23	A	19/19	0	11
8	1/1	0	0/2	+2	13		20	1/4	+3	2/6	+4	19
9	15/23	+8	9/10	+1	26		21	7/9	+2	4/8	+4	9
10	20/23	+3	2/2	0	18		22	8/12	+4	19/21	+2	15
11	10/17	+7	3/4	+1	26		23	2/6	+4	3/6	+3	33
12	1/4	+3	0/0	0	48							

The NFC application was voluntary for children. Therefore, the playing time varied from 3 to 64 minutes. If a child played on average 19 minutes or more, s/he learnt an average of 6.3 names but only about 1.8 letters. Children playing 9-18 minutes learnt 2.9 names and 1.5 letters on average. Those who played 8 minutes or less did not gain any new knowledge. The children who already knew all the names or letters are not included in the corresponding averages.

The first game, "Fox game", which we used as an *exploring mode*, was developed to be as simple as possible to test how small children are able to learn to use NFC technology in the context of their own names. The game only gave the children's names in two modes: in written and oral mode one at a time. Children learnt very quickly how to use the technology and they were excited about the names as they ran to their peers to show "my name" and "your name". Although the children were motivated to play, there were differences between girls and boys. The girls played 40.9 minutes and the boys 16.6 minutes in average. The girls also knew more names in the beginning therefore the context of game was more familiar for them.

But because there were, despite the children's young age, children who knew all the names and enough letters to decode the Finnish words, we introduced another game, the "Rabbit game", which we called *practicing mode*. This game was more complicated and challenged the more advanced children. The purpose was to find out how children use their knowledge of name recognition to define their phase and strategies in name recognition.

The "Rabbit game" first gave the name on the phone in two modes (written and oral) and then the child was to move around in the three rooms to look for a nametag (in their genuine places) to correspond to the name s/he had seen and heard on the phone. At the destination the phone gave a feedback for the response. The phone data showed that some children did not play this game at all, because the choice was not entirely based on the children. Instead, the teachers may have been selective in introducing the Rabbit game to some of the children only. Therefore, Table 1 does not include the playing time for the Rabbit game.

But the data which the NFC phones recorded from the Rabbit game was very interesting, because it revealed how children recognized the names. As described above, children used strategies typical for logographic word recognition, which meant that they confused names with the same initial letter or names with the same letter combination. The most confusing names were MARKUS and MARCUS which made the children try them several times in a row. More obvious logographic reading took place, however, with names having the same letters in a different position and order but still resembling each other, such as ANIINA and HANNA (note that all the names were printed in upper case letters). Even children who had recognized these names in the pre-test confused these names. Similarly, there was confusion between names such as EEMI and TEEMU. Initial letters were used as a cue for recognizing names e.g. JARNO, JOONA JESSICA, NIKO, NIILO, SOFIA, SISU, VALTO, VILMA and VÄINÖ. Final letter position confused children only with the two names JOONA and HANNA which have the same final two letters.

Based on the data recorded by the phones it seems obvious that the children started to use their letter knowledge as a cue for recognition. In fact, children who had enough or almost enough letter knowledge first made lots of errors, but touched the correct names later. This means that the children began to use their letter knowledge more accurately, looking at their order rather than using their logographic memory.

7 Discussion

We reported our first pilot study of an NFC-based learning application. This and our earlier prototypes (e.g. [2],[18]) illustrate the potential of NFC user interfaces. As predicted, all children learnt to use the application quickly. While we were instructing the teachers to use the application, some of the children spontaneously took some phones and started using them without any direct instructions. Some of the children even learnt by themselves, without any instructions, how to use the phone's camera to take pictures and videos of their peers.

NFC technology can be integrated into the environment and no technology-specific features need to be remain visible. The users can be instructed to use natural actions of touching, actions that are one of the first ones we all learn in our early childhood. This matches well the concept of calm computing [20]: computers vanish in the background and support us in our everyday activities without demanding too much focus or disrupting our activities.

Interaction by touching is easy. The users of this application are so young that they have not even learnt to read yet – and hence cannot use conventional user interfaces presenting textual information. Moreover, the phone keypad is not needed at all. NFC user interfaces are suitable for user groups that cannot read, have difficulties to read due to poor eyesight, or have difficulties in using the keypad, for example. One could develop NFC applications for such users using mainly graphical icons, images, animations, vibration, sounds, speech, and touching for interaction with the user.

An interesting observation is that quite modest phones are sufficient for NFC applications. As the interaction is based on touching objects in the environment with a phone, advanced GUI features and sensors like high-resolution touch displays and gyroscopes are not needed. Many useful applications (like the one described in this paper) do not even need network connectivity. The 6131 NFC phone model has limited features. However, for this application – and for many other applications utilizing the NFC reader – this model has all the features needed. In fact, it has even better usability than some newer NFC phone models, as the location of the NFC reader and the slightly curved form of the phone when opened enable quite natural touching actions with surfaces at different orientations.

Based on the results of the pilot study, it seems that children who already had some prior knowledge benefited more from the activities during the two-week period. It seems that knowing ten letters or more is instrumental for rapid growth of print related knowledge. The results suggest that the activities affected children's emergent knowledge, although the activity period only lasted for two weeks. Furthermore, during this period the children played at most 64 minutes – just a bit longer than one Finnish lesson at school, where about 7 lessons per week for several months have been reserved for teaching letters and their sounds. Considering the very short time the children spent playing, it is surprising how children were able to self teach with the phones not only the technology but some emergent literacy knowledge as well.

The time spent with the learning application varied among the children, as did their motivation. However, many children were keen on playing with the mobile phones and wanted to take them home to continue with the activities. The child's own name appeared to be a very important piece of text. However, there might be space for developing the application to use children's popular culture, for example as a context for learning the literacy concepts.

Indeed, the only text our application presented were the names of the children. It is very obvious that the children recognized the names as logos as children do in their process of becoming conventional decoders [9]. However, the names provided a context for learning the letters [12], [5] although the letters were not introduced at all. The results indicate that the application can facilitate learning letters, which is a prerequisite for learning to read. Moreover, this kind of application can familiarize children with new technology, multimodality, and emerging new literacy skills [5]. It is likely that this application would support acquiring decoding skills, if it was available for a longer period. However, more research is needed before the effect of the application can be estimated in more detail.

Interestingly, the literacy activities changed from individual practice to collaborative peer interaction. The children especially liked to share their texts on mobiles by showing them to their peers, and invited others to listen to their names. In addition, children were eager to ask for help and to advise their peers in using the mobile phones for name recognition. The teachers were very motivated to continue the activities. Indeed, it was their initiative to continue developing and making small changes to the application for the next implementation. It is worth noting that the teachers as well as researchers regarded the activities as different from both computer and pen-and-pencil literacy activities, because the phones allowed children to move around instead of sitting still. The application met the children's need to move. Therefore the activities were rather playing than learning exercises.

We have added functionality to the application and are currently testing it in a kindergarten. The new version also presents individual letters and asks children to touch the starting letter of a given name. We are considering control groups as they would produce more information about this application's effects on learning.

This was the first application. NFC technology offers remarkable potential to develop new learning applications that focus on acting in groups in a real environment rather than using conventional educational material and computers in a classroom. At its best, this technology can facilitate inclusion in learning: children that do not learn as fast as others can use this kind of applications to catch up with others. We will continue to develop new learning applications utilizing NFC technology. In fact, such a study is already in progress.

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Learning, Reasoning and Modeling in Social Gaming

Heinrich Söbke[1], Javier Alejandro Corredor[2], and Oliver Kornadt[1]

[1] InnoProfile "Intelligentes Lernen", Bauhaus-Universität Weimar, Coudraystr. 11a, 99423 Weimar
{heinrich.soebke,oliver.kornadt}@uni-weimar.de
[2] Department of Psychology, Universidad Nacional de Colombia, Ciudad Universitaria, Cra 45 26-30, Ed 212, Of 211. Bogotá, D. C. -Colombia
jacorredora@unal.edu.co

Abstract. In the last two years, the introduction of social gaming - playing video games in the context of social media - has created new possibilities for playing and learning. Social games attract a huge base of players that represents a different demographic than traditional video games. For this reason, it is worth asking whether or not they can be used for educational purposes. This paper examines the comments made on a single article within a wiki devoted to the characteristics of the Facebook-based social game FarmVille. In order to identify whether or not there is any evidence of learning or knowledge-construction around the game, this study explores and analyzes the conversations around the wiki article. Such evidence is reviewed with the goal of identifying the educational potential of social gaming in general, and FarmVille in particular.

Keywords: social gaming, social games, learning habits, FarmVille, game based learning.

1 Introduction

A fundamental motivation for all game-playing is learning [CPL03]. Gee [Gee05b] observes that many successful commercial video games are designed to encourage learning. These statements, among others, point to the fact that commercial video games can be used in education. This is very important because commercial video games can accomplish significant tasks for content learning, without being designed specifically for education. Given that the development of specialized educational games is an expensive and difficult task [FAS06] and that there are a lot of examples of unsuccessful combinations of educational content and game mechanics [Kir02], the role of commercial video games in education needs to be seriously considered. Civilization and SimCity are examples of the fruitful educational use of commercial video games with customized scenarios [Squ03, Ada98, Gab07]. Squire and Durga [SD09] for example, have shown that Civilization can be used in educational environments to develop historical

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thinking among at-risk populations. In general, research shows that commercial video games can be used to teach and develop skills. For example, at the University of Florida, the video game StarCraft has been used as a means to teach about “21st Century Skills” [Pol10] and, at Wabash College, the video game Portal has been employed to support a class about philosophical questions [Abb10]. Furthermore, Steinkuehler and Duncan [SD08] showed that educationally unaccompanied gameplay also fosters scientific habits of mind, such as reasoning and modeling. On one hand, video games support situated learning. In most traditional schooling, there is a separation between what students have to learn, the tasks' goals and the social meaning of content. Video games weaken this separation by presenting contents as related to goals and identities. When a player learns something in a game, he learns its uses within the game and its meaning within the community of players [Gee08]. Additionally, video games foster learning within the zone of proximal development. Contents and tasks presented to learners are always close to their actual level of performance [Gee05a]. In video games, players usually compete in groups that have a similar level of performance. This fact allows new players to enter gradually into the practices of the gaming community.

Additionally, video games produce learning because they create social situations in which players can share information and discuss content [Ste06]. For example, massively multiplayer online games (MMOs) motivate players to conduct complex calculations and share strategies in chat rooms and discussion boards [SD08, SW09]. In this sense, learning in a video game happens not just within the game, but in the social activities that the game produces. For this reason, studying learning within games necessarily implies also exploring the interactions that happen in spaces for online participation such as discussion boards, wikis and chat rooms. For example, Steinkuehler and Duncan [SD08] have shown in a careful study of online interaction how players of MMOs collaborate to build knowledge and conduct processes of collective reasoning that develop scientific habits of mind. As will be seen in the methods section of this paper, this study uses a similar strategy to uncover the reasoning processes that occur in social gaming.

The social nature of video games has been well studied [SW06]. Video games are modifying the way young people interact and are becoming fundamental spaces for social interaction. They are filling the role of third places in contemporary societies. Third places are spaces of interaction, separate from work-places and homes, that citizens use to interact and build social support networks. These spaces have special characteristics (e.g. playful and regular) that make them ideal for building social capital. Video games and other online spaces have become the new third places due to the slow but constant weakening of physical third places.

Social media, like video games, have become another contemporary third place. In social media, people share ideas and values, and discuss a variety of topics [Boy10]. Social media becomes a space where people can present their identities and establish ties with a community of friends [BE08]. For this reason, social media accomplish an important function for the development of healthy social identities in contemporary societies.

The rise of social networking services such as Facebook has facilitated the creation of games within these platforms. Many of these games require players to interact with other members of the player's social network, as a part of the game mechanics - hence the term "social gaming". This interaction creates social dynamics that extend beyond social media. These dynamics include discussions in wikis and information exchanges in virtual forums. It is possible that these social dynamics facilitate learning as it has been observed in other types of games [SD08]. Additionally, these types of games are self sustainable. They do not need a large investment from educational or governmental agencies. Social gaming generates huge revenues for the game providing companies. Driven by a business model where the entry in these games is free, but extras have to be paid as they are used, social games are expected to generate a turnover of $826 Million in 2010 [Bra10].

Although these games fulfill most formal definitions of a game, for example those given by Schell [Sch08], they are often not considered "real" games by established ("hard core") gamers. One reason for this phenomenon may be that social games open a new market with a different audience than traditional gamers. Because they are effortlessly available for everyone who is able to join a social network service, there is almost no technical entry hurdle. This makes social games accessible to different demographics: whereas the core target group for typical video games is 15 to 25 year old males [Goa10], the typical social gamer is older, and the portion of female players is higher [Sno10]. Furthermore, because social games are more casual and have shorter continuous periods of game play, they tend to have shallow game mechanics [Goo09] - mostly click and reward - which do not fit with the motivations of hard core or traditional gamers. They are marked as "dull, repetitive, and derivative" [Chi09]. Ian Bogost, the creator of a Facebook social game parody named "Cow Clicker", points in an interview to the compulsion with which social games are often played and to a phenomenon he calls "optionalism", the possibility to surpass game play through the use of real money [Ale10]. However, this view of social games forgets their importance as a social phenomenon and their possible applications for education. On one hand, social games mechanics might be simple, but they can scaffold complex calculations and collaborative processes of reasoning.

On the other hand, the genre of social gaming is still at the beginning of its development. In all likelihood, as it becomes better known, there will be improvements in terms of game mechanics, user-interface interaction and complexity. Social games, additionally, might be designed and implemented using a new development model in which games are continuously reviewed and changed as they are played online. In this way, the actual game-play can be analyzed and the designer quickly becomes aware of which features work as expected and which ones do not. In this way, games can be improved in small, steady steps. In traditional game development this does not work - the steps of improvement are bigger and less frequent [Goa10, Goo09].

Fig. 1. FarmVille

One of the most popular social games is the Facebook game FarmVille by Zynga. It is a farming simulation in which the player earns experience points and money by planting and harvesting. Additionally, game-processes can be accelerated through the use of real money transformed into gamebased currency. FarmVille was released in June of 2009 [Gar09], and as of this writing, it has 53 million monthly active players and 16 million daily active players [App10].

All these facts show, on one hand, that there is a demand for popular digital games. On the other hand, they show that there is a very new, but quickly rising game genre - epitomized by FarmVille - with new kinds of players. This leads to the question: Is there any educational value in this game and if yes, what does the player learn by playing it?

Since social gaming has arisen over the last few years and is a very young phenomenon, there is almost no related scientific research available on it. Nevertheless there are some sources which point to educational elements in FarmVille: The website Commonsensemedia.org, referring to the game, points out that "kids have to master simple math and organizational skills" [Com10] in order to play it. Along these same lines, Mbalog [Mba10] states that FarmVille "can be used to teach simple mathematical tasks". Finally Russel [Rus09] also notes that FarmVille develops skills such as estimation, strategic planning and application of algebra.

2 Research Method

As a part of the FarmVille community, there exist several wikis which document the game and give the players space for discussing game-play. FarmVille provides a steady stream of new items and mechanics to keep up the tension and prevent the players from getting bored. The player must become familiar with these new items. For important mechanics, this is done by in-game displays. For new items and details, the player has to look up the information by himself - for example in a FarmVille related wiki. This paper analyzes the comments made on one arbitrarily chosen article in one of those wikis, namely farmville.wikia.com. According to Steinkuehler & Duncan [SD08], these kind of comments constitute a valid measure of learning within games.

At the time of data-collection, three new buildings had just been introduced: (1) The *Orchard* for the collective handling of trees, (2) a *Turkey Roost*, a building for turkeys and (3) the *Fun House*, a decorative building. A FarmVille player needs to know about the mechanics connected with each building: the price, the harvest and other attributes for deciding whether he or she wants to use it on his farm. The articles in the wiki present a model of a FarmVille item, which is a description of the properties related to that object. This model is built collaboratively by gamers, not by FarmVille developers or Zynga employees. In this sense, these articles are an interesting example of bottom-up community discussion. After finding rich threads of discussion for the first looked up article - *the Orchard* [Wik10] - this assumption turned out to be right.

The work done for this paper is not a quantitative analysis of the comments; it is a qualitative analysis of single examples of collaborative learning or knowledge construction. The following observations are - where possible - connected to the criteria used by Steinkuehler and Duncan [SD08], which refer to the AAAS's "Benchmarks for Science Literacy" [AAA93] as an assessment base for scientific habits. In other words, this article tries to show that the discussions presented in the wiki article represent categories of scientific thinking that match those proposed by Steinkuehler and Duncan [SD08].

There are two features of the forum that make the analysis of the comments difficult: First, comments can be made anonymously - so single comments cannot be assigned to a single user. Second, there is no searchable history of the wiki article, which means that possible dependencies between comments and article changes cannot be tracked down. In spite of these facts, the comments to the wiki article provide evidence robust enough to draw a picture of the reasoning processes that are elicited by the game.

Fig. 2. Orchard

3 Findings

The wiki entry Orchard has 161 comments in 75 threads. The average thread length is 2.15 comments. 30 comments found no answer, 21 comments were answered with one reply, 15 got 2 replies. All these comments were issued within 23 days. Before the Orchard was actually introduced on Nov, 5th 2010, 9 comment threads had been started already. The knowledge about the introduction of the Orchard - and thus the possibility to start and comment on a wiki page about it even before it was available - was derived from announcements by Zynga and from analyzing files on their servers [Far10]. The rest of the threads were started the 11 days between the release of the *Orchard* and the date of data-collection.

Most of the comments (114) were made anonymously. Only 2 users answered regularly to comments, another 14 users had questions and/or contributed occasionally (max. 3 comments). Thus, in general the threads are not as long as those threads found in the World of Warcraft (WoW) forum study done by Steinkuehler and Duncan [SD08]. This may be because the models in FarmVille are easier compared to those in WoW. Another reason for shorter threads could be the artifact genre: The comments are made to a wiki article. This article already contains a model, which is - after creating an initial version - steadily reworked in response to the comments of the community. Everybody who has a question about the model can read either the article or ask a question as a post to the comments.

Fig. 3. Screenshot: Wiki article

In general, a wiki article can be considered an example of collaborative knowledge construction: One person writes an initial version and other people can read this article and correct it or make amendments. Its comprehensibility can also be improved through feedback posted in the form of comments. For example, when the question about how many orchards can be placed on a farm is made often in the comments, it becomes clear that the article needs to be clarified regarding this fact.

The mechanism of supplying an initial article and then correcting it by feedback is demonstrated by *Comment 95* and *Comment 96*. The first comment is made on an assumption about a characteristic of a game object. The next comment responds to the first by showing that the assumption is wrong. To do this, the second comment builds a mathematical model that explains why the numbers provided in the first comment are incorrect. Then, the second comment provides an external reference to strengthen the argument - an advancement of the first comment, probably made by the first person. Since both statements are made by anonymous posters, their identity cannot be established. However, the sequence shows how the underlying model is improved in a collaborative process, resulting in the much-improved current version of the article.

Comment 95	These mastery numbers are wrong. I've been working on Lime and the first mastery star was indeed 45 harvests, but the second is 90, not 135. Please go back to your source and confirm the mastery amounts.
Comment 96	roof your mastery table is wrong. Second star of Lime is 90, not 135: `http://forums.zynga.com/showpost.php?p=7352624& postcount=9` **Looks to me like your source, whoever they are, has given you running totals instead of discrete amounts.** (i.e. the cost of the second star is the first plus the second 45+90 =135, and the third star would be 45+90+135 = 270. But you are reporting these values 45, 135, 270 as if they are the individual level requirements for mastery and they are not.)

3.1 Use of Evidence

One of the most obvious characteristics found in the comments is the use of evidence: questions are answered by experimenting in the game, and observing the actual outcomes. In the following sequence, it is possible to observe how one of the participants tests the statements in the game, and then uses the results as evidence.

Comment 30	I could buy 2 orchards (one was released the first day, the other with coins). Now I see I can only buy with farmcash (it says limit 1 on the coin side). Is it a bug?
Comment 31	Player can place as many orchards as wanted, but one after another (i.e. after you complete building an orchard , you'll be able to get another one for 1000 coins to build, and so on. . .)
Comment 32	true, just happened

The same question - how many orchards a farm can have? - is answered in the next thread (*Comments 75-78*). The different justifications are very interesting: The first answer refers to an observation on a neighbor's farm - and classifies this as observation - not as a proof ("seems"). The second one quotes an external reference that supports the statement being presented. The third poster just points to the number of orchards on his farm. These postings demonstrate three distinct forms of evidence.

Comment 75	Is there a limit to the amount of orchards you can have? [...].
Comment 76	i have a neighbor iwth five orchards. **it seems like there's no limit**
Comment 77	Quoting from the FarmVille podcast, "You can have as many Orchards as you have [...] space for, provided you are building only one at a time." `http://farmville.wikia.com/wiki/Podcast_Transcript_2010-11-05`
Comment 78	I have 22.

3.2 Model Based Reasoning

The term "model-based reasoning" refers to the set of practices that aim at creating a simplified version, or model, of the game, which allows players to predict how the game will behave in a given set of circumstances. This type of reasoning has been considered an example of scientific practice within games [SD08]. Players learn how to use models by constructing small versions of the game. This is a fundamental practice in science. In the next conversation, two players exchange information about the production rates of two types of game objects.

Comment 67	So the Orchard can be harvested every 48 hours, regardless of what types of trees are put inside... This means that some trees suddenly become much more profitable, like: The Mango Tree becomes just as good as the Ginkgo Tree.
Comment 69	Among permanent trees you can buy with coins, Lime Tree is now an excellent option. **You can harvest them with the rate of 600 coins per plot in one day (16*75 /2 =600) if you use orchards. This is more than three time's profitable compared to best permanent seeds** [...]

The use of equations can be considered a kind of **mathematical modeling**, which is also an element of AAAS's benchmark. The presence of this type of reasoning shows how sophisticated the construction of models can be among FarmVille players.

Another example of model-building and reasoning takes place in the next sequence of comments.

Comment 16	Hi all _ I have about 25 orchards, and since I began harvesting a couple of days ago, I noticed that I get a seedling about 40-60% of the time. [. . .] However, I just harvested over 10 in a row with *no* seedlings. Am I being punished for having too many orchards? I see that my neighbors w/only a couple of orchards tend to get a much higher (almost 100%) return. Can anybody else confirm these awful statistics? You know, the more time and coins you spend, the smaller the return? :(
Comment 17	At this moment I have 16 orchards and can say by me it is slightly less than 50%. The worst case have been 3 harvests in row, with no seedlings. May be you are right about having too many orchards. I had the similiar problem by helping friends. It was a time that I had only 10 neighboars. When I visited their farm, I could get around 15% of times, a collection. Now I have 150 contacts and it is less than 3%. I mean if I visit only 10 of my neighboars, almost certainly I would get no collection and no mystery eggs (only fuels). well, this is just my personal experience.

The first commenter hypothesizes that the probability of a certain event decreases when it logically should increase. The second commenter answers by referring to an analogy from another game mechanic. He cannot prove the hypothesis, but also cannot disprove it - he only points out that further research is necessary. However, the use of analogies in the game resembles the complex mechanisms of scientific reasoning used by researchers in actual discovery settings [DB01].

The reason why players engage in this type of practice is that model-based reasoning can be used to determine strategies which can obtain the best results. In this sense, the process of exploration and collaborative reasoning is seen by the players as part of the game, and is closely related to the goals of the task. An example is given here:

Comment 58	**I still cant decide if these take up more or less room than 20 trees spread out around the perimeter of my farm**
Comment 59	well they use up the **same space both 5x4 tiles**. however **advantage of orchard** is that u can harvest in less time and u can harvest 20 trees at once. **downside is** that u cant scatter ur trees around ur farm anymore.
Comment 60	It does take the same space, however, with them grouped together in a Orchard, it uses up good space. **Before you could place them in the unused space around the perimeter, now it uses up crop or buildings space.**

In order to play efficiently in FarmVille, it is necessary to use the limited resource "Terrainspace". In the example given before, *Comment 58* presents a question about the more efficient way of using the space in FarmVille. Both answers point out correctly that there is no difference in space usage, but the space distribution is less variable by using orchards. Missing in this discussion are the advantages of using orchards: They produce seedlings and can be harvested with less effort than 20 single trees (there are max. 20 trees in an orchard). The presentation of answers both by conducting calculations and by describing the distribution of space are examples of model-based reasoning within the game.

3.3 System Based Reasoning

There are even some suggestions and discussions of game mechanics which can be seen as an evidence of **system based reasoning**. System based reasoning refers to the ability to think in terms of complex processes in a way that accounts for the relationships among all the elements in a system. System based reasoning implies understanding how changes in one or several elements modify the relationship among all the other existing elements. In *Comment 132*, there is a discussion about how a greater gift box is necessary to respond to the growing number of tasks that require the collection of building parts. This comment shows a complex understanding of the game as a system, where changes in some levels modify or require changes in the other levels of the game.

Comment 132	[...] i would predict are Fv neighbors can send us these wateing cans sheww zynga needs to make are gift box hold more they keep coming out with new items for us to collect but have yet to inlarge the capacity of our gift boxes :)

Along similar lines, emergent game play can be observed in some of the comments. Emergent game play can be considered a sign of system based reasoning because to develop new strategies, players have to understand complex relationships among the elements of the game. In the next sequence, it is possible to observe an example of this type of reasoning:

Comment 40	**does the stable trick work for orchards**
Comment 41	**No, it doesn't.** If you fill an empty Orchards with a ready tree, it begings with 0% any way. If you remove a tree from a let's say 70% ready Orchards, the tree's status becomes again 0%.
Comment 42	As "Ramin Nekou Nam", no. **But you can have an Orchard with just one tree inside which is 100% ready, and then move more trees inside of it. It will stay 100% ready.**

The first observation uses the term "stable trick". This term is clearly connected to a well-known gaming practice in FarmVille which optimizes the harvest of a horse stable and which cannot be considered as intended game play, so the usage of this term shortens the communication - it is based on an already known idea. In the example above (*Comment 41*), the answerer understands the terminology and can respond in a precise way with a number-based example. The next answer (*Comment 42*) leads to an alternative type of emergent game play.

3.4 Analogies

In some of the comments, it is possible to observe the use of analogies in the process of collective reasoning. Analogies are considered means of scientific reasoning [DB01] because they permit the scientist to link the different elements in a problem, and to communicate complex ideas in a simple manner. As matter of fact, analogies are often used in the process of collective scientific reasoning. The next sequence exemplifies the use of analogies in the process of collaborative reasoning about FarmVille.

Comment 91	If you get a seed, do you lose the tree from which the seed came? **(kinda like your baby animals growing up in your nursery barn, I mean)**.
Comment 92	That is hell of a good question I will let you know in a . . . one more day, Have a second orchard and ready for the third. . . Gat a lot of trees.
Comment 93	lol no
Comment 94	No, they don't. The baby animals are growing up. The trees are already grown up and have offspring. **So, logically it works like the Dairy Farm and Horse Stable.**

The questioner suggests an analogy for the phenomenon he is describing ("like your baby animals"). Then in *Comment 94* he gets an answer in which another analogy is used ("Dairy Farm and Horse Stable"). So this should help the questioner to understand the underlying model fast. It is interesting also how the analogies used in this sequence require players to isolate the core elements of certain game objects (e.g., baby animals, dairy farm, horse stable). Analogies help players to develop the scientific habit of identifying the core elements of a problem, the skill to separate signal from noise.

In the last sequence, it is possible to observe also how the development of scientific habits of mind is closely related to social habits (e.g., the will to help). In *Comment 92*, the participant expresses its own excitement with the question being asked. This action in some way serves as some sort of social regulation. Additionally to that, he or she promises to give the answer one day later. *Comment 93* uses the abbreviation "lol" (="laughing out loud") which requires literacy in web based communication environments like forums or chat rooms. This comment can be viewed as impolite. Depending on the sensitivity of questioner the impoliteness can disappear in the sense that making someone laughing is a positive notion. As a matter of fact, "lol" is used to regulate the social interaction in online environments. This expression means that something is funny but that there is not intent of aggression in the interaction.

In general the conversation attitude in these comments is very calm and peaceful; there cannot be found any rude attitude. The questioners are encouraged to find answers by playing and reflecting on their own experiences - a good base for learning (Gee 2005a). However, social regulation also implies that players require other participants in the discussions to contribute to the collaborative process of discovery and not just receive information.

Comment 26	just finished my 12th one just one question, is there a downside to it in any way? or to a specific tree? and also, which type of cash/mystery-seed tree and which type of the coin trees are the most profitable if i put them in it?
Comment 27	What, no reply? Helloooo...!
Comment 28	Do you want us to play for you too?

Social regulation works not only to require collaboration from other, but also to provide positive feedback when participants do so. There is evidence, that the community members support and reward each other. This can be seen in the next sequence of comments in which participants describe their feelings (e.g., being tired) and get positive feedback in the form of thankful comments.

Comment 109	This needs a total re-work but I don't have the energy to fix the mess :P
Comment 8	Thank you for the rework of this page... It looks much, much better.#

3.5 Social Reasoning

Another common topic in the comments is the awareness of the game supplier company - Zynga. Game mechanics and bugs are no accepted as god-given, but they are connected to Zynga. This implies that participants understand the social context in which game production happens. This understanding allows participants to create a social model of the game. This social model explains the characteristics of the game in terms of the social context in which the game is produced. In other words, the players develop a social model that explains the functional model of the game that was discussed in the model based reasoning section.

Comment 104	Vote to fix mini-botanical `http://zynga.custhelp.com/app/answers/detail/a_id/2645` [...] Actually, I contacted Zynga via their customer help chat when I had this problem. They fixed it, [...]. Then, I went and took orchard out of giftbox and it turned to mini-botanical. [...]. Zynga now has a serious problem...
Comment 19	21 harvests without a single seedling??? Mine is now 12 in row without any seedling. I agree , this is not acceptable!! Let's wish it is not again another foolish strategy by Zygna. [...] a while ago they set a 50% tax on crafting cotages which caused most users to quit crafting in 48 hours. Hopefully they reacted immediately and changed the tax again to 15% and saved the business. I hope it is really a bug, otherwise I think I would quite using orchards [...]

In *Comment 104*, the problems are blamed to Zynga. This can be seen as a connection back to the real world. *Comment 19* makes a reference to a former game mechanic of FarmVille which was not successful and was changed by Zynga, probably because of the economic impact - players of FarmVille mostly are customers of the company. These comments show that game is perceived as a piece of a broader context - an element of real life - in which the player takes the role of a customer. This type of understanding is evidence that FarmVille develops some form of financial, economic, business and entrepreneurial literacy, a skill that has been recognized as a core for the 21st century [PAR09].

4 Conclusion

The analysis of the comments has shown strong evidence that contributors use scientific habits to create common knowledge in FarmVille. Among the habits identified in this article it is possible to mention mathematical modeling, model based reasoning and system based reasoning. This fact allows players to use and thus train skills that are needed in real life. FarmVille represents a new type of game - the social game - that has started to be popular among an almost totally new and also large group of people. Although there have been identified a few educational elements in this game, there should be further examinations of how, with what content and to which extent FarmVille and other social games can serve as educational media to this group of new game players. This task is even more important in the face of the expected further rise of this segment of the gaming market and in relation to the possible improvements for game play of social games in general. Furthermore playing these games online enables instant usable feedback for game developers and, for this same reason, it creates a process of continuous improvement of these games - a totally new development approach in the game industry.

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Social Media Communication – Social Media Used Both as a Learning Content and as a Learning Style

Jana Riedel[1], Romy Wolff[2], Corinna Jödicke[2], Eric Schoop[2], and Ralph Sonntag[1]

[1] Hochschule für Technik und Wirtschaft, Chair of Marketing, Especially Multimedia-Marketing, PF 120701, 01008 Dresden
{Riedel,Sonntag}@htw-dresden.de
[2] Technische Universität Dresden, Chair of Business Informatics, Especially Information Management, 01062 Dresden
{Romy.Wolff,Corinna.Joedicke,Eric.Schoop}@tu-dresden.de

Abstract. Social media are no longer just a private medium for communication. For the last years, a growing number of processes in enterprises are getting penetrated. To prepare students for the enterprises' requirements it is necessary to familiarise them with current developments in the corporate processes. We assume that the knowledge about concepts and technologies of social media can best be developed if they are used both as a learning content and as a learning style within learning activities. Based on an innovative blended learning arrangement with electronic lectures (e-lectures) and problem-based case study work in the virtual classroom, this paper develops a research design to identify success metrics of e-lectures and to discuss the utility of e-lectures for problem-based case study work, thus supporting our assumption.

Keywords: Higher and further education, social media, blended learning, e-lectures, virtual classroom, collaborative learning.

1 The Project "Social Media Communication"

Social media are no longer just a private medium for communication. In the context of an enterprise 2.0 debate, social media also dominate everyday professional life. Companies successfully use social media and the social media presence of their employees as an interaction channel and as an instrument for new, customer-oriented value-add models. With the exception of one, all German DAX 30 companies have at least one presence in social media employment [1]. More and more, enterprises recognize the economic benefit of social media [2]. In this context, specific social media competence will increasingly be required for professional qualification. This is a result of shifted opportunities and communication effects with social media. The main aspects can be summarized as follows:

- Opportunity for everyone to produce media content and thus gain access to a potentially unlimited public (proactive consumer),
- Individual collection, distribution and interlinking of a wide variety of information,

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- Diffusion of private and professional spheres [e.g. 3],
- Growing economic importance and spread of social media presence among enterprises (e.g. social commerce, social shopping).

The necessity of social media competence is repeatedly emphasized in blogs by social media practitioners. The definition and development of such competence is, by contrast, not yet on the agenda of higher education curricula. The project “Social Media Communication”[1] of the Hochschule für Technik und Wirtschaft (HTW) Dresden and the Technische Universität (TU) Dresden concentrates the definition and development of social media-specific competencies.

The project is structured in several phases, with the development and testing of a complex blended learning arrangement at the center. The blended learning arrangement supports the use of social media for professional purposes. The learning program is offered as an additional qualification for students of all disciplines and various higher education institutions. The present article assesses the first three phases according to fig. 1. The subsequent project evaluation aims at providing a best practice arrangement for a deployment of the blended learning arrangement at the involved universities and other higher education institutions in the region.

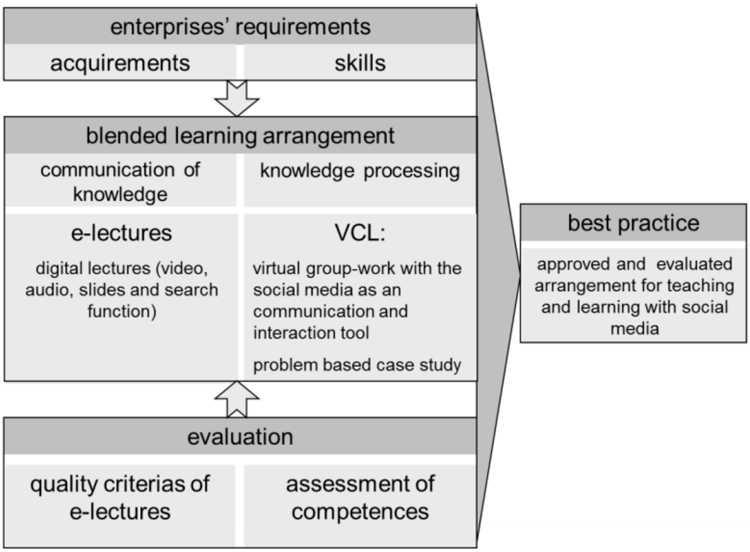

Fig. 1. Phases of the development of an additional qualification in the field of social media

[1] Supported by the European Social Fund, funding code 080949279 (07/10-12/11). For details see project blog `http://social-media-experten.de/`

2 Social Media as Learning Content

Objective of the additional qualification is the development of social media competence for the utilization of social media in professional context. The authors consider such competence an essential part of professional work competence, encompassing personal, social, methodological competence and professional expertise. These dimensions can be divided into the elements knowledge, skills and attitude [4].

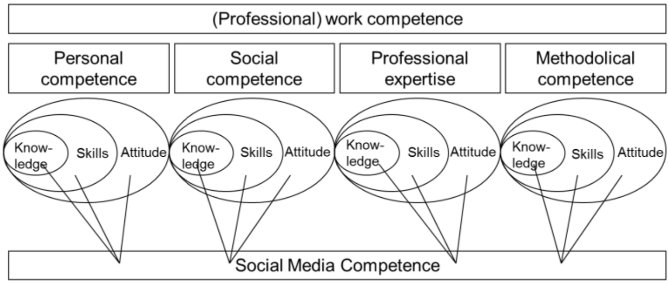

Fig. 2. Terminology of social media skills (own illustration)

A theoretical discussion or an empirical research of competencies needed for a professional use of social media does not yet exist. First approaches to identify knowledge, expertise and experience of social media skills as professional work competence show the methodological variety of how these can be determined [5, 6, 7]. They can be derived from theoretical observations of special features of social web communication, empirical data collection through expert interviews in companies and agencies, or from analyses of competency profiles of newly created job descriptions or job advertisements.

In order to specify the elements of social media competence and to determine the learning content and learning objectives, the project initially started with a series of interviews among companies and agencies in Saxony. The participants were asked to evaluate knowledge and attributes of future social media experts according to relevancy. Table 1 shows the highest-ranked skills and attributes as well as their allocation to the elements of social media competence.

Table 1. Elements of social media competence

Knowledge	Skills	Attitude
• General knowledge about social media • In-depth knowledge about the use of social media along the value chain	• Concept/strategy development • Journalistic skills • Project management • Capacity for conflict • People knowledge/ empathy • Intellectual agility/ flexibility • Quick perception • Initiative/ independence	• Motivation to use social media in professional context

3 Social Media as a Learning Style

The use of social media as a learning method is increasingly being discussed in scientific literature. Therefore, prior to the description of the blended learning arrangement developed in the project, a few theoretical observations are prefixed.

Kerres [8] formulates specific requirements concerning future learning platforms, which follow the rules of Web 2.0 and which were adapted in the project (cf. [8] for the following paragraph).

According to Kerres, a learning platform functions as a guide to information and material in the internet. The material provided by lecturers is mainly aimed at structuring the learning process (mainly through study assignments). The learning environment offers tools for collaborative work on assignments, sharing of content and knowledge, and categorizing it in keywords. The selection of communication and collaboration tools lies with the learner. Learning processes and learning results are automatically documented by the learning platform (for example communication history in discussion forums). Learners are motivated to reflect on the learning process. The learning platform serves as contact agent and supports group processes through publication of contact data and additional information about the individual learner (interests, skills, activities in the learning environment). Lecturers participate by shaping the content as well as by actively offering feedback and support through the learning platform. It is therefore no longer a closed hypertext environment without external interface, but a service offer which enables an individual design of the personal learning environment (PLE).

Social media can be used for various purposes. Bernhardt and Kirchner [9] divide social media tools according to their taxonomy into online communication tools (information exchange and discussion), social networks (establishment and maintenance of contacts between the learners), social collaboration tools (working together on documents), social publishing tools (publication of own content for various purposes: individual information storage, reflection, discussion [10]) and hybrids (combination of several functions). All these functions are applied in the learner-centered blended learning arrangement developed in the project.

Besides these possible applications of social media in formal learning processes, Kuhlmann and Sauter [11] as well as Erpenbeck and Sauter [12] explicitly refer to the potential of social media technologies as supporting tools for competence development. Erpenbeck and Sauter describe social media technologies as competence learning software. They trigger emotionally challenging and therefore value-creating processes which are necessary for the development of competencies. According to Kuhlmann and Sauter [11] there are four phases of competence development: communication of knowledge, knowledge processing, knowledge transfer, and competence development. Kuhlmann and Sauter [11] assert that the use of social media technologies facilitates communication among learners in the knowledge transfer phase and the competence development phase. The project "Social Media Communication" also applies social media technologies for group communication in the knowledge processing phase. The virtual environment allows for a time- and location-independent exchange of experience between individuals and supports the further processing of knowledge in the group. Social media eases the development of learning communities and pushes the reflection needed for a transfer of knowledge [11].

Furthermore, the collected experiences with solving complex problems with interactive social media tools motivate and enable learners to subsequently interact in self-initiated groups in real-life professional situations. The use of social media as an educational method also contributes to the creation of communities of practice in informal learning processes. They build the basis for self-organized, informal learning processes integrated in a network and support the competence development in real decision-making situations [11, 12, 13, 14].

The requirements for a learning approach which supports competence development in the area of social media are derived from the conditions for competence acquisition as well as from a moderately constructivist learning comprehension. Thereby learning is understood as a process in which the learner actively and independently constructs his knowledge in specific situations; from time to time the lecturer guides the learner in order to secure the learning success [15]. The learning arrangement should therefore have the following features:

- Motivate self-directed and informal learning processes [11].
- Provide a preferably authentic and realistic design of the learning environment, in which the learners work on concrete problems and cases from their immediate environment and feel a sense of ownership for the assignment [15].
- Address learning content from different perspectives so that the learner will not be too constrained by one situation (ibid).
- Cooperative work on an assignment or problem in a group in order to bring in alternative viewpoints and trigger discussions in which individual opinions are independently represented (ibid).
- Lecturers design the learning environment and if needed give support through instructions, demonstration, moderation or counseling (ibid).

4 Blended Learning with and for Social Media

4.1 Flow of the Blended Learning Arrangement

The concept of the learning arrangement is based on survey results on the learning content of the additional qualification as well as on theoretical observations. The developed and tested arrangement is divided in two formal learning phases and motivates the learners to participate in a third, informal phase (cf. fig. 2).

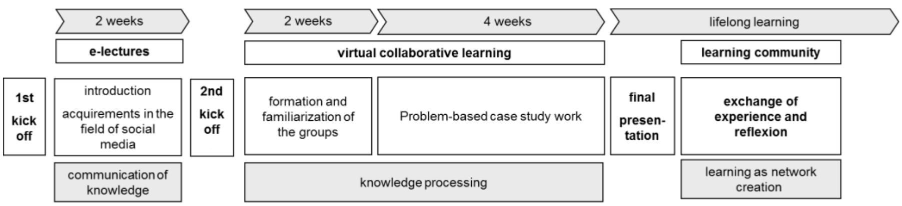

Fig. 3. Flow of the blended learning arrangement

The specific learning content and learning objectives for the additional qualification were defined, among others, on the basis of survey results (see chapter 2). A holistic approach was applied for the use of social media in enterprises, which can be used for all organizational units. Not only departments such as Marketing benefit from the use of social media, but also Corporate Communications, Human Resources, Research & Development, Operations, Sales, Customer Management and Service. The learning arrangement also demonstrates implications for an interactive and customer-oriented added value.

Furthermore, the arrangement shows how the different social media channels (blogs, social networks, wikis etc.) can be employed and trains the development of social media-specific strategies. The possibility of independent learning aims at supporting the development of self-initiative, and group learning fosters the communication and collaboration skills of the participants.

The first part of the arrangement teaches specific knowledge of the construct "social media competence". This includes 18 e-lectures[2] featuring a variety of different topics, which the learner can conduct at any time and place and as often as needed. Already in this phase the learning process is self-controlled, since the learner can define the order and the navigation within single e-lectures independently. The e-lectures were developed in cooperation with well-known social media experts across Germany.

After an introduction to the topic of "social media" the learners deepen the acquired knowledge though work on realistic, complex case studies. The problem-based case study is integrated into a learning scenario according to the Virtual Collaborative Learning (VCL) approach [in particular 16]. For more than 10 years this method has been successfully applied in teaching by the cooperation partner at the TU Dresden. The existing know-how and experience has partially been adapted for the newly designed blended learning arrangement.

Starting point of the learning phase *knowledge processing* is a learning platform, in which participants introduce each other through a personal profile and a fictitious application letter (designed as a social network). Based on these profiles participants independently build groups and determine the social media tools, which they want to use for communication and collaboration while working on an assignment (online communication tools, e.g. Skype, and social collaboration tools, e.g. Dropbox). The students are asked to develop a social media strategy for an organizational unit of a fictitious chocolate company. This task is divided in subtasks, which are solved either as group work or individually. The groups document and reflect on the progress of the problem solving in a blog (social publishing).

Through social interaction and the use of social media technologies for communication and interaction, participants develop and improve their abilities in dealing with social media, their social competence, communication skills, approach to conflict, as well as the ability for self-managed work. The exchange among learners also contributes to a deeper understanding of the learning content [17].

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[2] E-Lectures are digital recordings of lectures, in which audio, video and presentation slides are reproduced synchronically. The learner can select and jump between slides.

The virtual learning phases are complemented by face-to-face attendance phases, in which organizational frameworks and group results are presented and discussed. In a closing event participants consciously reflect on their approach and solutions. Combined with a learning community, in which the participants exchange and reflect their practical experience and knowledge, the attendance phases enable a transfer of knowledge. Through managing the first three phases of competence learning according to Kuhlmann and Sauter [11] the learners are prepared for the fourth phase, competence development. This phase can start after completion of the additional qualification in a professional context, in which the learners are confronted with knowledge-related as well as emotionally challenging problems. In this context, competence development takes place as an individual process of the learner in real decision-making situations by translating values in personal emotions and motivations (value internalization) [11].

The described blended learning arrangement was tested in two trial rounds. The first trial round started in December 2010 with 50 students of the HTW Dresden and the TU Dresden and was completed in January 2011. The second trial round took place between May and July 2011 with 100 participants from all over Saxony.

The adequacy of the arrangement for the teaching of learning content and for the development of competence was examined in the trial rounds through different evaluation procedures (cf. figure 3). A pre- and post-knowledge test on the content of the e-lectures was conducted among the participants to verify an increase of knowledge on the topic of “social media” after taking the e-lectures. In interviews participants were asked to evaluate the e-lectures on the basis of defined quality criteria following Niegemann [18] as well as Rohs and Streule [19]. The virtual form of group work allowed an observation of participants on the basis of standardized reports. These were the basis for the development of competency profiles. In open discussion rounds and in written format participants were asked to give feedback on the content as well as on the methodological design of the blended learning arrangement. A concluding survey on the usability of the knowledge transmitted through e-lectures in case study work completed the evaluation.

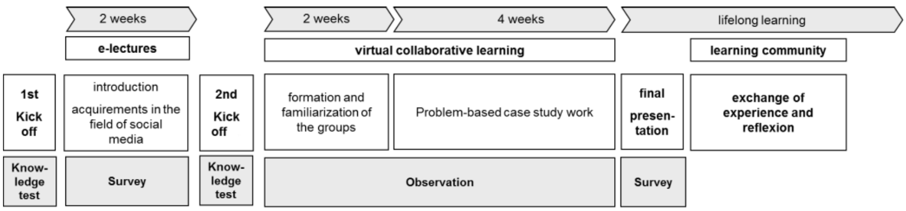

Fig. 4. Design of the evaluation

4.2 First Evaluation Results

The following findings result from the evaluation of the first trial round. The test on knowledge increase on the topic of “social media” consisted of 20 questions, which corresponded in terms of content with the topics of the e-lectures. The data of 23 participants (6 male, 15 female, 2 not specified) were utilizable for the analysis.

For each question 2 points could have been achieved. This corresponds to a maximum of 40 points in total. In the pre-test participants reached an average total score of 18.12 points, in the post-test 21.43 points on average. Considering an error probability of 5%, the increase can be regarded as significant (T: 2.169, df: 22, Sig.: 0.041). This result postulates that the e-lectures are suitable for the teaching of content in the area of social media.

The survey results on the quality of e-lectures yielded a similar picture. The survey addressed the topics learning content (being interesting, quantity), length, lecturer (structured presentation, comprehensibility, additional explanations, language), design of presentation slides (layout, structured presentation, additional graphics, supporting the understanding of text through graphics) and perceived learning effectiveness. The average reponses by the participants across all e-lectures is captured in fig. 4.

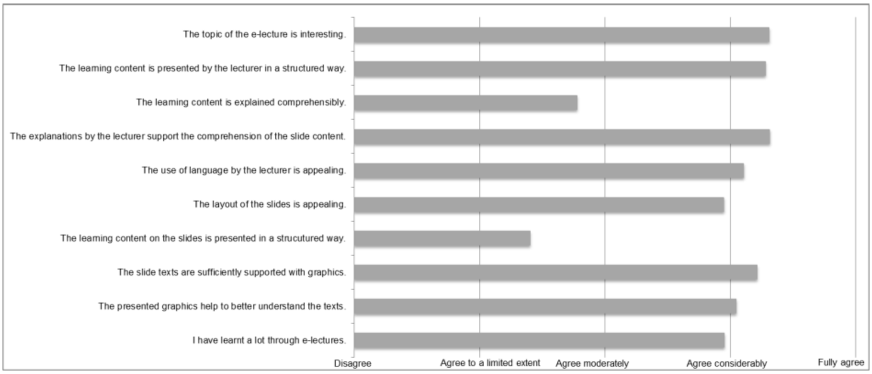

Fig. 5. Results of the qualitative survey

The validation of knowledge after working on case studies was made on the basis of evaluation of assignment results. The assessment shows a large difference between different groups and participants in terms of quality. The level of completion of the assignment varied between the groups from 97% to 44.65% and between the participants from 99.1% to 13.4%.

Based on the standardized observation report each participant was assessed during the virtual group work with regard to specific competency features. These resulted in the development of individual competency profiles[3], which were reported back to the participants after completion of the additional qualification. On the basis of this information the participants were able to explicitly work on deficits, which laid the foundation for competence development [11]. The levels of knowledge, skills and attitudes varied strongly between the participants depending on their level of involvement (cf. fig. 5). However, the average value of 80% suggests the existence of social media skills among the participants.

[3] The following knowledge, skills and attitudes were recorded: social media knowledge (quality of group and individual performance), presentation skills (design of submitted documents), reliability (adherence to deadlines and completeness of submitted assignment), capacity for teamwork (contribution to group work), self-initiative (taking over additional assignments independently).

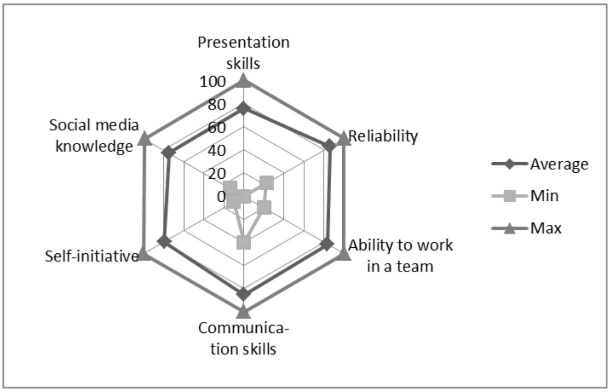

Fig. 6. Competency profiles of the participants

The blended learning arrangement as a combination of e-lectures and virtual group work with problem-based case study assignments was evaluated by the participants in open feedback sessions mainly positively (10 of 13 mentions). They emphasized that they have learned a lot (5) and that they plan to follow up with the topic (4). Participants regarded the timing of the additional qualification as rather negative due to the fact that the final phase of the learning arrangement overlapped with the start of the examination period of their regular studies, which resulted in less time to spend on additional qualification (6). The open formulation of assignments has caused some lack of clarity among participants (3).

In respect to the open question on how useful the e-lectures were for the work on case studies, 15 statements were usable (number of mentions). According to these, the content of the e-lectures provides an important knowledge basis (10), which had to be completed with further sources (14). The final decision on the usefulness of the e-lectures for the work on case studies yielded the following answer distribution: yes – 11 participants (61 %), no – 2 participants (11 %), partially – 4 participants (22 %).

In summary it can be concluded that e-lectures seem to be an appropriate instrument for teaching knowledge in the field of social media. In combination with work on problem-based case studies according to VCL they support the development of social media competence. The next project step will evaluate the data of the second trial round. Based on the evaluation results and the project experience a best practice arrangement will be developed which will be provided to higher education institutions for teaching social media learning content.

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