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TLIC PAPER

Occupational Accident Prevention Training through Experiencing Stories of Success in Time Travel Prevention Games

Hans-Holger Wache[1], Ronny Franke[2], Oksana Arnold[3](✉), Klaus P. Jantke[4]

[1]Institution for Statutory Accidents Insurance and Prevention for Raw Materials and Chemical Industry, Prevention Center Berlin, Berlin, Germany

[2]Fraunhofer Institute for Factory Operation and Automation IFF, Magdeburg, Germany

[3]Erfurt University of Applied Sciences, Erfurt, Germany

[4]ADAMATIK GmbH, Weimar, Germany

oksana.arnold@fh-erfurt.de

ABSTRACT

Fiction is an ancient virtual reality technology that specializes in simulating human problems. The stories told are the media and, according to Marshall McLuhan, the medium is the message. The technology is interwoven with up to date digital media design and information technologies including artificial intelligence (AI). According to Keith Oatley, stories are the flight simulators of human social life. From the many fields of human life, emphasis is put on the training of occupational accident prevention. The potential of storytelling is deployed for the prevention of accidents to preserve human lives, to avoid human injuries, the damage of installations and financial losses. Aiming at effectiveness and sustainability, the task under consideration is the interdisciplinary design of spaces of stories with a high educational potential. The authors abandon the educational paradigm of telling stories of disaster. Interactive digital storytelling is tailored to allow for unprecedented learner engagement in stories of success. Prevention training is designed to appear playfully based on the original concept of time travel prevention games. Trainees who failed to complete their task—thereby possibly ruining a (fortunately only virtual) technical installation—are enabled to travel back in time to do better the next time. AI guides the trainees to a success of their own. In the condition of training with time travel prevention games, designing spaces of stories to be experienced playfully is an ambitious variant of gamification. The design of stories in story spaces is a particularly complex case of dynamic AI planning. Patterns that occur in story spaces wrap educational theory as well as ideas of game design. The plan generation concepts foster interdisciplinary co-operation of educators, domain experts, VR specialists, game designers, psychologists, and others in creating spaces of affective stories of success.

KEYWORDS

occupational accidents, industrial accidents, accident prevention, digital storytelling, stories of disaster, stories of success, training experience, time travel prevention games, adaptivity, artificial intelligence, game AI

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1 INTRODUCTION

This paper expands on the authors' *The Learning Ideas Conference 2024* paper [1] substantially extended by a discussion of their preferences for stories of success over stories of disaster including the deployment of AI to turn a human trainee's efforts into a personal success worth remembering and worth telling.

There is a rather long standing debate about rewards vs. punishment in pedagogy. "Based on seemingly overwhelming empirical evidence of the decremental effects of reward on intrinsic task interest and creativity," as Eisenberger and Cameron put it, "the use of reward to alter human behavior has been challenged in literature reviews, textbooks, and the popular media" ([2], p. 1153).

1.1 Stories of disaster

Telling stories of disaster is an established approach to accident prevention [3–7]. In earlier days, it was a respected and, at least to some extent, successful approach to pedagogy in childhood. By way of illustration, the book [8] was for far longer than a century the best-known collection of stories of disaster addressing German children.

Fig. 1. Last page of "Der Struwwelpeter", first edition, that became the cover page later on and illustration of some story of disaster in this book, this one entitled the "Fidgety Philip"

Notice that the author's name Reimerich Kinderlieb in [8] is a pseudonym of the true author Heinrich Hoffmann who made this book by hand as a Christmas present to his son Carl in 1844. The following editions were published under his real name [9].

Three years after the first book publication in Germany, "Struwwelpeter" was translated into English and became incredibly successful as a cautionary children's book [10].

In learning psychology and behavioral studies, there have been long lasting worries "that the strengthening of performance by reward causes the unpleasant experience of being controlled by others and reduces task interest and creativity" (see [2], p. 1153). Drawing one's own conclusions from disastrous stories seems more self-determined.

There is an apparent need to engage in deeper investigations of and practical experimentation with the alternative of stories of success in dependence on the addressees.

1.2 Stories of success

The present contribution is practical resulting in implementations and in training applications [1], [11], [12], [13], [14], [15]. It has a firm theoretical basis, first, in AI planning [11], [12] based on [16] and this, in turn, based on [17], second, in AI based adaptivity to human needs and desires [13], third, in modal logics [18], particularly deontic logic [14], [15] for which, in turn [19], [20], [21], [22], [23], [24], are prominent sources, and fourth, in the original concept of time travel prevention games [25] originally developed for crime prevention [26].

When playing a time travel prevention game for training occupational accident prevention, disasters are likely to happen—at least, virtually. But in contrast to the above-mentioned approaches [3], [4], [5], [6], [7], time travel enables the trainee to impact fate.

The following section 2 is intended, quite similar to section 3 of [1], to provide the audience with a touch and feel of accident prevention training by means of playing a time travel prevention game.

In the authors' approach to occupational accident prevention by playing time travel prevention games, human trainees experience stories in virtual industrial installations. Human trainees do not only get told stories of accidents and how to prevent them. They experience stories, they actively participate in stories that unfold when playing. Instead of the conventional term *Interactive Digital Storytelling*, the authors coined the term *Interactive Digital Story Engagement* that seems to be more appropriate [1].

Figure 2 might be helpful to survey the authors' progress from stories of disaster to the experience of stories of success that are perceived as a trainee's own achievement.

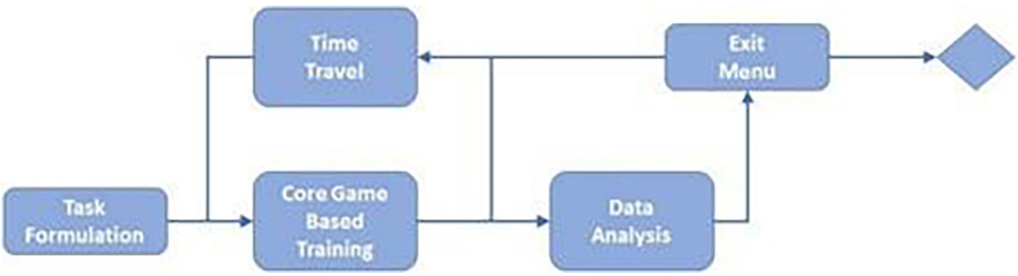

Fig. 2. A flow chart—in fact, some storyboard graph, a technical concept to be introduced later—showing anticipated game play that allows for repeated training by means of time travel

The larger boxes describing nodes of the graph on display in Figure 2 are episodes. An episode may consist of more complex actions, interactions, and events, an issue to be investigated later in more detail. Within the Core Game Based Training episode, undesired events ranging from pollution of the workplace through damage of part of the installation to fatalities may take place, in this way establishing a story of disaster.

But after a critical assessment within the episode of Data Analysis, a trainee may get the offer to travel back in time. With the disaster before, the story is not yet over.

Experiencing Core Game Based Training once more, a trainee may try to do better this time. Notice that time travel may be deployed more than once in dependence on the intermediate outcome. It is the task of the game system's AI to guide a trainee to a successful completion of the mission experienced as the trainee's own achievement. The result is a story of success worth remembering and worth telling.

2 TRAINING WITH TIME TRAVEL PREVENTION GAMES EXEMPLIFIED

This section is based on the authors' prior work and is intended to demonstrate the essentials of training with time travel prevention games. Readers may consult [1], section 3, pages 185 et seqq. for a rather similar effort underlying the present section. The authors' intention is to convey to the audience something like a touch and feel of industrial accident prevention training with time travel prevention games setting the stage for the investigation of novelties that arise from the perspective of storytelling.

Accident prevention training is of societal relevance in risky environments such as chemical industry installations. It is a blueprint for prevention in many other areas.

Fig. 3. One of the virtual factories from Fraunhofer IFF deployed by the German Institution for Statutory Accident Insurance and Prevention for Raw Materials and Chemical Industry, Training Center Berlin, for accident prevention training (see [1], Figure 1 for comparison)

In such a virtual world set up for training, human trainees get assigned some tasks. It may happen that a training session suddenly ends with an undesired event like, e.g., an explosion with fire shown in Figure 4 on the right (a more subtle event on the left). As the authors put it in [14], page 27, those undesired events are desirable. Nothing is more affective and, therefore, effective than the experience of a self-induced accident.

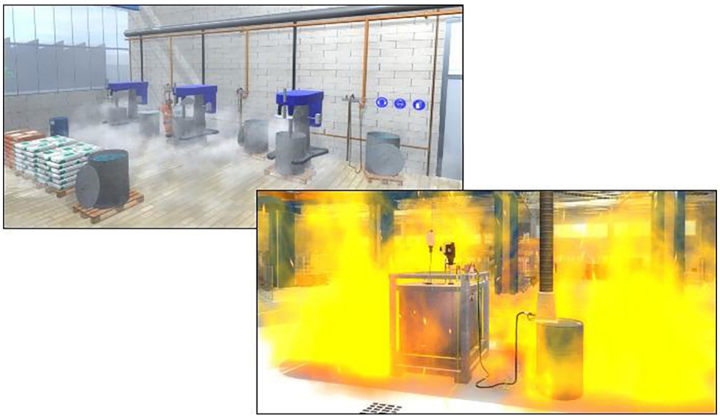

Fig. 4. A trainee's self-induced accident: Unforgettable experience, motivation for time travel, origin of efforts to turn the story toward a success experienced as an own achievement

When participating in a story that is threatened by disaster, human trainees may get offered opportunities of time travel to impact fate. Trainees shall have experienced their own story of success. The authors consider this a decisive principle of didactics.

So far, storyboarding was understood as the organization of experience ([16], p. 25). As discussed in paper [1], storyboarding becomes the design of story spaces [27,28] in which human trainees navigate toward the ultimately successful story worth telling. Storyboard graphs such as the top-level graph on display in Figure 2 specify event sequences of intended human-system interactions. Some more details will follow. Whereas replay results in varying stories, a phenomenon of meta game play [29], virtual time travel arranges alternative player actions in a single game play—one story.

Time travel gamification is bringing into the story repeated occurrences of events.

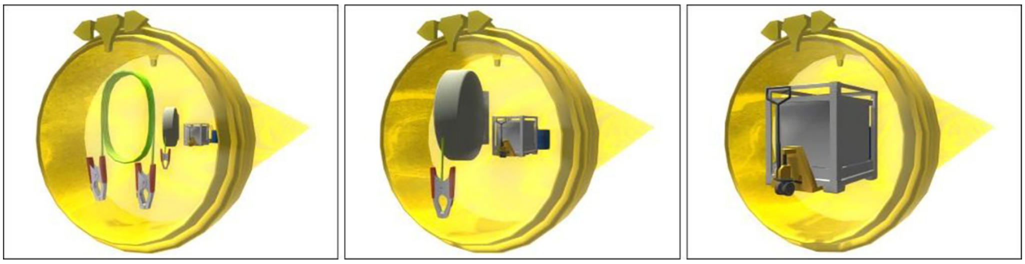

Fig. 5. A time tunnel specifying destinations by means of objects that represent scenes of inter-action from the past—scenes within the episode of Core Game Base Training, see Figure 2

For selection of the concrete destination of time travel, the authors prefer a rather intuitive time tunnel in which scenes of the past have an iconic representation (Figure 5). By way of illustration, the center screenshot of the time tunnel stops at the wall-mounted grounding cable. The trainees may zoom in or out and select a scene from the past to travel to. The time tunnel has three buttons on top. With the left button, one dives forward into the past, from the state on display in the center to the next state on the left. Using the upper right button, one turns back coming closer to the present. These buttons refer to the direction of a clock's arms as costumary. A click to the button in the middle selects the central icon on display bringing the player to the past scene inside of the core game-based training episode where this object has been used.

Trainees might have thought about such a return in a mental time travel [30], [31], [32], [33], [34], [35], [36], [37]. The authors' realization makes a trainee's daydreams come true in unfolding stories.

However, the crux is that repeatedly trying does not necessarily lead to success. Nevertheless, effective, sustainable training shall be experienced as finally successful. Toward this very end, the authors developed what they call cascades of intelligent user guidance [13]. The system's adaptivity is key to the human's success in training. AI plays a key role in didactics.

Readers are directed to [1], section 2, for aspects of time travel beginning with [38] and including *the nature of time* with references to [39], [40], [41], [42], [43]. To keep it here very short, according to Bergson's philosophy [39], [44], *time is pure activity* [41], i.e. the order of actions and events. Such an order is usually partial.

The human trainee's time travel may bring with it a re-ordering of past events and—particularly relevant to the ultimate success—the disappearance of events as well as the sudden occurrence of new events. The latter phenomena are instances of logical properties such as non-linearity and non-monotonicity [27].

3 EDUCATIONAL STORYTELLING WITH TIME TRAVEL PREVENTION GAMES

This contribution, similar to [1], aims at an amalgamation of the authors' prior applied approach to industrial accident prevention by means of time travel prevention games as documented in [1], [11], [12], [13], [14], [15] and briefly illustrated by means of the preceding section 2 with ideas, concepts, design methods and techniques of interactive digital storytelling.

Human trainees experience stories in virtual industrial installations (see section 2). Trainees do not only get told stories of accidents and how to prevent those events. They experience stories. Trainees actively participate in and carve out these stories which results, as said before, in *Interactive Digital Story Engagement*.

Such storytelling becomes particularly exciting when time travel may be invoked, especially because those journeys in time shall be adaptive and highly personalized.

3.1 Storytelling in the evolution of humanity

Being aware of fundamental work on storytelling, in general, such as [45], and on storytelling under widely varying perspectives ranging from performance arts [46], e.g., to VR [47], the authors do not even dare to attempt drawing the complete picture. They confine themselves to a few essentials relevant to their applications.

Even dreaming is storytelling; the brain, be it a human's, a cat's, or a dog's brain, is telling stories to itself [48], which is assumed to have an educational function. "Who has not wondered […] why his brain decided to stay up all night just to torture itself?" ([45], p. 71) But those issues are beyond the limits of the present contribution.

As Gottschall put it, "the world's priests and shamans knew what psychology would later confirm: if you want a message to burrow into a human mind, work it into a story." ([45], p. 118) One cannot overestimate the reach of storytelling, because "fiction does mold our minds. Story—whether delivered through films, books, or video games—teaches us facts about the world; influences our moral logic; and marks us with fears, hopes, and anxieties that alter our behavior, …" ([45], p. 148). The latter is considered the connecting factor to deploy storytelling for purposes of education.

3.2 Influential storytelling

Fiction is an ancient virtual reality technology that specializes in simulating human problems ([45], p. 59). "The power of narratives to change beliefs has never been doubted and has always been feared. Consequently, censorship has been ubiquitous for centuries" ([49], p. 701).

Storytelling has been educational from the early beginning with stories training the human mind that serve, so to speak, as flight simulators [50] of the human social life.

Using Gottschall's words cited above, the authors practice to work knowledge and skills for accident prevention into stories. This will be exemplified by means of the following section 4.

There are, nevertheless, certain difficulties that should be taken very seriously. Reference [51] reports some experiments demonstrating that "too much immersion" of VR storytelling has been hindering knowledge transfer.

3.3 Storytelling through digital games—stories unfolding when playing

Expanding on the societal relevance and on the educational power of storytelling, the authors focus on training through digital storytelling in virtual realities, more focused on game-based training, and to cap it all, on time travel prevention games. Human trainees shall experience participation in effective and unforgettable stories.

Even very simple digital games tell stories [52]. Games may allow for the active contribution to and the exciting experience of stories. As Stern put it, "the first wish that most players, developers and researchers originally feel when first encountering and considering interactive story, is the implicit promise to the player to be able to directly affect the plot of the story, taking it in whatever direction they wish" [53].

An unfolded story itself is a partially ordered set of events [28]. To narrate a story means to present its events in a certain linear order, perhaps, with some repetitions. The narration may be refined by a variety of presentation modes. The attractivity may further benefit from suitable exceptions of linearity and monotonicity [27].

3.4 Authoring and the emergence of stories

Since pioneering work by Plato and Aristotle [54], [55], "narrative theories have been heavily influenced by the idea that narrative must be authored" ([47], section 1.3).

When those who are addressed by the story contribute to the story (see [53] above), the original authoring process changes fundamentally to become "storification" [47]. Furthermore, in game-based training, it is gamification [57]. As soon as time travel comes into play, both approaches are becoming more involved and more expressive. Last but not least, in the present application conditions, authoring is didactic design.

The authors adopt the perspective of authoring as storyboarding [27] that may be considered a planning technology [56]. The result of dynamic plan generation is not just a single plan, but a space of potential plans. Details unfold at execution time [17] allowing for sophisticated didactic design using, e.g. ideas of non-monotonicity [28].

3.5 Artificial intelligence driving the unfolding of stories

Storyboarding as introduced in [16] is an AI technique [58] similar to dynamic plan generation [17]. Authoring, be it considered storification, gamification, didactic design or whatsoever, results in spaces of potential stories—in the authors' applications of occupational accident prevention [1], [11], [12], [13], [14], [15]—designed for the trainees' experiences.

Every story space is a collection of graphs hierarchically structured with respect to graph expansion by node substitution. Graphs on different levels of granularity reflect the essentials of layered languages of ludology [59], [60]. Nodes on all layers represent events and the space of events is partially ordered. Furthermore, there are relations of events such as mutual exclusion [28]. The graph-theoretic background is firm [61], [62].

Game play may be considered traversing the story space dynamically [63] deciding at play time where to go next and how to expand compound nodes. The story unfolds. Game AI guides the trainees to success [13] and may talk to them deontically [14], [15], i.e. direct them to fundamental principles of the logic of obligations and ought [19].

4 PREVENTION OF OCCUPATIONAL ACCIDENTS—STORIES OF SUCCESS

The perspective of interactive digital storytelling is an intellectual design technique supporting educators in designing the space of forthcoming learners' experiences and implementing the educational AI to guide learners to their individual ultimate success. Designing a story means designing a forthcoming experience. Designing a story space means designing a whole world of potential experiences to which any user—a learner, a trainee, a player—can contribute, can experience the freedom of choice, can enjoy their own impact on the outcome, and can experience their own achievements in the domain.

Story spaces are designed step by step through creating modular storyboards [16] that, in fact, are dynamic plans of forthcoming interaction processes [17]. In a sense, such a storyboard is a pattern of storytelling and the stories that possibly unfold when playing the game are its instances [64]. Components of the storyboard are patterns of pedagogy, of game play, and the like. When a pattern's instance unfolds in a story, the underlying principle of pedagogy or game play affects the human recipient.

Interested readers find more details in [11], where storyboards are treated as finite hierarchically structured families of graphs and storyboarding means the process of creating storyboards graph by graph according to the methodology developed in [17] and later on adopted and adapted in [16].

4.1 Application domain of the storytelling case study

From [1], the authors adopt the application domain to tell stories about successful training for the prevention of occupational accidents in the paint and coatings industry as demonstrated in their earlier work [14], [15].

Compared to the accident visualized by means of Figure 2, problematic events in the paint and coatings industry may be more subtle and less easy to recognize (see Figure 7).

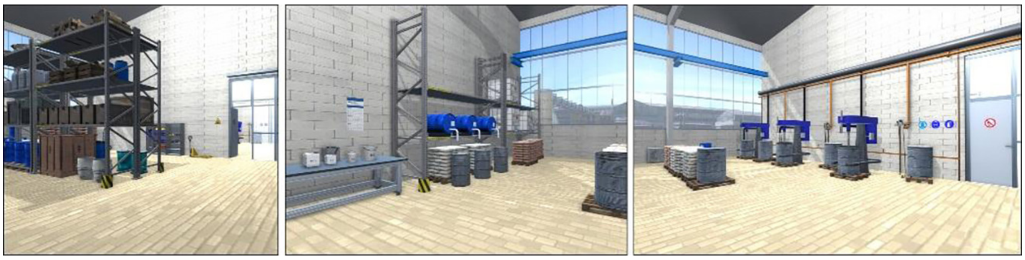

Fig. 6. Industrial installation of the paint and coatings industry by Fraunhofer IFF deployed by the Institution for Statutory Accident Insurance and Prevention for Raw Materials and Chemical Industry, Training Center Berlin, for industrial accident prevention training

The screenshots in Figure 6 show from the left to the right the factory's receiving store, working material dispensers, and the workplace equipped with basket mills. Among the necessary events/actions in the story space one needs steps of exploration. Using the dispensers and the basket mills will play an important role in the case study subsequently.

The following figure illustrates a few events that have been called undesirable in preceding discussions.

Fig. 7. Undesirable events in training accident prevention for the paint and coatings industry

Whereas the rightmost screenshot of Figure 7 visualizes some deflagration clearly observable like the explosion with fire event on display in Figure 4, the leftmost screenshot illustrates that there may be more subtle undesirable events in the paint and coatings industry. Vaporizations that took place may be unobservable, establishing a crucial problem of some events and causing difficulties to trainees.

When a human trainee needs to travel backward in time to fix problems in the past, the game AI has opportunities to dynamically change the past. By way of illustration, a vaporization may be made visible as above, avatars may appear to offer support, etc.

After this short sketch of the application domain, the authors are going to explain several aspects of trainee engagement in stories of success.

4.2 Engagement in stories of success exemplified

Educators including domain experts and IT specialists negotiate the building blocks that at execution time constitute the experiences forming a story of success.

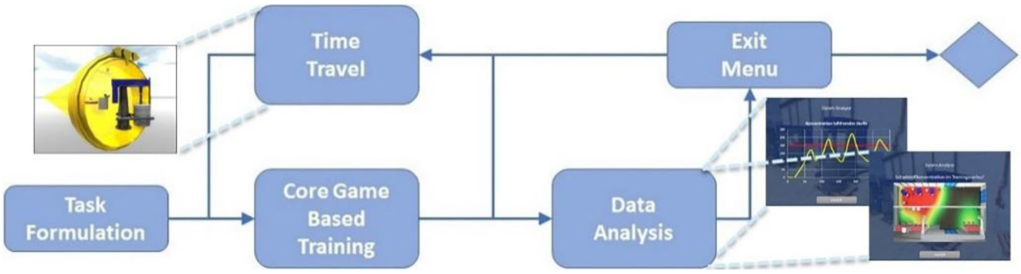

Fig. 8. Variants of expansion of the Data Analysis episode visualizing data of vaporization depending on game play history and Time Travel depending on the player's choice

From one perspective, this means authoring, and from another perspective, this means dynamic plan generation. Anyway, it means gamification and didactic design. The negotiation and design of the building blocks, i.e. graphs of a storyboard used for expansion, brings with it certain relations such as time—pure activity, i.e. succession—and conditions—depending on the game play history—of node expansion and execution.

Figure 8 is intended to illustrate the idea without going into too much technicalities. Episodes such as Core Game Based Training, Data Analysis, and Time Travel are placeholders, so to speak. At execution time, they are expanded. The interdisciplinary team of designers, in the design process of storyboarding, determines expansion such as, e.g., alternative visualizations for data analysis (see Figure 8 on the right).

From a perspective of software technology, storyboard graphs are interpreted [63]. At execution time—time of training, time of game play—recent data determine what comes next and how it runs ranging from the trainee's options to presentation modes. Formally, there are logical formulas saying in which conditions which expansions do apply. By way of illustration, when a human trainee fails frequently and, therefore, arrives at the Data Analysis episode repeatedly, the details of data analysis including accompanying explanations are modified. It is the system's goal to guide everybody to an ultimate success [17] contains all the details and [11] refers to some of them.

In a prototypical digital training game session for the paint and coatings industry, the trainees get assigned the task to mix the ingredients for a product, say 'Colourino'. The related unfolding of stories is discussed throughout the remainder of this section.

Fig. 9. Key steps of the 'Colourino' mission within the episode of Core Game Based Training

Trainees need to select containers such as a bucket or a jerry can for transportation of ingredients to be mixed (left screenshot in Figure 9). Ingredients are collected and filled into a basket mill. The raw materials are stirred. The authors' training game is played from a first-person perspective [65], apparently a case of a First Person Stirrer.

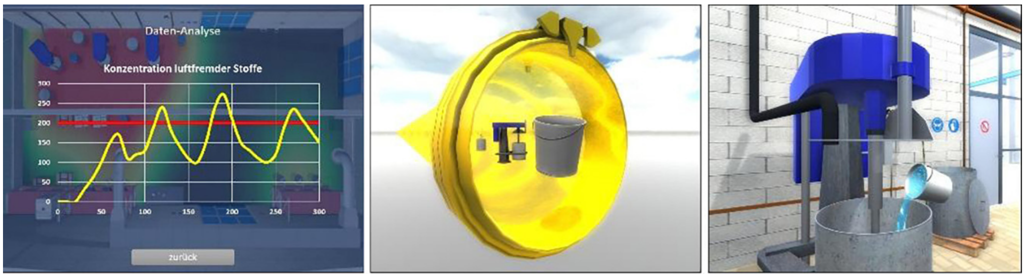

Fig. 10. The end of a story of disaster is no end at all; training continues and ends successfully

After the main episode of Core Game Based Training is completed, trainees are confronted with key data (left screenshot in Figure 10). In case of unsatisfying results, they get offered the opportunity of a journey back in time.

The time tunnel enables the human trainee to select the destination of the journey. When time travel occurs repeatedly, the game system has the opportunity to modify the sequence of stations offered in the time tunnel, a feature more intensively studied in [12], see especially figures 8 and 9 therein.

When to do this and how to do this is an issue of storyboard design negotiated within the interdisciplinary team of designers. Formally, the control of time travel destinations is represented by means of alternative expansions of the Time Travel episode node (see Figure 8) and by related formulas determining the conditions in which the one or the other expansion does apply. This is one way in which the digital game system is equipped with artificial intelligence (AI). This AI implementation in the storyboard reflects the domain knowledge, the didactic principles, and the rules of game design advocated by the designer team. In brief, the game AI implements the designer team intelligence.

Fig. 11. Scenes from the story space that may occur in the Core Game Based Training episode

Potentially, a story space allows for the unfolding of overwhelmingly many stories. Most of them are bothersome, tedious, or simply too long. Artificial Intelligence (AI) is invoked to guide trainees through the huge story space aiming at an ultimate success. The authors have developed cascades of increasingly more helpful AI assistance [13]. A particular feature is the dynamics of the past that no longer is what it used to be. How to do this represents once more the knowledge, the principles, and the decisions resulting from negotiations of the designer team when storyboarding the story space. Notice that the design of the dynamics of the past under consideration causes further negotiations relating ideas of didactics, psychology, and game design to issues of technology and implementation such as visualization, animation, sound, and the like.

The AI supports trainees, e.g., by making problems visible such as vaporization due to mistakenly using open buckets for transportation of solvents of a high vapor pressure. If this visualization (leftmost screenshot in Figure 11) is still insufficient, the game AI sends an avatar offering some jerry can instead (see center screenshot). The adaptivity may be further refined by means of communication between trainees and avatars.

Notice that several of the AI features prepared in the story space for human trainee guidance bear the potential to arouse interest. Trainees usually recognize changes of the past upon repeated arrival. Changes stimulate pondering the reasons behind.

Furthermore, the dynamics of the virtual world—the turns of the story at execution time—are worth remembering and, in many cases, are worth telling.

5 CONCLUSIONS

Within the authors' approach, trainees are not losers who should draw conclusions from certain self-induced disasters. They are winners. They are experienced and have witnessed varying problems, but they have always been able to overcome difficulties and to turn the tide.

Trainees engage in stories and drive every story to an ultimate success experienced as their own achievement. This includes that stories appear highly individual.

From a high-level pattern perspective, it appears that the story experienced when being engaged in a time travel prevention game is a story of great success, possibly embedding minor stories of disaster, perhaps even repeatedly. The success is lasting.

Facing the current hype of AI, it is necessary to relate the authors' approach to AI that guides human trainees through participation in a personalized successful story. As Chris Dede put it: "A Large Language Model (LLM) is like a digital parrot. It can express combinations of sounds/symbols without any understanding of these meanings or any capacity to explain how it arrived at what it is articulating" (The Learning Ideas Conference 2024, Keynote, June 12, New York). It is insufficient by nature [66,67].

In contrast, the authors' AI encodes (part of) the designer team's intelligence. Designers anticipate training experiences and prepare alternative opportunities of actions and responses in dependence on a human trainee's strengths and weaknesses. Design decisions, no matter whether they are based on topical knowledge, educational principles, psychological thoughts, or whatsoever are represented in the story space.

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7 AUTHORS

Hans-Holger Wache, Berlin, Germany, Institution for Statutory Accidents Insurance and Prevention for Raw Materials and Chemical Industry, Prevention Center Berlin.

Ronny Franke, Magdeburg, Germany, Fraunhofer Institute for Factory Operation and Optimization IFF (ORCID: 0000-0001-5662-1680).

Oksana Arnold, Erfurt, Germany, Erfurt University of Applied Sciences (E-mail: oksana.arnold@fh-erfurt.de; ORCID: 0009-0001-3148-4314).

Klaus P. Jantke, Weimar, Germany, ADAMATIK GmbH (ORCID: 0000-0003-4327-7192).