Storyboard Interpretation Technology Used for Value-based STEM Education in Digital Game-based Learning Contexts

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Keywords: Digital Game-Based Learning, Game Design, Moral Dilemma Situations, Open Educational Resources, Storyboarding, Storyboard Interpretation Technology, Usability Engineering, User Experience Design.

Abstract: Digital games, particularly serious games, are seen as an important element for providing stimulation and simulation in educational settings. The Storyboard Interpretation Technology (SIT) is a feature to support the development of games, especially for educational contexts. The Experimento Game is a prototype based on concepts of SIT. This prototype aims at supporting the development of a students critical reflection in STEM contexts, taking into account that students must be encouraged to understand the deeper meaning of a problem. In order to determine the suitability of the digital game, a user experience evaluation with a game test was carried out for the target group of students at the age of 11 to 13 years. In this paper we firstly outline the motivation of developing a gaming module called Experimento Game, secondly the theoretical background, and thirdly the progress of development. Finally we discuss the results of the user experience evaluation by means of a survey study and the collection of game data using Data Mining.

1 MOTIVATION

Digital games can be understood as moral objects, as well as mediators of ethical values (Wimmer, 2014). Game narratives, rulesets, high scores or achievements suggest righteousness and virtue. Following this approach, moral dilemmas embedded in digital games could potentially sensitize gamers in respect to real-world moral dilemmas and therefore stimulate critical thinking and ethical reflection (Sicart, 2013; Krebs, 2013).

In general a Dilemma is defined a situation with serveral decision-making possibilities. Every possibility is neither wrong nor right. Which choice you ultimately make has a lot to do with morality but also with emotional distance (Avram et al., 2014).

How people make decisions in such difficult situations for themselves and others depends mainly on three factors: the consequences of their own actions, both intended and unintended (Avram, 2014). It also depends on whether you have to intervene actively, or only to allow you to do what is happening anyway (Greene et al., 2009). And it depends on which socially defined perceptions there are about which one is morally bound - and what is taboo (Haidt, 2001). A weak moral dilemma is a dilemma in which the moral failure, in contrast to the lack of clarity and urgency of the decision, plays no great role (Sellmaier, 2008).

The article outlines the peculiarities of moral dilemmas in STEM contexts in Digital Game-Based Learning (DGBL) scenarios. The so-called Storyboard Interpretation Technology (SIT), which is applied in the current game design of Experimento Game, is the underlying technological approach published for the first time in (Fujima et al., 2013) and (Arnold et al., 2013a).

The Experimento Game is part of Experimento, the international educational program of the Siemens Stiftung (Siemens Stiftung, 2017b). The program Experimento is based on the principle of research-based learning and offers teacher trainings and curriculum-oriented hands-on experiments from the fields of energy, environment, and health. With Experimento, the Siemens Stiftung also aims to strengthen the teaching and formation of values during science and technology lessons. All Experimento teaching materials and additional media are available as Open Educational Resources (OER) on the media portal of the Siemens Stiftung. The online portal helps teachers to find age-appropriate media to introduce their students to global challenges such as renewable energies, the greenhouse effect, or the production of clean water.

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To strengthen the foundation of values during experimentation, the Siemens Stiftung takes a new path: the development of a gaming module, which is based on the principle of learning through discovery. That implies that children and young people actively shape their individual learning processes while playing, discovering and understanding scientific and technological interrelationships through moral dilemma situations implemented in a digital game.

Figure 1: Title screen of the Experimento Game.

2 THEORETICAL BACKGROUND

Open Educational Resources (OERs) are becoming increasingly popular in Germany as well as other countries. The Paris Declaration issued by UNESCO in 2012 defines these resources as freely accessible material that may be altered and adapted as needed (United Nations Educational, Scientific and Cultural Organization, 2012). These are educational materials which are accessible under so-called open licenses. As a result, OERs open the way for children in the world's more destitute regions to have access to educational resources. Special potential is offered by the cooperative development and enhancement of these resources as well as in the simple modification and distribution thereof.

OERs can be modified and customized in a legally compliant manner, thereby fulfilling important requirements for locally differentiated, but inclusive instruction in increasingly heterogeneous school classes. For students, the active use of educational resources promotes self-determined learning, in addition to an understanding of the internet and media. In broad terms, OERs support a creative working relationship between teachers and students, and facilitate new collaborative forms of teaching and learning. (Siemens Stiftung, 2017b)

2.1 STEM and Values: How Values Can Be Taught in Schools

There is big potential in combining STEM education (science, technology, engineering and mathematics) and values together, not only for individuals but at the same time for further developing society at large. Currently there are just a few teaching methods, which promote technical knowledge and at the same time strengthen students ability to form values. Experimento Game, a digital game, tackles this approach.

2.1.1 Digital Game-Based Learning (DGBL)

Definitions of Digital Game-Based Learning ordinarily emphasize that it is a type of game play with defined learning outcomes (Plass et al., 2016).

Digital Games are a complex genre of learning environments that cannot be understood by taking only one perspective of learning. Numerous of the concepts, such as motivation, include aspects relating to different theoretical foundations: cognitive, affective, motivational, and sociocultural; which are important in the context of game design and game research (Plass et al., 2016).

Plass et al. (2016) argue that all these perspectives have to be taken into account, with specific emphases depending upon the intention and design of the learning game, to achieve their potential for playful learning.

2.1.2 Experimento Game: A New Path of Experimento

Experimento, the international educational program of the Siemens Stiftung, has been developed by educationalists for use in preschools, elementary schools, and secondary schools. It offers teachers and educators a practical and curriculum-oriented selection of topics in the areas of energy, health, and environment. Some 130 experiments developed for age groups 4-7 (Experimento|4+), 8-12 (Experimento|8+) and 10-18 (Experimento|10+) ensure that children and young people gain knowledge they can use throughout the educational chain. They can explore, reflect upon and understand scientific and technological subjects independently and further develop their knowledge of global challenges in a way that is appropriate to their age group. (Siemens Stiftung, 2017a)

The Siemens Stiftung is going to expand their offer with the gaming module called Experimento Game, developed by Fraunhofer IDMT.

The Experimento Game is an adventure game, with a classic point-and-click core game mechanic.

Like other adventure games, the protagonist has to solve puzzles to progress in the game. Within Experimento Game, the player deals with two different moral dilemma situations, which are implemented as a trigger for two major topics:

(I) Will I share my last mouthful of water with a stranger? This moral dilemma triggers the topic of how to produce drinking water/ methods of purifying water.

(II) Will I stop my grandmother from burning her garbage on the road? This moral dilemma is triggering the topic of waste separation.

The moral dilemmas are situations where players weigh the consequences of their choices carefully, because there are at least two or more values battling against each other and there is no optimal answer or choice (Schuldt, 2017).

2.1.3 Driving Value-based STEM Education

How can ethical values be successfully promoted in STEM subjects?

Moral concepts and moral stances are not only special characteristics that set us apart, but also educational capabilities. The importance of successful value promotion is therefore extremely significant in terms of individual development. The most important thing here is, that values should be conveyed and imparted during childrens early formative years as part of real life and in relation to everyday life as much as possible (von Siemens, 2017).

This is where STEM education comes in: Anyone dealing with science and technology issues will not be able to avoid reflecting on them, making assessments and taking decisions. Therefore, there is no need for new subjects to be introduced: The didactic approaches simply need to be shaped accordingly. New approaches are therefore required, such as DGBL, combined with value-based issues.

Digital games are able to engage learners on an affective, behavioral, cognitive, and sociocultural level in ways few other learning environments are able to (Plass et al., 2016). Digital games have the potential to unleash motivation and interest for science and technology themes.

Since digitization also affects the education system, teaching methods should be adapted appropriately. Learning and especially DGBL in the sense of acquisition of knowledge and its application requires interactivity, contextualization and goal orientation (Schuldt et al., 2017). Motivation, player engagement, adaptivity, graceful failure and feedback systems are also influencing factors in DGBL-environments (Plass et al., 2016).

2.2 Storyboarding

When Digital Game-Based Learning goals and tasks are ambitious, related systems are easily becoming complex. Storyboarding is a methodology of the systematic reliable design of Digital Game-Based Learning applications.

The authors rely on the basics as introduced by (Jantke and Knauf, 2005) and confine themselves to those notions and notations needed for the purpose of characterizing serious games. Recent work on storyboarding digital games such as (Arnold et al., 2013c; Jantke and Knauf, 2012; Schuldt, 2017), e.g., is worth some comparison. Storyboards are described as finite, hierarchically and structured graphs.

> ”The composite nodes are named episodes, whereas the atomic nodes are named scenes. Composite nodes may be subject to substitution by other graphs. In contrast, atomic nodes have some semantics in the underlying domain.” (Arnold et al., 2013b)

2.2.1 Storyboarding as a Methodology of Game Design

The authors interpret digital storyboarding as a methodology that is suitable for anticipating user experience of media interaction including game play and learning.

> ”Storyboarding means the organization of experience.” (Jantke and Knauf, 2005)

Therefore, storyboarding can be understood as a methodology of didactic design. The authors refer to more detailed explanations by (Krebs and Jantke, 2014). Storyboarding enables authors to incorporate psychological and/or pedagogical positions into a technologically enhanced educational framework such as a gaming module like Experimento Game.

2.2.2 Storyboarding for Experimento Game

Games of the adventure genre are mostly story-driven, meaning that a good story is a fundamental part of this type of game (Fernandez-Vara and Osterweil, 2010). Therefore, the two moral dilemma situations in Experimento Game (see 2.1.2 Experimento Game: A New Path of Experimento) are embedded into a whole story. In addition to a tutorial level, there are two more levels covering different topics:

- Level 1: *How to produce drinking water? The method of purifying water.*
- Level 2: *How to protect the environment? Separating materials for recycling purposes.*

The flexibility of storyboards allows to connect seamless gameplay, dilemma situations and learning experiences.

3 TECHNOLOGY AND DEVELOPMENT

As mentioned previously, the Experimento Game is an adventure game with sorting puzzles. In order to progress in the game, the players make decisions and solve puzzles. The core game mechanics are similar to those of classic point-and-click games. The Players only need a mouse (or finger for the tablet version) as an input device. The Experimento Game is a short 2D Game and has been developed with UNITY 3D.

3.1 Storyboard Interpretation Technology for Experimento Game

The Experimento Game uses the Storyboard Interpretation Technology (SIT) by Fraunhofer IDMT. The essence of this approach is to make digital storyboards immediately executable. SIT includes a toolkit that supports the creation of storyboards and ensures the integration into software products. The definition of a digital structure for dynamic stories and rules for interpreting these stories are an additional part of SIT. The technology has already been used in previous projects by Fraunhofer IDMT for creating highly complex story-driven applications (Arnold et al., 2013c; Arnold et al., 2013b).

3.1.1 Features of SIT

Depending on the requirements of the Experimento Game, it was necessary to advance SIT. However, storyboards are now stored in JSON data and no longer in an online RDF database in comparison to (Arnold et al., 2013c). New tools support the story authors to create a tabular storyboard. Like the traditional storyboards, the digital tabular storyboard contains drawings and descriptive texts, as well as control information for the game. More information about the technology of the Storyboard Editor was published in (Schuldt, 2017). A parser converts the tabular storyboard into a JSON file that can be interpreted by the storyboard engine module (see Figure 2).

Now, the storyboard engine contains an interpreter and a processor. The interpreter understands the structure of the storyboard files and reads the control information from the storyboard. The interpreter sends this information to the processor. The processor is

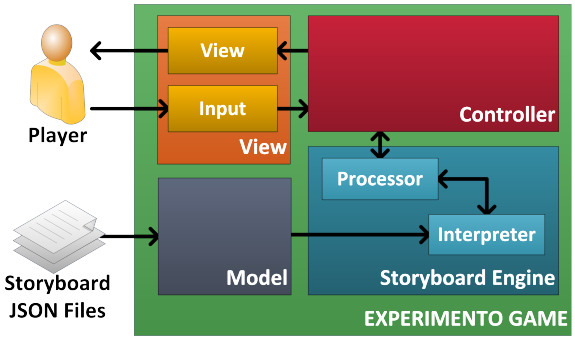


Figure 2: System design of the Experimento Game.

connected to the game interfaces and processes the control commands in the game immediately.

The storyboard engine reads the nodes from the storyboard, executes control commands and reacts to the players feedback. Depending on game events the storyboard engine manages the progress in the game. Therefore the storyboard engine has all relevant data like the node structure of the storyboard (see Figure 3) or the conditions for the transitions. It is not intended to read any of the inscriptions in the storyboard graph below, but to get an impression of some storyboard as a whole.

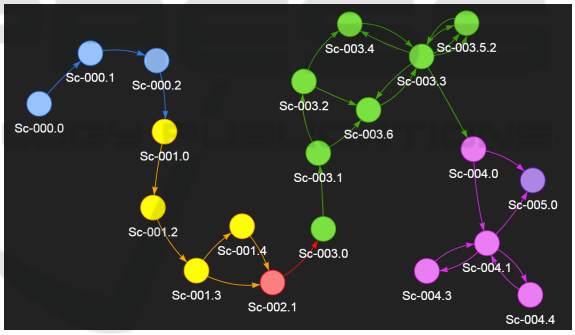


Figure 3: Shows the storyboard of the tutorial level. Dots represents nodes, arrows represents possible transitions. The color of the dots indicates the corresponding subcategory of a node.

3.1.2 Application Area of SIT

The use of SIT not only allows game developers to write a story, but also to create adaptive gameplay content. For instance, the story in Experimento Game adapts, depending on the player's decision in the dilemma situations. Finally, the use of SIT improves and accelerates the development process. The following positive experiences have been made with the use of SIT:

- Storyboard authors don't need a long training period for the Storyboard-Tool. They are familiar

with the traditional tabular storyboard user interface.

- SIT reduces the workload during development. Storyboard authors and developers can work separately from each other.
- Changes to the storyboard can be implemented quickly.
- An assitstance system uses automatic input checks to prevent incorrect storyboards.

The use of SIT has also demonstrated the limits of the current technology. Although the limitations have not affected the gaming design process of the Experimento Game, future research should solve the current drawbacks:

- SIT cannot be used for open-world storyboards.
- The mechanics of arcade games are hard to turn into a storyboard.

3.2 Development

At the beginning of the project there were some technical challenges, like the cross-platform capability of the game and the support of low performance devices, according to the usual school equipment. In addition to these challenges, the game should be suitable for various technical infrastructures. A further challenge was to create a satisfying game for the target group. Throughout the entire development cycle, we used usability engineering to improve the game's user experience.

3.2.1 Technical Challenges

To support lower performance devices certain design decisions have been made and special techniques have been used. For instance, there are only 2D objects without a polygon-geometry in the game. All sprites are assigned to one of eleven render layers. Two layers are for the graphical user interface elements and nine layers for the 2D objects in the game.

To reduce rendering effort, the game automatically disables objects that are located outside of the camera view. To get a quick access to objects in the same location the game uses a location map with a grid.

Furthermore a state-engine was built to separate the different states in the game and to split the complexity of the code with 10 states (Initialization, Menu, (Un-)Load, Play, etc.). The game will be released in different regions such as Africa, South America and Germany, so all texts in the game are interchangeable. Separate language files make it easier to add new languages or update existing texts. The design has simple 2D graphics and is an abstraction of the real world, to be appealing to a variety of cultures. The environment is not similar to any certain region.

Depending on the technical infrastructure there is an online- and an offline-version of the game available.

3.2.2 Game Mechanics

To ensure that players are familiar with the control mechanics of a point-and-click game, there is a tutorial-level as introduction implemented.

There are two puzzles in the game, both uses the same mechanics and game rules. During a time of approx. 60 seconds, the players have to sort objects. During this time objects appear and move from left to right like on a conveyor belt. In the first mini game the player has to drag components of a water filter and drop them in the correct order into an empty filter (see Figure 4). If the assignment is correct, the score increases.

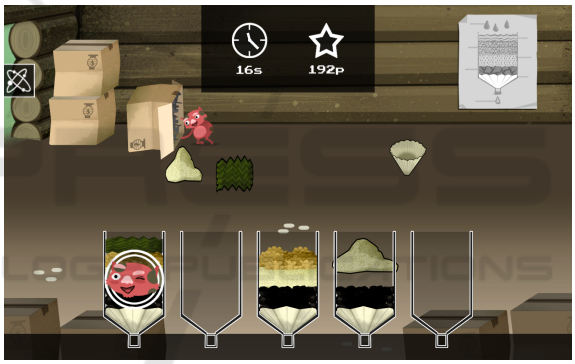


Figure 4: Screen-shot from first Mini-Game.

In order to increase the replayability of the game, there is a hidden score. The players get points for various actions during the game. At the end of the game a result screen shows what points have been awarded. The players achieve points for:

- playing time is less than 12 minutes,
- pick up of waste while playing,
- score of the first mini game (build water filter),
- score of the second mini game (recycling).

4 STUDY AND RESULTS

Going beyond the concept of usability, user experience is a holistic approach that embraces the complete effects of a users experience before, while and after using an interface (Deutsches Institut für Normung,

2011). It also includes aesthetic or emotional factors such as joy or fun while using a product.

In order to summative examine the games user experience (UX) according to the target group of 11- to 13 year old students a survey-based study including a playtest of the final prototype has been carried out in early July 2017.

A suitable usability and UX concept was already conceived right in the beginning and has been adjusted systematically in the projects course to optimize the game in an iterative design process (Schuldt, 2017). In preparation of the study, a pretest was conducted in June 2017 to test the prototype on the one hand and to test the research setting and the instruments (see 4.2 Methodological Study Design) on the other hand. It confirmed a playtime of around 15 minutes and an adequate understanding of the questionnaire as well as a working log file analysis. Subsequently, minor changes were made in the games source code and the questionnaire according to usability issues.

4.1 Objectives and Research Interests

The UX of Experimento Game formed the primary research subject of this study. One goal of the study was to evaluate the game's suitability for school students and the context of lessons and the specific curriculum. Besides, there was a strong interest to examine the impact of the game using dilemma situations as a method to foster reflection about norms and values in class.

The study design was set up to give an answer to the following research questions:

(I) UX: How is the overall user experience of Experimento Game within the target group of highschool students at the age of 11 to 13?

(II) Dilemma: How does the target group of highschool students at the age of 11 to 13 cope with decision making in the moral dilemma situations?

(III) Learning: How is the games impact on the students awareness of the environment issues mentioned in the story?

(IV) Context of use: How suitable is the game for the use in class?

4.2 Methodological Study Design

The challenge was to set up a study design being close to the future context of use of the game in classes with young students. The whole setting should fit into a school lesson and should be easily to understand and to be answered in short time. Therefore, the following instruments were employed:

- standardized questionnaire including the topics: personal data, user experience, emotions while playing, decision making, learning with the game;
- user experience questionnaire (UEQ) in simplified language as part of the main questionnaire: set of 26 pairs of opposite items belonging to the scales attractiveness, perspicuity, efficiency, dependability, stimulation, and novelty. (Hinderks et al., 2012; Hinderks et al., 2014; Hinderks et al., 2017);
- log files: e.g. total playing time, usage of sound, choice of character, decisions made in dilemma situations, scores in mini games and other challenges.

Within the scope of the study, the game was tested and evaluated by the target group of 11 to 13 year-old high school students in Germany using a setting integrated in a school lesson. There was first an introduction by the accompanying scientist and the teacher. Afterwards the students were asked to play the game on their own while log files were collected and the scientist kept the minutes in an observation protocol. Finally, the students filled in a questionnaire to evaluate the game and their experiences made.

The sample of students taken was not representative, but self-selective as existing school classes were asked to take part in the study. The questionnaires were imported and analysed by using the survey software SPHINX to generate descriptive data. The UEQ Data Analysis Tool by Dr. Martin Schrepp see (Hinderks et al., 2017) was applied to analyse the items belonging to the user experience questionnaire. The data mining was realized by implementing a data acquisition tool and a final analysis in Microsoft Excel.

The survey was conducted in German language and then translated for this paper.

4.3 Study Results

The examination was conducted at a secondary school in Lower Saxony, Germany in June 2017. Altogether n=49 participants tested the game and filled in the questionnaire. Furthermore, data were collected via data mining and an additional observation protocol. In addition, n=2 teachers filled in the questionnaire concerning the teacher's view. The students taking part attended classes in 5th and 6th grade and were aged from 9 to 14 years; there were 51 % male and 46,1 % female (n=25 male, n=23 female, 1= unknown). Most of them were experienced in playing digital games at least sometimes, but - if at all - very

exceptionally had the chance to get in touch with it as a method in lessons. (see Figure 5)

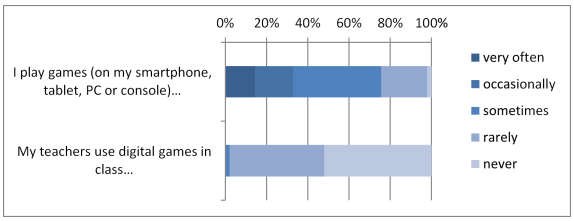


Figure 5: Previous experience with computer games.

4.3.1 Results UX

On the whole, there is a positive overall impression of the game as the majority of the test persons (62.5 %) claimed they liked Experimento Game and only few persons (6.3 %) disagreed. (see Figure 6) In addition, similar results showed up concerning the students emotions while playing: Most of the test persons were in a good mood, felt motivated as well as happy when playing the game. (see Figure 7)

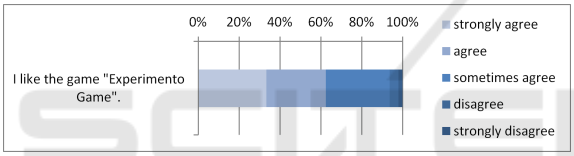


Figure 6: Assessment of the game by the students.

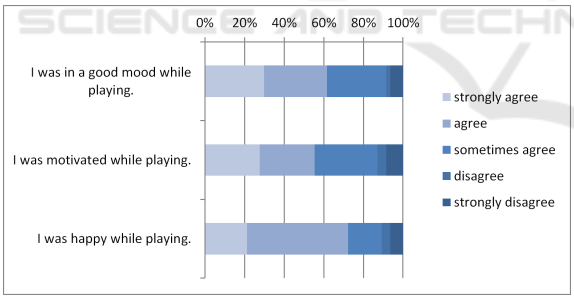


Figure 7: Emotions while playing.

Regarding the scales of the UEQ, the game was altogether rated positively by the test persons. (see Figure 8) For explanation: According to (Hinderks et al., 2017) the values between -0.8 and 0.8 represent a neutral evaluation of the corresponding scale, and values greater than 0,8 represent a positive evaluation. Due to the calculation of means over a range of different persons with different opinions and answer tendencies values above +2 are rather unlikely to achieve.

- The dimension **attractiveness** means the overall impression of the evaluated system. The results given in the UEQ concerning Experimento Game correspond to the positive students answers in (Figure 6) and show satisfying trends (see Figure 7).

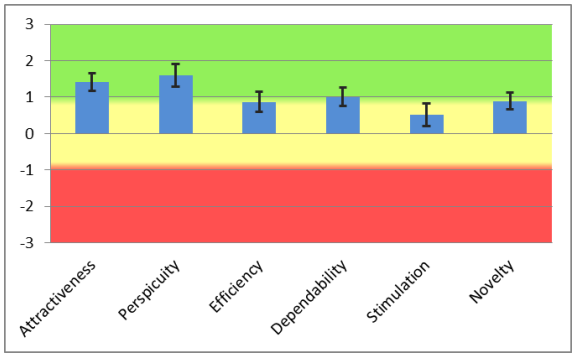


Figure 8: UX results according to the UEQ-Scales.

- Dimension quality of use:
  - The scale **perspicuity** measures if a system is easy to understand and to learn. The test persons obviously did not have any severe problems to use the game.
  - The scale **efficiency** measures, if the users can work quick and efficient with a system. It showed satisfying results in the context of a digital game.
  - The scale **dependability** measures how safe and predictable the interactions are. The results confirm that the adolescent testers were generally able to cope with the game. Some problems were mentioned in the free-text fields of the main questionnaire and mostly referred to the high speed of the mini games or some minor usability issues that were adjusted afterwards.
- Dimension design quality:
  - The scale **stimulation** measures how interesting, stimulating and motivating the system is. Some helpful comments for further improvements of the game were given by the test persons concerning implementing more characters to choose/ to create, and raising the tension of the game through leaving out predictable parts.
  - The scale **novelty** refers to the extent of innovation and creativeness of the design which is in the case of "Experimento Game" mainly positively rated.

Accordingly, the majority of the students taking part in the study accepted the game as part of their lesson and could imagine to play more games like Experimento Game in class (82,9 %). For the most part they felt that comfortable with the game that they would also recommend it to friends. (see Figure 9).

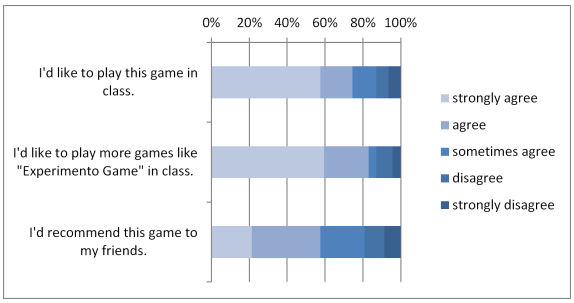


Figure 9: Suitability for learning.

4.3.2 Results Dilemma

Generally, the students identified themselves in the dilemma situations and told phrases like 'To me all the waste lying around was ugly.', 'Those poor birds', 'Why is grandma that dumb? Thats simply not done!'. In both dilemma situations decision making felt rather easy to most of the test person (see Figure 10). Roundabout one fifth of them had difficulties to get aware of the consequences of their decision making as well as to take a decision. (see Figure 11)

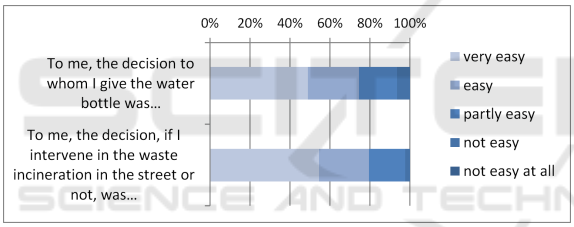


Figure 10: Feelings about decision making.

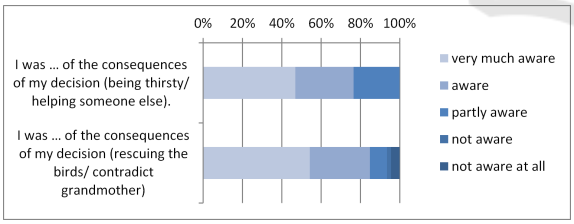
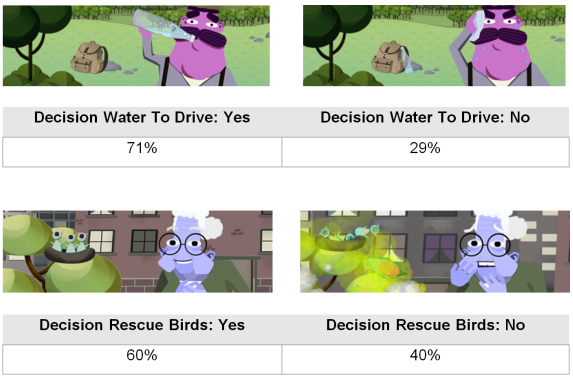


Figure 11: Awareness of consequences.

The dilemma situations already led to first discussions in class within the test session. Thus, they serve the purpose of fostering moral argumentations about contents relevant to the students curriculum. The test persons decision behavior in the dilemma situations did not yet appear completely balanced (see Figure 12), but there still is a need for a greater sample to see a clear tendency. Altogether, the students definitely experienced the use of dilemmata as one exciting method to get involved in new topics.



Decision Water To Drive: Yes	Decision Water To Drive: No
71%	29%

Decision Rescue Birds: Yes	Decision Rescue Birds: No
60%	40%

Figure 12: Distribution of responses in dilemma situations.

4.3.3 Results Learning

The results concerning UX (also including some free-text comments as well as observations in class) clearly show acceptance among the target group of the game. More than half of the test persons agreed to have learned something new while playing the game. (see Figure 13) An even bigger share (> 74 %) claimed that the game drew their attention to the importance of the environments topics treated in the story. A similar amount of test persons would like to play Experimento Game in class.

The topics chosen are relevant for the curriculum. And, what's more, the environment-related dilemma situations of this module can be used in classic STEM subjects, but are also suitable for further subjects like ethics. Although the game can only treat limited topics, its interactive features foster tackling with environmental issues and serve as one method get students involved.

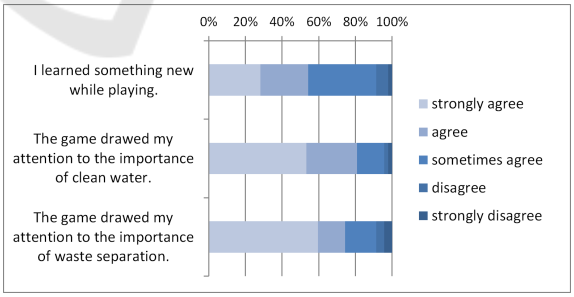


Figure 13: Assessment of learning with Experimento Game.

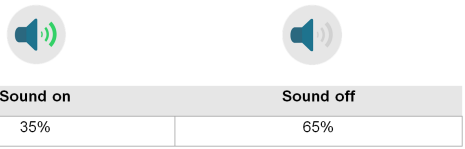
4.3.4 Results Context of Use

The logfile data concerning playing time (around 15 minutes) and scores (mini games, collecting trash, and time score) confirmed the suitability of the game for its usage in lessons as well as an adequate challenge for highschool students. (see Figure 14).

	Playing_Time	Score MG1	Score MG 2	Score_Trash	Score_Time
Min	00:08:21	0	0	0	0
Average	00:16:37	123	59	432	62
Max	00:23:11	600	215	600	400

Figure 14: Logfile data - Times and scores.

The game was used with as well as without sound while testing. (see Figure 15) It is working in both situations.



Sound on	Sound off
35%	65%

Figure 15: Used sound settings.

It is justified to implement a choice of character as all of them were chosen as avatar. Dante and Mokobe were the most popular among the test persons. (see Figure 16)

Character Dante	Character Sappho	Character Mokobe
46%	19%	35%

Figure 16: Logfile data - Choice of character.

The logfile data as well as students feedback (see Figure 17) shows that the recycling mini-game was more difficult than the water filter mini-game.

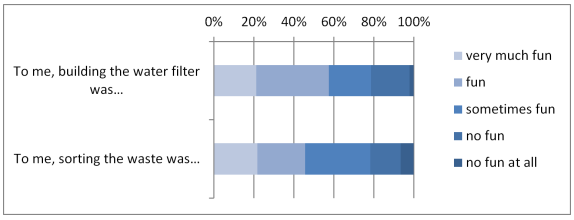


Figure 17: Feelings about playing mini games.

There was also a teacher-version of the questionnaire asking for their opinion about the game and it's suitability for classes. Due to the small teacher's sample, we will not give a detailed description of the results.

5 DISCUSSION

The overall user experience of Experimento Game within the target group of highschool students was rated positively, especially the dimensions attractiveness and perspicuity. Only the dimension stimulation was rated neutral. For some students the decisions were not too difficult in the moral dilemmas, but not all of them were aware of the consequences of their decision. The study showed that the games impact on the students awareness of the environment issues mentioned in the story is quite high and therefore a good method for learning in STEM contexts. Teachers and students appreciated the Experimento Game approach and rate the game suitable for the use in class.

The study underlies several limitations concerning the target group and the specifications of the survey. There were strong limitations concerning time capacities (school lesson) as well as suitabiliey of the research method for rather young high school students (length, comprehension, focusing the overall impression of the game). According to the content of the survey, it would also be desirerable to distinguish the emotions while playing between overall playing experience and decision making in future research. The emotions in the survey refer to the overall playing experience, but not to how specific parts of the dilemma story was experienced by the users (cf. 4.3.2 Results Dilemma).

The underlying user-centered design approach allowed for a continuous adjustment of the game during development. In the final UX-Study we got positive feedback from students and teachers equally.

The questionnaire was adapted to the target group and improved through a Pretest-Setting.

Games as educational media are time-consuming and quite expensive to produce and then unfortunately not always accepted. They can and should not stand alone, therefore we supported teacher with an extra handout with suggestions of how to embed the game in their lessons.

Extensions within the Experimento-Program are possible, although there are challenges in spreading OER, due to the publishers, thus making no profit with these offers.

SIT enables easy language variants and different areas of application (for instance, in our case the story must fit for different cultures).

6 CONCLUSIONS AND OUTLOOK

Experimento Game is designed to motivate students intrinsically and activate environmental awareness and sustainability. The game enables decisions in a "sheltered" gaming environment and stimulates discussions for reflection of different behavior.

Experimento Game fits into today's everyday habits of children and adolescents; the majority consumes regularly games on different platforms (Feierabend et al., 2016). Currently, digital games are used rarely by teachers in the classroom; the infrastructure in schools is given in many places, that this would in principle be possible (Kantar TNS, 2016).

The novelty of the project is to use SIT to develop tasks and teaching materials that bring STEM topics to life and enable a fun way of learning. Many curricula still focus on conducting exams. Students learn more easily and more sustainably if they actively use new knowledge instead of memorizing it.

The Experimento Game was very well received in the study by the subjects. It has not only caused many positive reactions among the participants, but has also enabled them to experience their own personal experiences. It has proved to be a suitable game to introduce environmental education in the classroom and to stimulate reflection on the behavior of different actors.

The teachers confirmed both the acceptance of the pupils as well as their own. They thought the material provided was helpful and they would like to use the game in future lessons.

Experimento Game can contribute to education as a suitable offer to students to modernize and enrich learning, and thus the goal of a meaningful digital education in schools.

In the future, it is recommended to transfer the game to other cultures and languages as well as to elaborate further modules that address new content and controversy. The numerous comments from the testers should be used to make future developments even more interesting and to respond more intensively to the previous experiences of the potential users. A mobile version of the game, such as a tablet version, is the next step in development.

The Storyboard Interpretation Technology was used to implement a story. This Technology made it possible to write stories easier, faster and more effective. In the future, SIT should be tested to see whether it can also be used in other learning areas, such as interactive virtual laboratories.

Serious Games must have a pedagogic-didactic quality and should focus on the application of knowledge. The matter in question and the content design must be measured by the fact that they have an actual added value about real experimentation, discussion, etc..

Further research questions are interesting to investigate: (a) Do the emotions of the students have an influence on the playing experience with Experimento Game? (b) Is SIT as an authoring tool suitable for universal use?

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