Gamification of the Internet of Things

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ABSTRACT

In modern day society, information and data is all around us and more fast-paced than ever. The view on learning has changed drastically through the last decade, mainly from passive information acquisition, to active gathering of and reflection on information. A method to achieve this way of learning is through the use of gamification, creating an application with learning and gaming elements, to achieve a motivational environment for fun and learning. To test the learning performance of gamification in comparison to traditional learning, three different learning methods were tested on learning performance: a gamified application with more added game elements, a gamified application without additional content and a traditional PowerPoint presentation. The gamified application created can be described as a game with an explorative goal, non-contextual to the topic to learn. Each version contained information slides with the same information in the same format, about an advanced topic, in this case the Internet of Things. The performance was tested using a quiz with questions about the presented information, resulting in a correctness score. This was expanded by a questionnaire about fun and perceived retention and effectiveness, to further analyze why gamification might or might not be effective. No evidence was found to support that a gamified application, in general, works better than a PowerPoint presentation. There is, however, an indication that gamification might increase performance for audiences that like games, as long as the game is not distracting them from learning.

KEYWORDS

Gamification, PowerPoint, presentation, Internet of Things, IoT, retention, cognitive load, learning theories

1. INTRODUCTION

1.1 Difficulty in learning

Collins and Halverson (2018, p.2) tell the story of a bored teenager dropping out of school and starting to teach himself about computer programming using online courses. Enabling him to start working for a bank and using the bank's educational program to further study the banking business.

The method of learning, together with the retention and absorption of the material is described in learning theories. Some prominent evolutions in learning theories are (Harasim, 2012):

1. **Behaviorism**:

Focussing on the observable and measurable to understand behavior.

2. **Cognitivism**:

Adding the importance of the mind to behaviorism, cognitivism states that the mind is a logical machine following steps leading to a certain behavior.

3. **Constructivism**:

In contrast to cognitivism, the mind is not a machine and responses to stimuli can differ. People learn by creating their own understanding and reflect on this knowledge by experience. Learning is about actively comparing old information with new information to create a new or better understanding.

As of the digital age, humans are more and more dependent on technology and information. These can be used to redefine the ways of teaching and information gathering (Beetham & Sharpe, 2013). However, instead of using the technology to stimulate active learning and information gathering, the technology is mainly used to support more traditional ways of learning, for example by using PowerPoint slides instead of a blackboard to project information (Beetham & Sharpe, 2013).

1.2 Methods of learning

A popular method in traditional education is the use of PowerPoint presentations, but the effectiveness of this method is questionable. It is argued that PowerPoint presentations are not focussed on the individual needs of the learner and that the use of critical thinking is suppressed (Harlin & Brown, 2007).

More active approaches should be used as learning methods since there is evidence that active learning is increasing learning performance, as illustrated in the constructivism learning theory (by reflection on information) and as shown in the research of Freeman et al. (2014).

A newer method of active learning is through the use of gamification or game-based learning. Gamified applications consist of both elements of learning and gaming, merging education with entertainment, creating a fun and more immersive environment (Yang & Change, 2013). Engagement, flow, and immersion can help students learning performance (Hamari et al., 2016). Bíró (2014) goes as far as calling gamification a new learning theory, taking a more proactive approach to learning, by increasing motivation and achieving a higher level of engagement, through the use of diversity, rewards and different learning paths. Serious games are an example of such gamified implementations. However, the focus of serious games lies in realism and are therefore very expensive to create (Dubbels, 2013). Therefore, the game created for this research focuses on implementing game and learning elements into a game, without the simulation and realism introduced in serious games.

1.3 Topic "The Internet of Things"

The goal of this research is to investigate the difference in learning performance between using traditional PowerPoint presentations and gamified learning. To test whether the methods are effective, a subject of higher education is used, in this case, the topic of the 'Internet of Things' (IoT). The Internet of Things is a connected network of devices that enable data exchange in order to create smart and reactive environments (Patel & Patel, 2016). This subject is chosen because it is explainable without the need for a lot of background information while having a lot of different features to inform about.

1.4 Research question

It is to be determined whether a gamified application can be created to increase the effectiveness of understanding the Internet of Things and if this method is more effective than the traditional PowerPoint presentations. The research question is formulated as:

How effective is the use of a gamified application in learning advanced topics, in comparison with a PowerPoint presentation?"

To research this, the pros and cons of both methods need to be examined. First of all, it is important to know what makes parts of IoT difficult to understand, so a proper collection of learning material can be created for the participants to learn. Next to this, it has to be identified which aspects make presentations ineffective for learning and how gamification is used to tack these effectivity problems.

2. RELATED WORK

This section will discuss the research questions and is used to identify the know issues of presentation and the benefits of gamification.

2.1 Difficulties in learning IoT

The term Internet of Things first arrived with the creation of networked radio-frequency identification tags (RFID), where radio waves are used to transfer and save information on tags, which could be present in any kind of device (Wortmann & Flüchter, 2015). However, the Internet of Things has currently a much broader application field. It is now used as an infrastructure of interconnected things that can collectively work together in an informational and communicational setting (Wortmann & Flüchter, 2015). The term of IoT is open for interpretation and has thereby become a collective name for many applications, ranging from simple sensor networks to interconnected machine to machine communication and this vagueness is used by businesses to use the name of IoT as a selling point (Atzori et al., 2017). Some examples of products created by business as an application of IoT are:

1. The IoT starter kit of Vodafone. This starter kit consists of some interconnected sensors (measuring for example heat and movement) together with a development and monitor board (Iot.vodafone.nl, 2019).
2. KPN describes an IoT application where, with the use of IoT, a stolen bike can be found within 24 hours using sensors on the bike and the GPS network (Kpn.com, 2019).
3. A smart home system, where an architecture exists of household devices communicating with RFID tags to create an interconnected network, as described by Jie et al. (2013).

These are some examples of the broad applicational possibilities of IoT. While there are many very different possible applications, the underlying architecture of IoT remains the same, which is often not covered in descriptions of an IoT system. Patel and Patel (2016) state that, for example, IoT systems are very resilient to changes in devices and are able to connect almost anything to the global information network (known as interconnectivity), even if the devices are very different from each other (heterogeneous). A general view of IoT applications is easily obtained, yet the exact inner workings can be hard to understand and remember.

2.2 Ineffective learning aspects of presentations

Popular ways of giving university lectures are through the use of blackboards or presentations, with students preferring presentations (Savoy et al., 2009). However, the effectiveness of presentations as a learning method is disputed. Harlin and Brown (2007) argue that powerpoint presentations are not focussed on the individual needs of the learner and that the use of critical thinking is suppressed. The thought process in presentations is reduced by bullet points missing critical explanation, little space for text and overused templates (Tufte, 2003). Gurrie and Fair (2010) support this by stating that passivity is created when teachers use only PowerPoint slides and reading them aloud. Clark (2008) states that presentations are only effective if they are varied and are stimulating interest.

2.3 effective learning aspects of gamification

Another, new method for learning is with the use of gamification. Gamification is described as "the use of video game elements in non-gaming systems to improve user experience (UX) and user engagement" (Deterding, 2011, p.1). Although this definition specifies **'video** game elements', these elements are also commonly used in non-video game contexts, such as board games. This method is using the positive functions of games (e.g. leaderboards) to increase productivity or create a learning environment. AjazMoharkan et al. (2017) describe four benefits of Gamification in E-learning:

1. A game creates a large amount of engagement and fun and Gamification combines this with the possibility to learn. This increases recall and retention.
2. Gamification can create a better, safe learning environment, resulting in an increase in memorizing information.
3. Through feedback, users can learn and understand their weaknesses and this knowledge can be used to solve them.
4. Game elements in Gamification can increase motivation and thus can increase the time is spent to learn the subject matter. The game elements stimulate the user to keep on learning through, for example, a reward system.

This research suggests that these gamification elements, such as creating motivation, can be used to resolve the passiveness imposed by PowerPoint presentations.

2.4 Using gamification to solve effectivity problems identified in presentations

The main problems found with presentations (in Section 2.2) are a lack of motivation to pay attention, the lack of focus on individual needs and the overuse of non-varied presentations. Students are mainly only passively paying attention without the incentive to remember and understand the subject matter.

The use of gamified elements can create the motive to learn by stimulating and/or rewarding the students for engaging with the subject matter and thereby increasing achievement. Kim and Lee (2015) are introducing their 'Dynamical model for gamification of learning', that implies that improving the effect on learning can be achieved by utilizing the factors of curiosity, challenge, fantasy, and control, coined the "key characteristics of a learning game" (Kim & Lee, 2015). By creating an environment that is challenging and evoking curiosity, the students are inclined to pay more attention, which in turn may result in a higher attention span and better retention of information. Active learning can increase information retention and understanding, while the gamification elements can create immersion and support or guide the learning process (Bíró, 2014). Reflection on material after the game can further support the understanding (Gros, 2007).

3. METHODOLOGY

This section describes the method by which this research is conducted. The goal of this research is to create a gamified application and research the effectiveness opposed to the traditional presentations often used in university lectures.

3.1 Participants

Seventy-four students participated in this experiment (29 males and 45 females). Participants were sampled from the University of Amsterdam's (UvA) Faculty of Law, Faculty of Humanities and the Faculty of Economics and Business. The faculty of Science was excluded because of the high number of computer science students, with likely knowledge of IoT. The perceived knowledge of IoT between students was slightly below 'Neutral', according to the Likert scale (Mean = 2.85; SD = 1.257).
The mean age of the participants was 22.35 years (SD = 2.5772). Participants were chosen using convenience sampling, by asking as many people on the location if they did want to participate. Participants were assigned randomly to one of three versions.

3.2 Design

The experiment used a between-subjects design with one independent variable with three levels. These levels did consist of two gamified implementations and a PowerPoint presentation as validation. The dependent variable that was measured was the number of correct answers given by the participant (to determine the effectiveness of the method). The following three settings were created:

1. A standard set of presentation slides presenting the information to be learned.
2. A game containing and displaying the information in a gamified educational setting.
3. A stripped version of the game as presented by 2, with some game elements removed, but retaining the educational setting.

The presentation was used as a validation group, to investigate how the students are learning with a traditional way of learning, without the use of games.
The stripped version was used to investigate whether the game environment itself had a positive effect on learning. It was also used as a baseline for the full gamified version, testing whether the game elements were either a positive addition or a disturbance for the learning process.

3.3 Materials

3.2.1 Learning material

To research the effectiveness of Gamification as opposed to presentations in learning about IoT, different information about the topic was picked and combined. This information described the definition, architecture, characteristics, applications and adoption barriers of the Internet of Things. A full overview of the subject matter that participants were supposed to learn can be found in Appendix 1. The information between all versions was the same and presented using an image with information and a corresponding audio fragment.

3.2.2 Setting 1: PowerPoint presentation

This setup consisted of simple presentation slides, in combination with multimedia. The use of multimedia was chosen because multiple media can have a positive effect on learning, using one to understand the other (Fisher, 2001; Jian-hau, 2012). This is covered as the learning discovery view, “The discovery learning view predicts that students will learn better and more easily by playing a narrative computer game than by receiving direct instruction from a multimedia presentation devoid of a storyline and opportunities for exploration activity.“ (Adams et al., 2012, p.237).

An audiovisual presentation was created to accomplish this. Self-created images were composed to ensure visual consistency over all the images. This was important since the images were also used in-game and the consistency was used to maintain immersion. These images were then fitted with an audio track in the presentation. The audio tracks were created using the “Natural Readers” Text-to-Speech interpreter[1]. This resulted in a total of twelve slides. The information to be learned, in the form of the images and audio transcripts, can be found in Appendix 1.

3.2.3 Setting 2: Game

While designing the game, the components of the MDA (Mechanics, Dynamics, Aesthetics) framework were used (Hunicke et al., 2004). Mechanics are the basic rules of the game, dynamics the behavior of the mechanics on users input, and aesthetics the emotions experienced by the player. The gamified applications were created using the Unity 3D game engine (Unity Technologies, 2019).

The game that was created can be categorized as an explorative game. The goal of the game was to find the missing notes, which are the same images as contained in the powerpoint slides. The basic game mechanics are shown in the image below (Image 1). The user had to navigate through a dynamic world searching for hidden notes/collectibles (Image 2). The exploration was used to instigate curiosity to create fun and immersion.

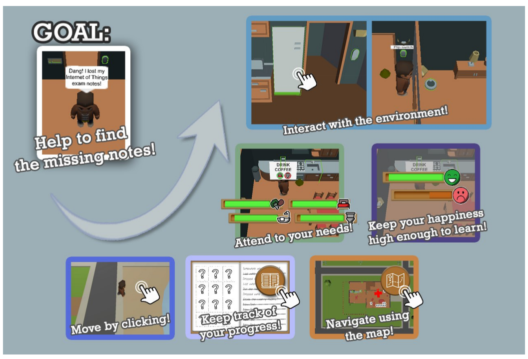

Image 1: Basic game mechanics

Image 2: Collecting a note

To further stimulate immersion and to introduce more challenge, ‘moods’ were introduced. The character had to remain stimulated to learn (just as the student in real-life). To accomplish this, the player, for example, had to interact with the fridge to eat (Image 3). Not fulfilling needs resulted in the character refusing to pick up notes.

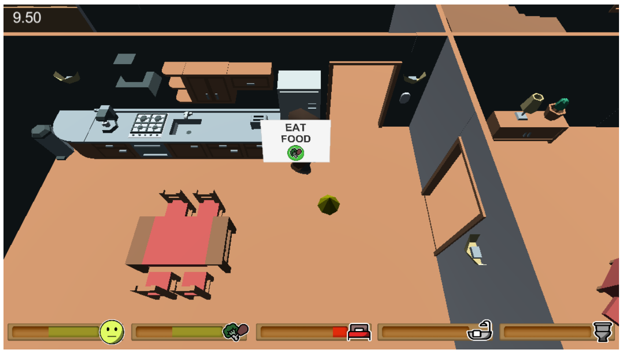

Image 3: Mood bars and interaction

To maintain flow and immersion, each area containing a collectible had a new unique way of accomplishing the task, as well as a new visual environment. This was used to stimulate the player and to create a feeling of progression/exploration. For example, the user needed to squash snowmen in the snow environment (Image 4), navigate through a castle (Image 5) and dodge enemies while navigating through a maze (Image 6).

Image 4: Destroying snowmen in the snow

[1] https://www.naturalreaders.com/online/

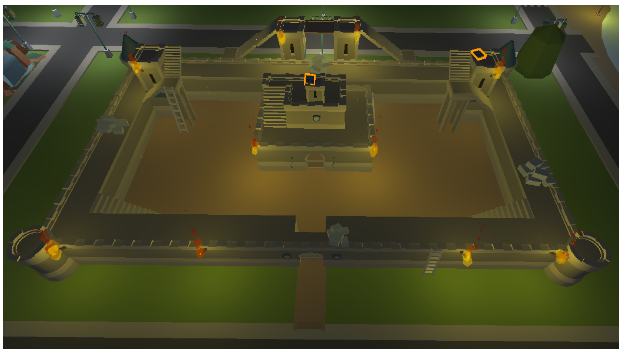

Image 5: Castle environment

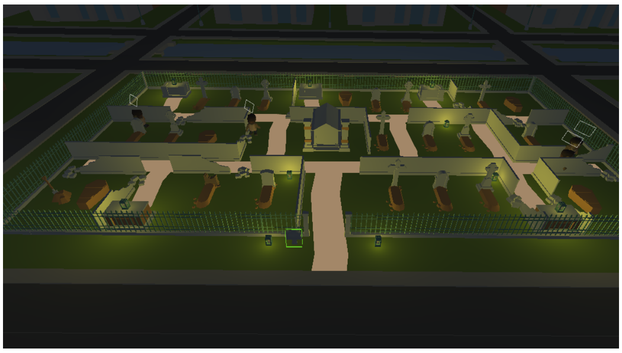

Image 6: Navigating a maze

To guide the player, a log (Image 7) and map (Image 8) could be opened, showing which collectibles had been found, and hints on where to find the yet undiscovered collectibles. This was to ensure the player was not lost and to provide support since the main goal was learning.

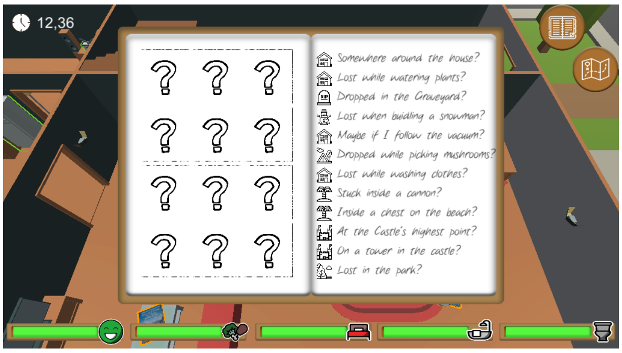

Image 7: Log with progress

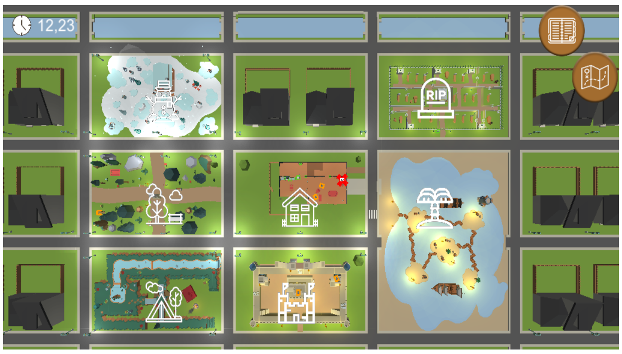

Image 8: Map

3.2.4 Setting 3: Game with game elements removed

It was possible that the added game elements were more distracting to players than that they were helping them learn. To test this, a second version of the game was released, with certain elements removed. In this version, the mood bars and environmental interactions were removed, explained in section 3.2.2 and shown in (Image 3). This, for example, removed the need to maintain 'hunger' by eating. Specifically these game elements were selected to remove because they were used challenging the player, but were of no influence to the goal of the game, to collect information. Thus the elements were supposed to add more challenge and interaction to the game but this might prove to be a distraction to the player.

3.2.5 Consistency and piloting

To ensure consistency between the different versions, certain measures were taken. The images with audio in-game were always in the same order, regardless of pick-up order, to be in accordance with the presentation. To test if the game was understandable and working correctly, a pilot was executed using the Thinking Out Loud method, explaining their thoughts, ideas, struggles, and improvement points. This was followed by a short informal interview further examining the points mentioned. Five people were interviewed using these methods, consisting of the same target audience of university students (described in section 3.1). With the newly acquired information, improvements on movement, gameplay and general performance were made (Appendix 2).

Completion times of the game were logged by the game to an online database, upon completion of the game.

3.2.6 Distribution

All versions were uploaded online and a framework was built in the form of websites using Google Sites[2]. All websites contained the same introduction with slight changes to reflect the appointed version (further described in section 3.4 *procedure*), followed by one of the versions, each followed by the same quiz and questionnaire (section 3.2.6).

3.2.7 Quiz and Questionnaire

To measure the effectiveness of the method in learning, a quiz was created, followed by a questionnaire about general info and experience of the version. Both were created using Google Forms[3] and were contained in a single form. The quiz consisted of eleven four-option multiple choice questions, one for each slide (excluding slide 7, which is a visualization of slide 6).

[2] https://sites.google.com/
[3] https://docs.google.com/forms

Answers to the questions were sorted alphabetically. Examples of question are:

"How can IoT be defined?"

- *As a cloud computing network.*
- *As a global positioning network.*
- *As a network of machines.*
- *As a network of physical objects or people, called things. **

"Which of the following is not a difficulty of interoperability?"

- *Existence of many data formats and different programming languages, which can be based on different modeling principles.*
- *Many devices, sensors, equipment, etc. in the environment need to communicate and exchange information.*
- *Many different devices with different purposes over multiple manufacturers are created, making a globally accepted standard difficult.*
- *Safety for personal data and physical well-being must be minded. Therefore securing the networks and endpoints is important. **

It was hypothesized that the experience with the method might influence the performance and therefore the quiz was followed by a questionnaire about general information (gender and age) and nine statements on a five-point Likert scale (from strongly disagree to strongly agree). The statements contained questions about the previous knowledge of IoT, the experience and perceived effectiveness of the assigned method, the thoughts about learning with this method. Some categories with corresponding questions are:

FUN

- *"I like this way of learning."*
- *"I thought this way of learning was fun."*

RETENTION

- *"I was able to remember what was said."*

EFFECTIVITY

- *"I think this way of learning is efficient."*
- *"I think this way of learning is better than traditional learning (with books or lectures)."*

A full overview of the quiz and questionnaire can be found in Appendix 2.

3.4 Procedure

Students were selected using convenience sampling, approaching students and asking if they would like to participate in a test which is part of a thesis research, and were informed it would take about 10 to 35 minutes, depending on the version. Testing was performed in an empty classroom at the University, with three to five respondents at a time. Three laptops were available, including headphones, with additional respondents using their own laptops. The requirements to run the experiment was having access to the internet using the Google Chrome web browser[4] and having access to sound (with headphones to not distract other respondents). When seated, respondents were asked to browse to a shortened link[5], which redirected to a random version using a random number generator.

An introduction was presented at the beginning of each website[6]. This introduction informed the participant in the goal to investigate the learnability of IoT. They were also informed that participation was anonymous, only used for research purposes and that participation in the questionnaire was voluntary and could be stopped at any time. This was followed by a short introduction about the specific version (either game or presentation), the time it would take and that there would be a questionnaire and quiz following the test.

During the test, participants were allowed to ask questions or report problems. Questions about the subject matter/questions about IoT were not answered, instructing the respondent to remember and understand what is presented in the version as best as possible.

After submission of the quiz and questionnaire, the participants were able to see how they performed (number of correct questions) and the correct answers (Made available automatically by Google Forms). The participants were then thanked for their participation.

3.5 Analysis

Python (version 3.6.5) with the module Pandas (version 0.23.0) was used to preprocess the data. Preprocessing was used to, for example, convert Likert scale- and version labels to number. Plots were created using the Python module Seaborn (version 0.9.0). Data was further analyzed using IBM SPSS Statistics (version 24). The rejection level for all analyses was set at a p-value of .05.

4. EVALUATION / RESULTS

De data of the questionnaire was used for statistical analysis after the preprocessing was performed. The game with elements had the lowest mean (M = 5.67, SD = 2.078; table 1), followed by both the presentation (M = 7.13, SD = 1.329; table 1) and the game without elements (M = 7.04, SD = 1.732; table 1). In the following tables and graphs in this section, the following abbreviations are used:

"***present.***" for presentation, *"**game w/** (with) **elements**"*

[4] https://www.google.com/intl/nl/chrome/

[5] https://bit.ly/2M4wqL7

[6] presentation: :https://sites.google.com/view/iot-presentation/
Full Game: https://sites.google.com/view/iot-gamefull/
Stripped Game: https://sites.google.com/view/iot-gamecut/

for the game with all game elements and *“**game w/o** (without) **elements**”* for the game with some game elements removed.

Table 1: Descriptives version

version	N	Mean	Std. Dev.	Variance	Min	Max
Game w/ elements	*24*	*5.67*	*2.078*	*4.319*	*3*	*10*
Present.	*24*	*7.13*	*1.329*	*1.766*	*4*	*9*
Game w/o elements	*26*	*7.04*	*1.732*	*2.998*	*4*	*10*
total	***74***	***6.62***	***1.841***	***3.389***	***3***	***10***

A box plot was created to visualize the distribution of the scores for the different versions (Image 9).

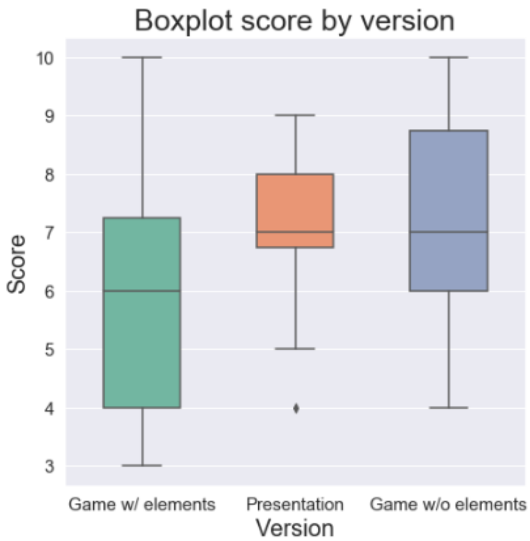

Image 9: Boxplot score by version

To research the homogeneity of the variance, a Levene’s test of homogeneity of variances test was performed. According to Levene’s test the variances in score were not equal between versions ($F(2,71) = 3.92$, $p = 0.024$). An ANOVA test shows that the groups were significantly different in score($F(2) = 5.37$, $p = .007$), as well as the Welch’s adjusted F ratio (4.48) was significant ($F(2, 62.87) = 4.48$, $p = .017$).

A contrast test was used to analyze which group was varying from the others. According to the contrast test (not assuming equal variance), only the game with elements was significantly different from the presentation ($p = .006$) and the game without elements ($p = .015$).

In addition, A Spearman's rank-order correlation was used to determine the relationship between scores and different variables in the questionnaire. A weak relation can be found between the achieved score and the perceived enjoyment ($r_s = .284$, $p = .014$), perceived effectiveness ($r_s = .385$, $p = .001$) and perceived ability of retention ($r_s = .314$, $p = .006$). The correlations between each individual group are shown in table 2, and correlations between all variables are shown in Appendix 4. An overview of all questionnaire statements and their mean, median and std. dev. can be found in Appendix 5.

table 2: correlations for each group

		perceived enjoyment	**perceived effectiveness**	**Perceived retention**
Game w/ elements (N = 24)	**Corr. coeff.**	*.200*	*.337*	*.219*
	sig.	*.348*	*.107*	*.304*
Present. (N = 24)	**Corr. coeff.**	*.105*	*-.106*	*-.161*
	sig.	*.624*	*.623*	*.453*
Game w/o elements (N = 26)	**Corr. coeff.**	*.391*	*.353*	*.316*
	sig.	***.048****	*.077*	*.116*
Total (N = 74)	**Corr. coeff.**	*.284*	*.385*	*.314*
	sig.	***.014****	***.001****	***.006****

Note. Asterisk (*) indicates significant differences (p < .05)

To analyze if there is a difference in the distribution of correct questions, a horizontal bar plot was created, ordered by the different versions (Image 10), sorted by the questions. Different sort orders (sorted on the version) are available in appendix 6.

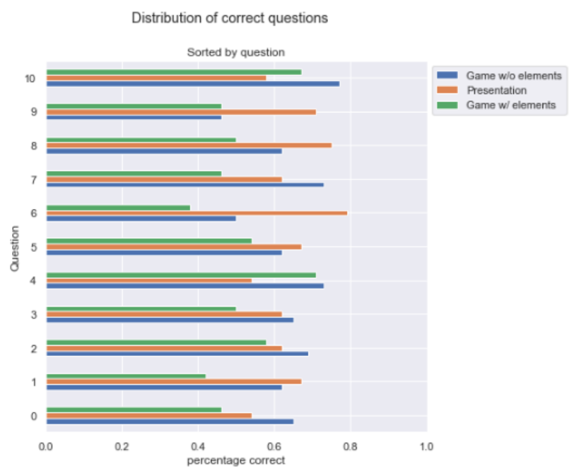

Image 10: distribution correct questions by version

No connection could be found between the distribution of questions in accordance with the different test versions.

5. CONCLUSION & DISCUSSION

5.1 Conclusion

Evidence shows that the game with game elements performs worse than a traditional PowerPoint presentation. A possible explanation for this is that the extra game elements added in the game are distracting the player, taking the focus away from learning and onto playing the game. This is supported by the cognitive load theory, which states that learners are only capable of processing and remembering a limited amount of information, which is spent on learning and playing the game instead of learning about the specified topic (Adams et al, 2012; Hawlitschek & Joeckel, 2017). High levels of game-like attributes can cause distraction from learning objectives in learning games (Shelton & Wiley, 2007). This is further supported by Conati (2002), stating that high levels of engagement are hindering reflective cognition.

Therefore it might be important to search for a balance of in-game elements and learning elements.

There is no evidence found that the game without elements is performing better (or worse) than the traditional PowerPoint presentation. However, as shown in the box plot (Image 9) and the descriptives table (table 1), the variance of scores in the gamified groups is larger than the variance of the presentation group. This might suggest that the gamified method might work very well for certain people while working adversely for others. This can be further supported by the outcome that there is a (weak) correlation between enjoyment of the method and the achieved score. This might suggest that learning with gamification is more effective than traditional learning for specific people who like to play videogames.

A possible explanation for the difference in performance might be the interval between each new information slide. This time is longer in the gamified version than in the PowerPoint presentation (since the game takes longer to complete). This also causes the effect that the time between receiving information and having to answer a question about that information is longer (for example the information is presented at minute one, while the question needs to be answered when the game is completed, 25 minutes later). However, as shown in image 10, no explicit relation can be found between the question order and the correctness of answers. This is supported by the research of Putz and Treiblmaier (2019), where retention was measured between gamified and non-gamified workshops over an interval of right before, 20 minutes after and two weeks after observation, with the retention declining about the same between groups. Different mechanics and implementations might, however, have a different effect on retention, and some implementation can increase retention, according to the research of Brull and Finlayson (2016).

In conclusion, to answer the research question: "How effective is the use of a gamified application in learning advanced topics, in comparison with a PowerPoint presentation?", there is no evidence found that gamification works better for learning in general than a PowerPoint presentation. There is, however, evidence that gamification can increase performance for certain audiences, as long as the cognitive load is not too high.

5.2 Cost analysis

The question remains if gamification is worth the effort since creating a game can take a considerable amount of time. The game created for this paper took about two months to complete (it must be taken into account that this included learning how to use Unity and program in the language C#). However, the game was set up using a minimal context related environment (being the Internet of Things in this case). The game itself is not specifically created around a certain topic. The game only provides an environment, not a specific narrative. This means that the images and audio can easily be swapped to any other topic, or the game can be extended to include more information in the form of slides and audio. Further research is needed to conclude whether the use of gamification has a positive effect on scores for people liking to play games. A tradeoff has to be made between the time it takes to build an application and the improvement in performance in comparison to traditional ways of learning. However, the use of gamification might be beneficial if used on the right group of students (who perform better with the active way of learning using gamification) or certain advanced topics. Additionally, the gamified applications might reduce the workload of teachers and enables them to use the gamified applications as a support tool as an extension of the lectures currently used.

5.3 Discussion

5.3.1 Limitations

Several limitations and remarks have to be pointed out. First of all, the sampling used in this research could be improved. The tests were performed on a total of seventy-four students from the University of Amsterdam's (UvA) Faculty of Law, Faculty of Humanities and the Faculty of Economics and Business. This can create biases because of the possible lack of diversity of students. To improve this, sampling can be performed over multiple universities with more students. Moreover, It is noteworthy that the grades received were not of influence to the students, in contrast to real grades. Student behavior and motivation to learn might be quite different when the received grade would be important to them. This may, for example, cause stress, where gamification might reduce or increase stress levels.

Another point of critic is the questionnaire and quiz. The questionnaire included eight questions about opinions and experiences. In retrospect, it would have been interesting if more questions were added about how learning, in general, is experienced and how gamification is helping, to create a more complete picture. This could have also been achieved by interviews after the test. Besides, the quiz consisted of eleven multiple choice questions, where most answers were mentioned in the audio and slides, without the need for reflection to answer the question. More questions should be added with increasing difficulty levels and that requires reflection to be correctly answered. Additionally, open questions could have been added to test the understanding of the given information.

Some remarks about the different versions can also be stated. The different versions have a significant difference in completion time, with the presentation taking around 7 minutes to complete, while the game versions take about 30 minutes. This means that, for example, the time between getting information about the first question and answering that question is 6 minutes for the presentation and 29 minutes for the games. A method to compensate for this effect could have been taken into account. Furthermore, it was decided to create the game in a way to trigger exploration, by tasking the player to search for information while being challenged. This would be beneficial if the game would be used for different subjects, as described in the Cost analysis (section 5.1). However, it should be noted that different kinds of games or different kinds of objectives could have a different effect on learning performance, which is why it is important and hard to find an optimal gamified application. Moreover, while it has been taken into account that users were not supposed to know a lot about the Internet of Things, it was not measured if the respondents had a lot of experience with gaming. This can influence performance since they would spend less time learning the game and this may reduce the cognitive load.

Lastly, the presentation that was created might differ from traditional presentations used in academic settings. For example, to ensure comparability between versions, the presentation only consisted of audio and images, without the use of a teacher.

5.3.2 Future work

Using this research as a setup, a couple of things could be further examined. First of all, as described in the discussion, the performance could be influenced by real consequences. Therefore it would be interesting if the effect of gamification is researched in a real academic learning setting, with the students caring about their result/grade, rather than a research setting.

Another point of interest is the relation between liking the learning method and performance. It could be researched how different audiences react to gamified learning and examine which traits are distinctive for the audience that performs better when using a game to learn. This can then be used to create gamified applications that are more specifically produced for the target audience. This is specifically important to distinguish the performance between people who have more or less experience with gaming. A test can be set up to research the cognitive load in gamification between gamers and non-gamers. This could give insight into the different performance and an idea which features in-game might work for gamers while not working for non-gamers. This could, in turn, be combined with a research about retention of information. In this setup, the quiz was taken directly after completing the different implementations. It could be researched whether the retention of gamified applications is better or worse over time, by for example taking another test after a week or month.

As a final remark, it is also important to note that the Internet of Things was used as the topic for this research. Further research is required to analyze the performance of gamification on different topics and especially more difficult topics. Additionally, the actual implementation of the game might influence learning performance. More research is required to determine more precisely which characteristics of a game can have a positive effect on learning, to create a more optimal application in the future.

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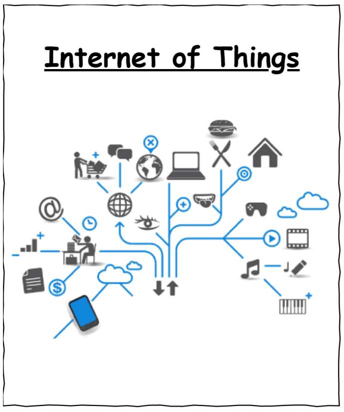
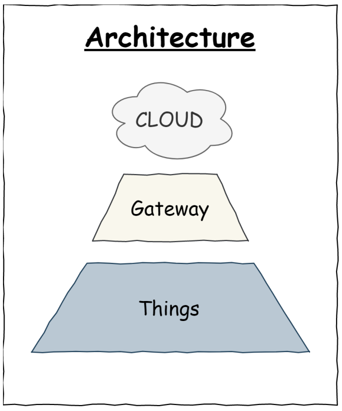
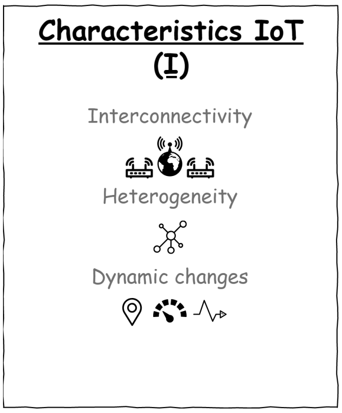


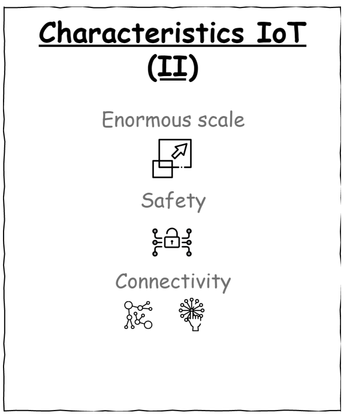
SLIDE 1
"The Internet of Things can be defined as a network of physical objects or people called things. These things are embedded with software, electronics, network, and sensors which allow these objects to collect and exchange data."
("Internet of Things (IoT) Tutorial for Beginners: Introduction, Basics, Applications What is Internet Of Things(IoT)?", 2019)



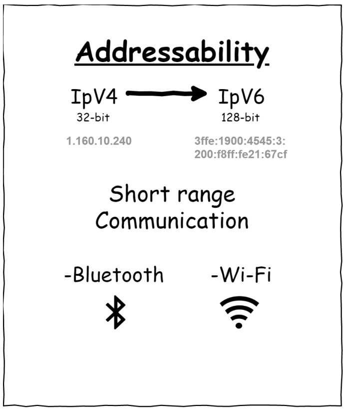
SLIDE 2
Information based on: Desai, Sheth and Anantharam (2015)
Cloud
A cloud server is used as a higher level IoT service, the way devices are functioning and passing commands.
Gateway: A gateway node is used as a bridge to receive the data and pass along commands from the cloud level.
Devices (Things): Devices are measuring certain variables(For example a thermometer measuring temperature and humidity).



SLIDE 3
Information based on: Patel and Patel (2016)
Interconnectivity
Anything can be connected with the global information and communication infrastructure.
Heterogeneity Devices are based on different hardware platforms and networks. They can interact with other devices or service platforms through different networks.
Dynamic changes The states (e.g. sleeping or awake), context (e.g. location and speed) and the number of devices can change dynamically.



SLIDE 4
Information based on: Patel and Patel (2016)
Enormous scale: The number of interconnected devices can be huge and there can be a large amount of intercommunication between devices.
Safety: Safety for personal data and physical well-being must be minded. Therefore securing the networks and endpoints is important.
Connectivity: Connectivity enables network accessibility (connecting to the network) and compatibility (being able to interact with the network).



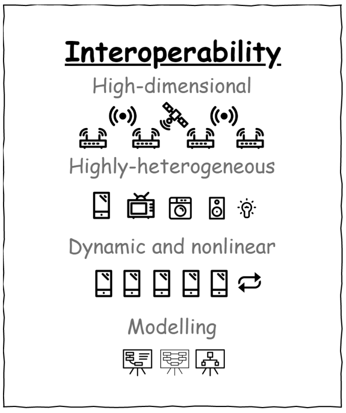
SLIDE 5

Information based on: Want and Jenson (2015)

To enable IOT, communication between devices is required, either wired or wireless. Devices need unique identifiers, such as IP-addresses.

IPv6 should be used over IPv4, because the limited amount of IPv4 addresses would be overflowed by the large amount of IoT devices. Examples of short-range wireless communication used are:

1. BlueTooth: the use of short-range radio waves, 2.4GHz band with Ultra High frequency.
2. Wi-Fi: Radio frequencies of 2.4GHz or 5.0GHz. It has a larger range and is faster than Bluetooth, but has a higher power usage.



SLIDE 6

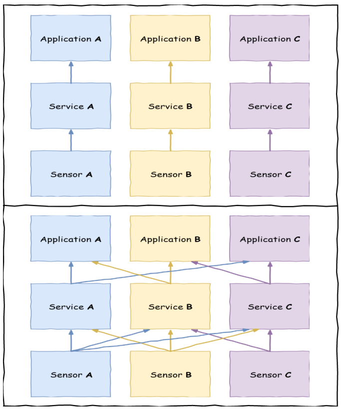
Information based on: Patel and Patel (2016)

Interoperability is the ability of two or more systems or components to exchange data and use information. The following in operability difficulties arise: **High-dimensional:** Many devices, sensors, equipment, etc. in the environment need to communicate and exchange information.

Highly-heterogeneous: Many different devices with different purposes over multiple manufacturers are created, making a globally accepted standard difficult.

Dynamic and nonlinear: New devices are coming and going in the environment.

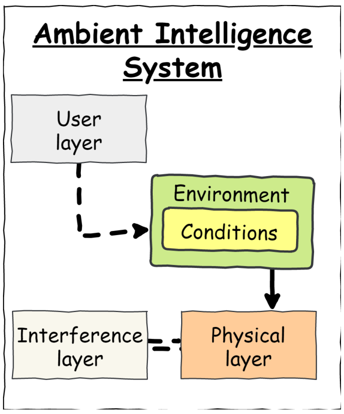
Modeling: Existence of many data formats and different programming languages, which can be based on different modeling principles.



SLIDE 7

Information based on: Patel and Patel (2016)

These images show the difference between a non-interoperable (on the top) and an interoperable (on the bottom) Internet of things system.

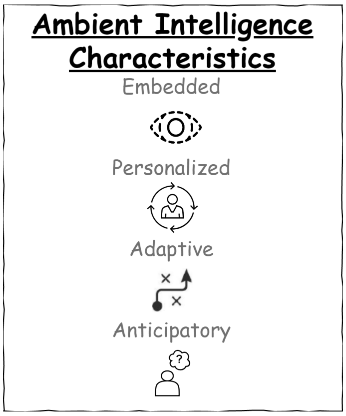


SLIDE 8

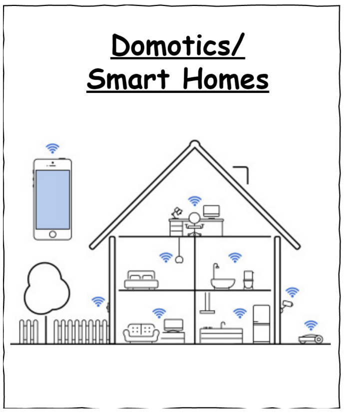
Information based on: Cabitza, Fogli, Lanzilotti and Piccinno (2017)

Ambient Intelligence is an application of the internet of things, where environments are created to support the people inhabiting them. IoT provides a framework for the proactive and autonomous behavior of the environment. The Ambient Intelligence system is composed of the three following layers:

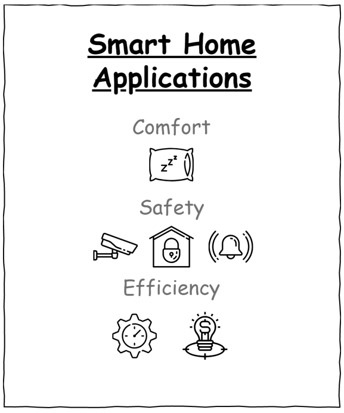
1. **The Physical layer:** This layer consists of all the devices and their sensors, which are collecting conditions and information.
2. **The Interference layer:** The layer Linking information and actions with the use of intelligent reasoning processes.
3. **The User Layer:** The interaction between inhabitants and the environment. Conditions that are changed provoke a response from the system to either assist or satisfy the user.



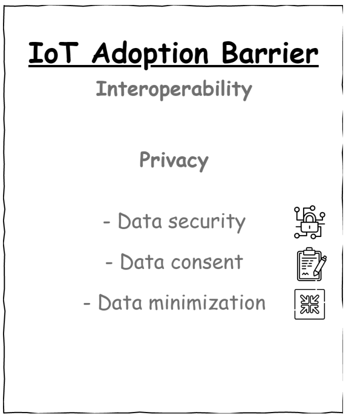
SLIDE 9
Information based on: Pieper (1998)
Embedded: The services are integrated in the environment and invisible.
Personalized: Devices can recognize a user and a context, which can be used for customization to the preferences of the user.
Adaptive: Devices respond to the user and environmental changes.
Anticipation: The system can anticipate the user's desires, and acts beforehand.



SLIDE 10
Information based on: Robles and Kim (2010)
Smart Homes (also called domotics):
An example of an Ambient Intelligence system is the so-called “Smart Home”, or home automation (domotics). In a smart home, the Internet of Things is used to link household devices (such as TV's, fridges, lighting, doorbells, etc.). Intelligence is created by observing the patterns and preferences of inhabitants of the environment, which is used to respond correspondingly. This can be controlled by, for example, a SmartPhone. Several stand-alone platforms or hubs are available (e.g. Amazon Echo, Google Home, and Apple’s Home pod) to connect smart products.



SLIDE 11
Information based on: Solaimani, Keijzer-Broers and Bouwman (2015)
Applications of Smart Homes:
Some categories with examples of Smart Home applications are:
1. Comfort: sensors accessing heating or air conditioning according to the hour of the day and persons present.
2. Safety: Opening doors for users, for example, the garage door if the car is near and identified as an allowed car.
3. Efficiency: Saving energy by switching lights on and off based on presence.



SLIDE 12
Information based on: Patel and Patel (2016); Nolan and Adair (2019)
IoT adoption barriers:
the internet of things and Ambient Intelligence are slowly adopted. Reasons for this are, amongst others:
1. Interoperability: There is no standard for devices and communication, making connecting devices hard.
2. Privacy, where the following things must be taken into account:
Data security: IOT devices must be properly secured to keep data private.
Data consent: The user must be in control of what data is collected.
Data minimization: Only necessary data should be collected.

Appendix 2: *POST-Test Changelog*

Movement

1. Increased **movement speed** from 3 to 4 and **angular speed** from 700 to 1200.
2. Set NavMesh **Stopping Distance** from 0 to 0.6, smoothing out walking.
3. Increased **Camera height** and **angle** for a better field of view/oversight.
4. Better pathfinding in ***Castle*** & ***Island***.

Performance

5. Disabled **Auto-Graphics API** of WebGL.
6. Time synchronization calculated from computer time instead of frames to ensure linearity across multiple computers.

Gameplay

7. Added **tutorial** at the beginning of the game.
8. Removed UI on clickable objects making it directly usable.
9. Changed happiness mood calculation from Minimal to Average.
10. Sleeping increases the in-game time.
11. Added location names to map to guide the player.
12. Added Icons to map and objectives to guide the player.
13. Improved smoothness of picking up books.

Questionnaire Internet Of Things

1. **What is your version number? See the title of the web page.**
   Markeer slechts één ovaal.
   - [ ] Version A
   - [ ] Version B
   - [ ] Version C

2. **How can IoT be defined?**
   Markeer slechts één ovaal.
   - [ ] As a cloud computing network.
   - [ ] As a global positioning network.
   - [ ] As a network of machines.
   - [x] As a network of physical objects or people, called things.

3. **Which of the following does not belong to the architecture of IoT?**
   Markeer slechts één ovaal.
   - [ ] Cloud
   - [ ] Gateway
   - [x] Performance
   - [ ] Things

4. **How can heterogeneity be described?**
   Markeer slechts één ovaal.
   - [ ] Anything can be connected with the global information and communication infrastructure.
   - [ ] Communication of similar devices in the same network.
   - [x] Interaction of different devices through different networks.
   - [ ] The state, context, and number of devices that can change dynamically.

5. **Which of the following does not belong to the characteristics of IoT?**
   Markeer slechts één ovaal.
   - [ ] Connectivity
   - [x] Reliability
   - [ ] Safety
   - [ ] Scale

6. **Which of the following is true about addressability?**
   Markeer slechts één ovaal.
   - [ ] Both are not used for identification.
   - [ ] IPv4 is preferred over IPv6, because the addresses are shorter.
   - [x] IPv6 is preferred over IPv4, because there are more IPv6 adresses available.
   - [ ] There is no preference between IPv4 and IPv6.

7. **Which of the following is not a difficulty of interoperability?**
Markeer slechts één ovaal.

- [ ] Existence of many data formats and different programming languages, which can be based on different modelling principles.
- [ ] Many devices, sensors, equipment, etc. in the environment need to communicate and exchange information.
- [ ] Many different devices with different purposes over multiple manufacturers are created, making a globally accepted standard difficult.
- [x] Safety for personal data and physical well-being must be minded. Therefore securing the networks and endpoints is important.

8. **Which of the following is not a layer of an Ambient Intelligence System?**
Markeer slechts één ovaal.

- [x] The communication layer
- [ ] The interference layer
- [ ] The physical layer
- [ ] The user layer

9. **What is not a characteristic of an Ambient Intelligence?**
Markeer slechts één ovaal.

- [ ] Devices respond to the user and environmental changes.
- [ ] The services are integrated in the environment.
- [ ] The system can anticipate the user's desires and acts beforehand.
- [x] The system can take away control from the user.

10. **Which is not a requirement of the setup of a Smart Home?**
Markeer slechts één ovaal.

- [ ] Household devices
- [ ] Sensors
- [ ] Stand alone hubs
- [x] Voice recognition

11. **Which of the following is not an example of efficiency of Smart Homes?**
Markeer slechts één ovaal.

- [x] Being able to login to the Smart Home from a distance.
- [ ] Disabling certain electric sockets when there are no users in the house.
- [ ] Lighting responding to presence of users.
- [ ] Turning down heating when a window is opened.

12. **Which of the following is not an adoption barrier of IoT?**
Markeer slechts één ovaal.

- [ ] Devices must be properly secured to keep data private.
- [x] Not enough data can be collected to properly create an Internet of Things system.
- [ ] Only necessary data should be collected.
- [ ] The user must be in control of what data is collected.

General Information

Almost done! Please fill in some general information. This information is anonymous and cannot be traced back.

13. **What is your gender?**

Markeer slechts één ovaal.

- Female
- Male
- Prefer not to say
- Anders: ____________________

14. **What is your age?**

____

15. **Statements**

Markeer slechts één ovaal per rij.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I had previous knowledge about the Internet of Things.					
I like this way of learning.					
I think this way of learning is efficient.					
I think this way of learning is better than traditional learning (with books or lectures)					
I was able to remember what was said.					
I found this way of learning difficult.					
I thought this way of learning was fun.					
I thought this way of learning was boring.					
I would like to see more learning through games.					

Appendix 4: *SPSS Statistics*

Contrast Tests

		Contrast	Value of Contrast	Std. Error	t	df	Sig. (2-tailed)
Score	Assume equal variances	1	-,09	,492	-,176	71	,861
		2	-1,46	,502	-2,904	71	,005
		3	1,37	,492	2,785	71	,007
	Does not assume equal variances	1	-,09	,435	-,199	46,504	,843
		2	-1,46	,504	-2,896	39,117	,006
		3	1,37	,543	2,524	44,944	,015

A4.1: contrast tests

Correlations

			Score	StatementsIlikethiswayoflearning	StatementsIthinkthiswayoflearningisefficient	StatementsIthinkthiswayoflearningisbetterthantraditio	StatementsIhadpreviousknowledgeabouttheInternetofThing	StatementsIwasabletorememberwhatwassaid	StatementsIfoundthiswayoflearningdifficult	StatementsIwouldliketoseemorelearningthroughgames	StatementsIthoughtthiswayoflearningwasfun	StatementsIthoughtthiswayoflearningwasboring
Spearman's rho	Score	Correlation Coefficient	1,000	,391*	,353	-,227	-,061	,316	,316	-,025	-,227	-,342
		Sig. (2-tailed)	.	,048	,077	,265	,767	,116	,116	,905	,265	,087
		N	26	26	26	26	26	26	26	26	26	26

A4.2 Correlations variables game without elements

Correlations

			Score	StatementsIlikethiswayoflearning	StatementsIthinkthiswayoflearningisefficient	StatementsIthinkthiswayoflearningisbetterthantraditio	StatementsIhadpreviousknowledgeabouttheInternetofThing	StatementsIwasabletorememberwhatwassaid	StatementsIfoundthiswayoflearningdifficult	StatementsIwouldliketoseemorelearningthroughgames	StatementsIthoughtthiswayoflearningwasfun	StatementsIthoughtthiswayoflearningwasboring
Spearman's rho	Score	Correlation Coefficient	1,000	,105	-,159	-,106	-,170	-,161	,160	,033	,206	-,151
		Sig. (2-tailed)	.	,624	,459	,623	,428	,453	,456	,878	,334	,483
		N	24	24	24	24	24	24	24	24	24	24

A4.3 Correlations variables presentation

Correlations

			Score	StatementsIlikethiswayoflearning	StatementsIthinkthiswayoflearningisefficient	StatementsIthinkthiswayoflearningisbetterthantraditio	StatementsIhadpreviousknowledgeabouttheInternetofThing	StatementsIwasabletorememberwhatwassaid	StatementsIfoundthiswayoflearningdifficult	StatementsIwouldliketoseemorelearningthroughgames	StatementsIthoughtthiswayoflearningwasfun	StatementsIthoughtthiswayoflearningwasboring
Spearman's rho	Score	Correlation Coefficient	1,000	,200	,337	,447*	,032	,219	-,279	,308	,435*	-,376
		Sig. (2-tailed)	.	,348	,107	,029	,883	,304	,187	,143	,034	,070
		N	24	24	24	24	24	24	24	24	24	24

A4.4 Correlations variables game with elements

Correlations

			Score	StatementsIlikethiswayoflearning	StatementsIthinkthiswayoflearningisefficient	StatementsIthinkthiswayoflearningisbetterthantraditio	StatementsIhadpreviousknowledgeabouttheInternetofThing	StatementsIwasabletorememberwhatwassaid	StatementsIfoundthiswayoflearningdifficult	StatementsIwouldliketoseemorelearningthroughgames	StatementsIthoughtthiswayoflearningwasfun	StatementsIthoughtthiswayoflearningwasboring
Spearman's rho	Score	Correlation Coefficient	1,000	,284*	,385**	,176	-,083	,314**	-,090	,207	,151	-,242*
		Sig. (2-tailed)	.	,014	,001	,133	,480	,006	,446	,076	,199	,038
		N	74	74	74	74	74	74	74	74	74	74

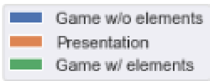
A4.5 Correlations variables over All groups

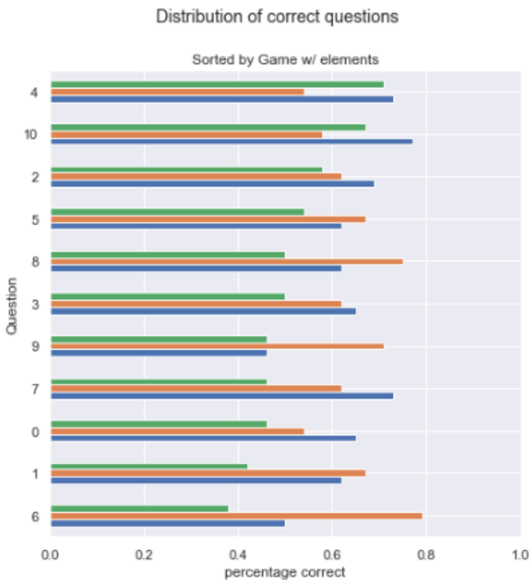
Appendix 5: *Descriptives individual questions*

Table A5.1 Descriptives questionnaire statements

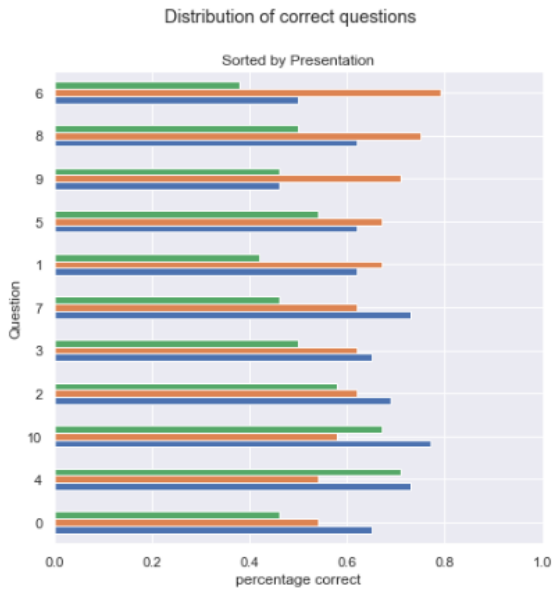
		I like this way of learning	I think this way of learning is efficient	I think this way is better than traditional	I had Previous knowledge of IoT	I was able to remember what was said	I found this way of learning difficult	I thought this way of learning was fun	I thought this way of learning was boring
Game w/ elements (N = 24)	**Mean**	*2.33*	*2.33*	*2.33*	*2.83*	*2.00*	*3.67*	*3.17*	*3.00*
	Median	*2.00*	*2.50*	*2.00*	*3.50*	*2.00*	*3.50*	*3.00*	*2.50*
	std.dev.	*1.404*	*1.129*	*.482*	*1.373*	*1.022*	*1.129*	*1.239*	*1.180*
Present. (N = 24)	**Mean**	*3.17*	*3.67*	*2.67*	*2.17*	*3.33*	*2.50*	*3.33*	*2.50*
	Median	*3.00*	*4.00*	*2.00*	*2.00*	*3.50*	*2.50*	*4.00*	*2.00*
	std.dev.	*.702*	*.482*	*.472*	*1.373*	*.761*	*.978*	*1.129*	*1.142*
Game w/o elements (N = 26)	**Mean**	*2.58*	*2.96*	*3.08*	*2.77*	*2.50*	*3.00*	*2.54*	*3.46*
	Median	*2.50*	*2.50*	*4.00*	*3.00*	*2.50*	*3.00*	*3.00*	*3.50*
	std.dev.	*.758*	*.999*	*1.017*	*.765*	*.510*	*1.020*	*.508*	*.582*
Total (N = 74)	**Mean**	*2.69*	*2.99*	*3.03*	*2.59*	*2.61*	*3.05*	*3.10*	*3.00*
	Median	*3.00*	*3.00*	*3.00*	*3.00*	*2.50*	*3.00*	*3.00*	*3.00*
	std.dev.	*1.046*	*1.053*	*0.891*	*1.215*	*.948*	*1.133*	*1.047*	*1.060*

Appendix 6: *sorted plots*

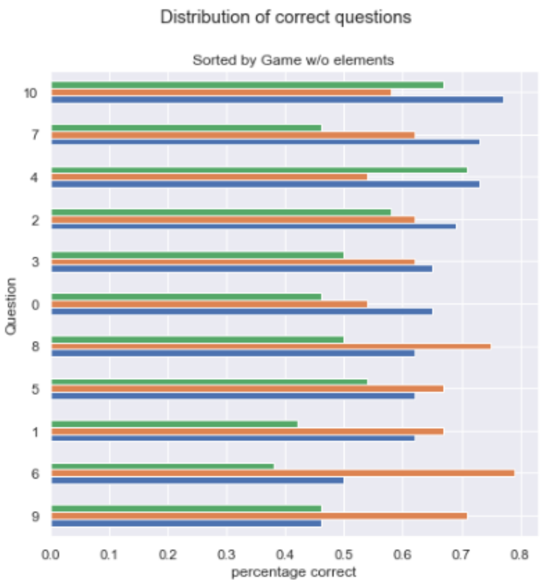




Plot A6.1: distribution of correct questions, sorted by **Game w/ elements**



Plot A6.2: distribution of correct questions, sorted by **Presentation**



Plot A6.3: distribution of correct questions, sorted by **Game w/o elements**