

Motivation in students as a product of performance gamification in an online inquiry
learning environment

Author:
Marc van Dijk
S2258730

Supervisor:
Henny Leemkuil

University of Twente

Abstract

This research investigates the effect of performance gamification elements on motivation in students that are using an online inquiry learning environment. This was done to allow for insight into the usefulness of this type of gamification for education. This was done with a sample of 30 children ranging from 7-9 years old. They participated in an experiment with a before and after questionnaire, which measured scores on 4 sub-categories of motivation and analyzed the differences in score between and within the two different conditions students were divided into. The first condition being with gamification elements and the second without those elements. The results show that for the condition without gamification elements, motivation decreases significantly in 3 out of the 4 selected categories. This decrease can be attributed to the lack of feedback, which results in a failure to fulfill the need of competence or mastery. Furthermore, the lack of judgment of their work also leads students to become significantly less anxious about the results, which also results in lower motivation for completing the task properly. Therefore, we suggest including performance gamification in standalone online learning environments.

Introduction

With education being the base of society in our modern world, potential improvements and adjustments are constantly being made to ensure the most effective learning process. One of these improvements that has been made and is picking up steam in science education is “inquiry learning” (Pedaste et al., 2015). In this form of learning students approach questions more like an actual scientist would. In this process students construct their own hypotheses and search for causal relationships between dependent and independent variables in experiments that they conduct themselves. This approach results in a shift of focus from teacher-centered learning to a form of learning that is more student-centered. This environment requires students to be more self-regulative (Elen & Lowyck, 2000).

When looking at previous research it becomes apparent that inquiry learning shows promising results when compared to other, more traditional types of learning. Research by Weinstein, Boulanger and Walberg (1982) shows “innovative curricula” which make use of inquiry learning result in higher average achievements for students than traditional curricula. This is also found in another study that shows that medium level inquiry results in higher achievements than low level inquiry (Lott, 1983). Moreover, recent studies have shown an even stronger effect for education with inquiry elements compared to education that lacks these elements (Schroeder et al., 2007). Furthermore, a meta analysis by Furtak et al (2012) showed an overall effect of 0.5 in favor of inquiry based learning when compared to more traditional learning.

This being said, it is worth mentioning that students can have problems with picking up the skills that are required for successfully engaging in inquiry based learning. This is seen in

them having trouble with picking the right variables, creating testable hypotheses and drawing the correct conclusions based on their findings (De Jong, 2006). These problems can be resolved however. One of the ways this has already been attempted is through computer based inquiry guidance, which has resulted in students improving their inquiry skills greatly. Through using these technological advancements, the application of these inquiry learning environments is becoming more widespread (Pedaste et al., 2015).

Gamification in inquiry learning

With the inquiry learning environment becoming potentially more widespread and effective than other forms of education, it is crucial to look at ways to implement it effectively. As mentioned previously, computer based guidance has already proven effective in improving the skills necessary to successfully engage in inquiry based learning. To further improve already existing forms of this web based guidance, it might be beneficial to look at gamification as a means of improving engagement and motivation in students. As these elements have already been shown to improve these in students (Dichev and Dicheva 2017). Gamification consists of “the use of game design elements within non-game contexts” (Deterding, Dixon, Khaled, & Nacke 2011). For the sake of clarity, it is important to mention that gamification is not the same as serious games. Since serious games are fully developed games for non-entertainment purposes whereas gamification only utilizes a few gaming elements in real world context. The process of gamification could benefit aforementioned web based guidance as it could motivate students to stay attentive to, and engaged with, the learning material. This might prove especially beneficial for inquiry based learning, since the environment is more student focused and thus requires students to self-regulate more than in a traditional learning environment (Elen & Lowyck, 2000).

Furthermore, these aspects might aid in the clarity of the guidance through e.g. feedback (Toda et al., 2019).

The ways in which gamification can affect motivation can be found in motivation research. Within this field of research there are six different perspectives on motivation that can be considered relevant: the trait perspective, the behaviorist learning perspective, the cognitive perspective, the perspective of self-determination, the perspective of interest, and the perspective of emotion. The perspective of self-determination proves to be especially relevant for the relation between gamification elements and motivation, this is the case since the theory of self-determination stresses the importance of the environment fostering motivation. Which can be achieved through implementing gamification elements within the environment (Sailer et al., 2017). Moreover, this perspective has already been successfully implemented in the gaming context by the likes of Przybylski et al. (2009). Within this perspective three needs are specified, a need for competence, autonomy and social relatedness. All of these needs can be fulfilled through utilizing elements that are typically in games. The need for competence for example can be fulfilled through awarding the player with points. The need for autonomy can be fulfilled through having an immersive storyline. Lastly, the need for social relatedness could be fulfilled through competition or cooperation (Sailer et al., 2017)

Aside from these elements there are numerous other elements that are often seen in games that could be used for gamification. To get an insight into what goals these elements aim for, it can be of use to look at the different types of elements. Whilst there are no fixed names for the different types of gamification elements, Toda et al. (2019) have constructed a taxonomy that divides roughly all gamification elements into different categories. These categories consist of “Performance”, “Ecological”, “Social”, “Personal”, and “Fictional”. Performance elements

deliver feedback in the form of rewards or simply displaying statistics. This makes sure players do not get lost in the environment and are reinforced when going in the right direction.

Ecological elements, such as rarity and chance make sure that the environment does not become dull since these elements allow players to become excited about their next item or reward. Social elements consist of ways to interact with other players within the same environment allowing for players to not feel isolated. Personal elements are mainly used to provide a sense of meaning to the player. This is done through using things like sensation and novelty. Lastly, Fictional elements can strongly aid in the sense of context that students have within the environment, through creating an immersive environment. In practice a lot of gamified educational tools use multiple if not all of these categories. However, to be able to more exactly pinpoint the source of the potential increase in engagement, motivation and ultimately achievement, this study will focus on the performance category.

Within this category Toda et al. (2019) identifies 5 aspects of gamification. The first of these is “Acknowledgement”. “Acknowledgement” can come in many forms like badges or trophies but ultimately functions as extrinsic feedback for players. Secondly, “Level” functions as a hierarchy in which a player of a higher level might also be able to unlock other features to which lower level players do not have access to. Besides this, “Progression” can be applied to give the player a sense of advancement as well as some orientation where they are currently within a certain program. Next, “Point” is a concept that is present in most gamified programs and functions as an extrinsic reward for players based on the correctness of their answers. Lastly, “Stats” are pieces of information about the player's activity, such as lessons completed or correct answers.

Components of motivation

To answer our research question, it is important to measure motivation in an accurate way. In order to do so however, this rather broad concept should be split up into different parts. For this study in particular, we will be using suggestions from Rheinberg and Vollmeyer (2001). Their suggestions are to split up motivation into four general components. These components are probability of success, anxiety, interest and challenge. Probability of success mainly focuses on the students self-efficacy. The crucial role of self efficacy in motivation has been supported in attribution theory, which suggests that people that attribute failure to lack of effort rather than lack of skill will be more likely to persist and stay motivated when faced with a difficult task. Whereas people that attribute their failures to a lack of skill will be more likely to give up (Weiner, 1985). The second component of motivation that will be discussed is anxiety. Whilst this may seem like an opposite of probability of success, it is not, since in anxiety the social aspects can play a big role. For example, someone can expect to succeed, which means they would report a high probability of success, but at the same time they would be anxious to fail because they would be embarrassed in front of others (Rheinberg & Vollmeyer, 2001). Anxiousness can provide an increase in motivation because of the negative incentive that is failure. However, it is worth mentioning that, for some very anxious individuals induced anxiety could relate to lesser performance (Atkinson, 1957). Third, interest in the subject's topic can have a great effect on the amount of motivation a student has for the task. Whenever a student is uninterested in a topic, motivation will lie lower than for a task that a student is interested in (Renninger & Hidi, 2017). Lastly, challenge makes up the last component of motivation that we will be looking at in this research. Challenge assesses whether or not a task is seen as something

to be proud of when it is achieved. Thus, it also correlates positively with motivation since if a task is perceived as a challenge, it is also perceived as more important (Wigfield & Eccles, 2002)

This Study

Within this study an insight is given into the effectiveness of performance gamification aspects in an inquiry learning environment. Ultimately answering the question: “To what extent do performance gamification aspects in an inquiry learning environment influence motivation when compared to an environment without these aspects?”

Hypotheses

For our first hypothesis, we expect students to have more interest in the task after completing the task in a learning environment with performance gamification elements when compared to completing it in an environment without these elements. We expect this to be the case since as suggested by Sailer et al. (2017) implementation of systems such as points and rewards, which we will be using, leads to fulfillment of the need for competence. Therefore we expect interest to rise, since students experience a task that they perceive themselves good at as more interesting than task in which they perceive themselves as less competent (Eisenberger & Cameron, 1996)

Secondly, we expect students to estimate the probability of success higher after completing the task in a learning environment with performance gamification elements when compared to completing it in an environment without these elements. This assumption was made based on the notion that the probability of success is mostly made up of self-efficacy beliefs (Vollmeyer, & Rheinberg, 2006), and thus would also increase when perceived competence increases

For our third hypothesis, we expect students to be less anxious after completing the task in a learning environment with performance gamification elements compared to completing it in

an environment without these elements. We expect anxiety to decrease, since a sense of competence has shown to be negatively related to anxiety (MacIntyre & Renée MacDonald, 1998).

Lastly, we expect students to perceive more sense of challenge after completing the task in a learning environment with performance gamification elements when compared to completing it in an environment without these elements. This is expected since students experience more pride when completing a task when they felt they were competent in completing the task (Cook, Wildschut, Thomaes, 2017)

Methods

Participants

Participants are a sample of 30 primary school students who range in age from age 7-9 with an $M = 8.13$ and a $SD = 0.17$. The sample of participants consisted of 15 boys and 15 girls. All of the participants were part of the same primary school group

Materials

The used learning environment is an environment created in Graasp. Graasp is an online tool that can be used to create learning environments through the use of different “apps”. As a base for the lessons used in the experiment, this research took a lesson made for the primary school and converted it into an online environment. This lesson consists of experiments and questions regarding the experiment which were conducted by the students themselves, with, if necessary, aid by the teacher. Two versions of this environment were created. One of them included performance gamification elements. The other lacked these elements but was otherwise the same. The performance gamification elements that were used, consisted of points awarded for

answering questions correctly and out of a medal that was awarded to them through completing all the questions. See figure 1 and 2.

Figure 1. Points

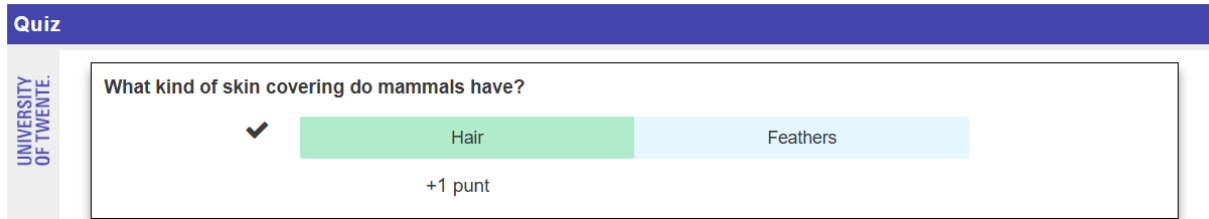


Figure 2. Medal



Rheinberg and Vollmeyer questionnaire

In order to measure the differences in motivation between both versions of the learning environment, a translated questionnaire by Rheinberg and Vollmeyer (2001) was used. The questions were adjusted to Dutch from German and potentially confusing questions were rephrased to be easily comprehensible for the participants. Questions were divided into four categories. Namely, challenge, interest, probability of success, and anxiety. Each of these represent different aspects of what makes up motivation. The questions that have been adapted for the sake of comprehension have been changed in such a way that they were still measuring


the same concept. In Appendix 1, the questions of both versions along with the fitting categories can be found.

Experiments

As mentioned previously, the students conducted several experiments during the lesson. The first two of these were necessary to answer the questions in the subsection that regards hair. The first experiment asked students to fill two glass containers with warm water and measure the water's temperature in each of them. Thereafter students put one of the glass containers in a bunch of wool. They were then asked to wait ten minutes and measure the temperature of both glasses of water again. After which they were asked which glass remained the warmest and why they thought that happened. This experiment was done in groups of 5, since getting two glass containers and thermometers for each of the students was not efficient nor feasible. However, answers to the questions were thought of by the students individually. The second experiment involves the students looking at the wool when it comes in contact with oil and water. Through analyzing what happens with the wool as they spray one of these fluids on it, they could answer the fill in the blanks questions in the lesson. See Figure 3.

Figure 3. Fill in the blanks question

Fill In The Blanks





a little

all fall off

stay on

very

UNIVERSITY OF TWENTE

Get the sheepwool. spray a little water on it with the plant sprayer. What happens?

The water drops the wool

Shake the wool. What happens?

The wool stays wet.

The last two experiments were focused on feathers. The first of these experiments entailed dipping a feather into both water and oil and analyzing what happened with the feathers. This time, as well as describing what happens, students were asked which of these two fluid feathers can resist and why that is the case. The second experiment asked students to cut a feather in half using a pair of scissors. This was done to reveal that the feathers have a hollow inside and ask the students why the feather would look like this.

The lesson gives a list of necessities for the experiments

For the hair experiments:

- 2 glass containers
- Warm water
- A piece of sheep wool
- Vegetable oil
- Thermometer
- magnifying glass
- plant sprayer
- stopwatch (or timer)

For the feather experiments:

- Scissors
- Feather
- Glass container with water
- Glass container with oil

(The entire lesson can also be reviewed through the link in the appendix)

Design

The study applies between and within subjects design. The students are divided randomly into two groups of equal size. Then each group was assigned one of two versions of the learning environment. Afterwards, motivation between both of the groups was compared through the

questionnaire (Rheinberg & Vollmeyer, 2001). Furthermore, within the groups the development of motivation was analyzed.

Procedure

Students were introduced to the lesson by their teacher who normally conducts the lessons for the class. Afterwards, the class was divided into two halves. The first half started with another subject while the other half started with the experiment. This was done to avoid students in the gamification element condition to talk with other students about the points and rewards that were awarded to them. When each group started the experiment, they were asked to sit at their tables in one half of the classroom while the other half of the classroom was being prepared with the materials for the inquiry learning they would conduct in the lesson. They were then asked to open the link to the lesson, the students started by filling out the Rheinberg and Vollmeyer (2001) questionnaire. After this questionnaire was filled out the lesson started. The first questions were filled in by the students after which students moved on to the second set of questions focused on hair, which started off with them experimenting at the separately set out tables with all necessary materials, after which students could answer the questions at their own tables. Thereafter students went on to the third set of questions which focuses on feathers. This set once more started with experimenting at the other tables after which students could answer the questions at their own tables. After having answered these questions the students could answer the last three questions in the last subsection. The experiment concluded with the students filling in the same questionnaire they did at the beginning of the experiment. After filling out the last questionnaire the data collection ended.

Data Analysis

The responses on the motivation questionnaire were compared in a before and after fashion. Through doing this it became clear how much motivation for a similar task had improved after having completed the task. Specifically the differences in motivation between both groups (With performance gamification elements and Without performance gamification elements) was of interest when trying to answer the research question. The measuring of motivation was done through breaking up motivation into the four different categories distinguished by Vollmeyer and Rheinberg (2006). For question 3 and question 14 values were inverted since it negatively correlates to probability of success. For example, Question 14: "I think I won't do well at the task." would have the highest probability of success when given a value of 1 whereas the value of 7 would insinuate the lowest probability of success.

The data analysis was conducted in SPSS where four different analyses were run. Firstly, two independent samples T test were run. One for all the before scores on the questionnaire and one for all the after scores on the questionnaire. With this analysis we could tell what the difference between both groups were prior and after the experiment. Secondly, two paired samples T tests were run, in which the first of these only selected the cases of the group with gamification elements and the second only selected the cases of the group without gamification elements. Through doing this, we were able to analyze the differences within the groups and look at the changes in score before and after the experiment.

Results

To get insight into our research question "To what extent do performance gamification aspects in an inquiry learning environment influence motivation when compared to an environment without these aspects?" We looked at the results gathered from the questionnaire that was taken before

and after the students engaged in either of the online inquiry learning environments. In the process of collecting the data, 3 out of our 30 initial participants were excluded because of incomplete data (missing/incomplete before and/or after questionnaire). Leaving us with a total of 15 participants in the group which was working with gamification elements and 12 participants in the group which was not working with gamification elements.

Between groups

To measure the differences between the groups before and after the use of the online inquiry learning environment, independent T tests were conducted. Firstly, an independent T test was conducted for all the scores gathered before the test. Looking at the results, we see Interest $t(25) = -.739$, $p = .467$, Anxiety $t(25) = .180$, $p = .858$, and Challenge $t(25) = -.649$, $p = .522$ showed an insignificant difference between the groups. Notably, Probability of success $t(25) = -2.085$, $p = .047$ showed a significant difference between the groups in probability of success. With the group without gamification elements perceiving their probability of succeeding significantly higher than the group with the gamification elements. Aside from this significant difference it is worth mentioning that across all categories the group without gamification elements tended to give higher scores as can be seen in Table 1. Though in all categories but probability of success, this difference was not significant.

Table 1*Comparison of Mean Scores and Standard Deviations from QCM Measurement*

Condition	Gamification		Control	
	Before	After	Before	After
Interest	4.93 (0.90)	4.94 (1.17)	5.22 (1.09)	4.68 (1.31)
Probability of success	5.10 (0.99)	5.61 (1.06)	5.88 (0.93)	5.67 (1.22)
Anxiety	3.37 (1.53)	3.19 (1.46)	3.47 (1.04)	2.60 (0.90)
Challenge	5.40 (0.80)	5.12 (1.31)	5.65 (1.17)	4.44 (1.27)

For the second test all scores collected after the use of the online inquiry learning environment were analyzed. A notable difference that is detected when looking at table 1, is that where the mean scores for students in the condition without gamification elements were higher in all categories, for the before condition this has reversed in the after condition for Interest, Anxiety and Challenge. When looking at the independent samples test, we see Interest $t(25) = .550$, $p = .587$, Probability of success $t(25) = -.114$, $p = .910$, Anxiety $t(25) = 1.439$, $p = .163$, and Challenge $t(25) = 1.355$, $p = .188$. All did not have any no significant differences between the categories after the experiment was conducted. Notably, the previously significant difference in probability of success has diminished to a difference that is negligible.

Within groups

After doing two independent samples t tests. We saw that there are little significant differences between the groups. However, in order to make an accurate conclusion about the effect of gamification elements or lack thereof, the difference within the groups also had to be analyzed. This was done through two separate paired samples. The first of these paired samples tests was on the group with gamification elements on the scores before and after the experiment. When

looking at the first paired samples test, we can see that Interest $t(14)=-.070$, $p=.945$, Probability of success $t(14)=-1.914$, $p=.076$, Anxiety $t(14)=.298$, $p=.770$ and Challenge $t(14)=1.253$, $p=.231$, all showed no significant difference. With the biggest difference that was shown being an increase of probability of success.

For the second paired t test, the scores before and after for the group without gamification elements were analyzed. When looking at the correlations between the paired samples. We saw that Interest $t(11)=2.766$, $p=.018$, Anxiety $t(11)=2.721$, $p=.020$, and Challenge $t(11)=3.781$, $p=.003$ showed a significant decrease in score from before to after the experiment. For Probability of success $t(11)=1.261$, $p=.233$ there was no significant difference to be found

Discussion

In this paper, an insight was given into the effect that performance gamification elements can have on the motivation of students. Ultimately, answering our research question “To what extent do performance gamification aspects in an inquiry learning environment influence motivation when compared to an environment without these aspects?”. However, as motivation is difficult to quantify, this research split up the concept into four different categories. Looking at the results that were gathered we see a relation between the lack of gamification elements and almost all of the categories that make up motivation. Since, in Interest, Anxiety and Challenge scores seem to lower significantly when there are no gamification aspects present. Whereas in the condition with gamification elements, there were no significant changes in scores within the categories. Revisiting our hypotheses, we can conclude that challenge and interest are indeed experienced more after students work with a learning environment that utilizes performance gamification elements when compared to an environment without these elements. Surprisingly, students did also experience higher levels of anxiety after working with the environment with performance

gamification elements when compared to an environment without these elements. Lastly, for probability of success there were no significant differences to be found between the two conditions except for the differences between groups beforehand and thus we can not confidently say that there is a difference in probability of success.

Knowing the nature of the differences between the categories is crucial to get a better understanding of how exactly performance gamification elements influence motivation. Therefore, it is important to address that all of the significant differences were due to the preservation of the scores in the gamification condition and a decrease in scores in the condition without gamification. Therefore, to assume that performance gamification elements “improve motivation” is not supported by these findings. Rather, as per these results, the conclusion can be made that performance gamification elements preserve initial motivation.

Motivation as a product of performance gamification elements

When taking a look at the results we can see that there is a serious effect of lack of gamification on scores in almost all categories. When looking at previous research the fact that interest was preserved better in the condition with gamification elements than in the condition without these elements is supported. For example, Eisenberger and Cameron (1996) found that if a quality dependent reward was given, which in this research case came from awarded points, it would improve stated interest by the participants. The reason this happens according to the symbolic cue hypothesis is that these rewards suggest high competence in the participants and thus increases their intrinsic motivation (Eisenberger & Cameron, 1998). This can also explain the relatively higher scores in challenge for the condition with gamification elements, since a feeling of competence is correlated with higher levels of pride when the task is completed (Cook, Wildschut, Thomaes, 2017). However, it is worth noting that this effect is larger when the

rewards are based on a specific threshold rather than an indication that participants are simply doing good. Another explanation is presented by Daniel and Esser (1980), they point out that extrinsic rewards may negatively influence intrinsic rewards. However, following findings by Kruglanski et al (1975), when the reward is perceived as part of the task this may in fact increase intrinsic motivation, which the points and medal in our task may be perceived as. That being said, these findings could also explain why there was a significant decrease in scores in the condition without gamification elements. Since these students did not get any indication of whether they did well or not they did not receive any fulfillment in those areas. Supporting that there is a need for competence as suggested in the theory of self determination (Sailer et al., 2017). This is further supported by Butler and Nisan (1986), they suggest that the decrease of motivation might be due to lack of feedback in general. The need for mastery relies upon information about the competence of the student. When this information is not given it becomes extremely difficult to evaluate one's mastery at a task and thus intrinsic motivation would be undermined if no such information was given.

Contrary to our hypothesis, we found that anxiety actually goes down when in a condition without performance gamification elements. A possible explanation for this could be that students are experiencing a tendency to avoid failure. Which means that in a situation in which students' performances are evaluated students experience more anxiety (Atkinson, 1964). Therefore, we might expect relatively higher values of anxiety in an environment in which points are collected when compared to an environment in which students are left without evaluation. Though this finding did oppose our hypothesis, it does support the overall notion that motivation is higher in the condition with gamification elements, as higher levels of anxiousness can lead to intrinsic motivation through negative incentive of failure (Vollmeyer & Rheinberg, 2006).

Anxiety can also be inhibiting motivation, however that is mostly seen in especially anxious cases (Atkinson, 1957), thus this would not play a big role in our sample which predominantly scored on the lower end for anxiety.

Implications for learning tools

Based on our findings it becomes evident that whenever a learning tool does not have an adequate feedback system in place, students might not be able to assess their own competence and thus will end up less motivated (Sailer et al, 2017; Butler & Nisan, 1986). Certainly in an environment where the students usually get feedback from their teacher, which can play a big role in intrinsic motivation (Hidi, 2015), the lack of feedback in a learning environment can greatly affect motivation. Therefore, for a learning tool to be a standalone effective tool, implementation of performance gamification elements can help in keeping motivation high. It is worth mentioning that, if the teacher takes up the role of giving feedback, a tool without performance gamification elements would work similarly to one with these aspects. However, it would then only be used as a complementary learning material rather than a standalone online learning environment.

Limitations and recommendations

While this research illustrates the importance of performance gamification elements in standalone online learning environments, there are suggestions that can be made for future research. First of all, the learning material used for the lesson was designed for the age group 7-9, which is the group that formed our participants. However, it is normally aimed at the faster students who finish the regular material and then move on to slightly more complicated material, which the material used in the lesson consisted of. This might lead to a more challenging task for the average student and might affect some of the scores students stated. That being said however,

due to the randomly selected samples for both groups within the classroom, we can assume that both groups had an even distribution of faster and slower students and thus between and within groups correlations would still hold up. For future research, it might be insightful to use learning material that is experienced as easier by a majority of the students.

Secondly, performance gamification elements are only part of the whole of gamification. In this research no other elements were used to isolate the effectiveness of performance elements. However, for a more accurate picture of what a good online learning tool looks like, it could be of importance to assess the effectiveness of a learning tool when using more than one kind of gamification. Therefore, further research should aim to explore the implementation of multiple types of gamification and its effect on the other types' effectiveness and overall motivation.

Lastly, the sample consisted of 30 participants, even without the three excluded participants, this sample would not be big enough to make extremely dependable results with only 15 participants for each of the conditions. Therefore, future research should aim to use larger sample sizes in order to create more robust findings.

Conclusion

This research aimed to give an insight into the effect of performance gamification elements on motivation in students. From our results we can conclude that when there are no such elements present, motivation as measured in Interest, Probability of success, Anxiety and Challenge, declines significantly. These findings support the notion that in order for intrinsic motivation to be gained, there is a need for competence or mastery. This research once more stresses the importance of feedback in learning, following earlier research in the field. Therefore we think that in the process of creating standalone online learning environments in the future, implementation of performance gamification elements should always be seriously considered.

References:

- Atkinson, J. W. (1957). Motivational determinants of risk-taking behavior. *Psychological Review*, 64(6, Pt.1), 359–372. doi:10.1037/h0043445
- Atkinson, J.W. (1964). An introduction to motivation. Van Nostrand.
- Bandura, A. (1997). Self-Efficacy: The exercise of control. New York: Freeman.
- Butler, R., & Nisan, M. (1986). Effects of no feedback, task-related comments, and grades on intrinsic motivation and performance. *Journal of Educational Psychology*, 78(3), 210–216. doi:10.1037/0022-0663.78.3.210
- Cook, E. M., Wildschut, T., & Thomaes, S. (2017). Understanding adolescent shame and pride at school: Mind-sets and perceptions of academic competence. *Educational and Child Psychology*, 34(3), 119–129.
- Daniel, T. L., & Esser, J. K. (1980). Intrinsic motivation as influenced by rewards, task interest, and task structure. *Journal of Applied Psychology*, 65(5), 566–573. doi:10.1037/0021-9010.65.5.566
- De Jong, T. (2006). COMPUTER SIMULATIONS: Technological Advances in Inquiry Learning. *Science*, 312(5773), 532–533. doi:10.1126/science.1127750
- Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From Game Design Elements to Gamefulness: Defining “Gamification”. Paper presented at the 15th International Academic MindTrek Conference, Tampere. <http://dx.doi.org/10.1145/2181037.2181040>.
- Dichev, C., & Dicheva, D. (2017, December 20). Gamifying education: What is known, what is believed and what remains uncertain: A critical review. *International Journal of Educational Technology in Higher Education Nature Publishing Group*. doi: 10.1186/s41239-017-0042-5.
- Eisenberger, R., & Cameron, J. (1996). Detrimental effects of reward: Reality or myth? *American Psychologist*, 51, 1153-1166. doi: 10.1037//0003-066x.51.11.1153
- Eisenberger, R., & Cameron, J. (1998). Reward, intrinsic interest, and creativity: New findings. *American Psychologist*, 53(6), 676–679. doi:10.1037/0003-066x.53.6.67
- Elen J. & Lowyck J. (2000) Homogeneity in students’ conceptions of instructional interventions: origins and consequences for instructional design. *Journal of Structural Learning and Intelligent Systems* 14, 253–265.
- Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and Quasi-Experimental Studies of Inquiry-Based Science Teaching. *Review of Educational Research*, 82(3), 300–329. doi:10.3102/0034654312457206
- Hidi, S. (2015). Revisiting the Role of Rewards in Motivation and Learning: Implications of Neuroscientific Research. *Educational Psychology Review*, 28(1), 61–93. doi:10.1007/s10648-015-9307-5
- Kruglanski, A. W., & et al. (1975). Effect of task-intrinsic rewards upon extrinsic and intrinsic motivation. *Journal of Personality and Social Psychology*, 31(4), 699–705. doi:10.1037/0022-3514.31.4.699

- Lott, G. W. (1983). The effect of inquiry teaching and advance organizers upon student outcomes in science Education. *Journal of Research in Science Teaching*, 20, 437–451. Doi: 10.1002/tea.3660200507
- MacIntyre, P. D., & Renée MacDonald, J. (1998). Public speaking anxiety: Perceived competence and audience congeniality. *Communication Education*, 47(4), 359–365. doi:10.1080/03634529809379142
- Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., ... Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review*, 14, 47–61. doi:10.1016/j.edurev.2015.02.003
- Przybylski, A. K., Weinstein, N., Ryan, R. M., & Rigby, C. S. (2009). Having to versus wanting to play: background and consequences of harmonious versus obsessive engagement in video games. *Cyberpsychol Behav*, 12(5), 485-492. 10.1089/cpb.2009.0083
- Renninger, K.A., & Hidi, S. (2017). *The Power of Interest for Motivation and Engagement* (1st ed.). Routledge. doi: 10.4324/9781315771045
- Rheinberg, F., & Vollmeyer, R. (2001). QCM: A questionnaire to assess current motivation in learning situations.. *Diagnostica*. 47.
- Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, 69, 371–380. doi:10.1016/j.chb.2016.12.033
- Schroeder, C. M., Scott, T. P., Tolson, H., Huang, T.-Y., & Lee, Y.-H. (2007). A metaanalysis of national research: Effects of teaching strategies on student achievement in science in the United States. *Journal of Research in Science Teaching*, 44, 1436–1460. doi:10.1002/tea.20212
- Toda, A. M., Klock, A. C. T., Oliveira, W., Palomino, P. T., Rodrigues, L., Shi, L., ... Cristea, A. I. (2019). Analysing gamification elements in educational environments using an existing Gamification taxonomy. *Smart Learning Environments*, 6(1). doi:10.1186/s40561-019-0106-1
- Vollmeyer, R., & Rheinberg, F. (2006). Motivational Effects on Self-Regulated Learning with Different Tasks. *Educational Psychology Review*, 18(3), 239–253. doi:10.1007/s10648-006-9017-0
- Weiner, B. (1985) An Attributional Theory of Achievement Motivation and Emotion. *Psychological Review*, 92, 548-573. <http://dx.doi.org/10.1037/0033-295X.92.4.548>
- Weinstein, T., Boulanger, F. D., & Walberg, H. J. (1982). Science curriculum effects in high school: A quantitative synthesis. *Journal of Research in Science Teaching*, 19, 511–522. doi:10.1002/tea.3660190610
- Wigfield, A., & Eccles, J. S. (2002). The Development of Competence Beliefs, Expectancies for Success, and Achievement Values from Childhood through Adolescence. *Development of Achievement Motivation*, 91–120. doi:10.1016/b978-012750053-9/50006-1

Appendix 1:

Rheinberg and Vollmeyer Questionnaire for motivation

Items used for the four motivation scales of the QCM

	Disagree	Agree
1. I like riddles and puzzles.	(I) ○—○—○—○—○—○—○	
2. I think I am up to the difficulty of this task.	(P) ○—○—○—○—○—○—○	
3. I probably won't manage to do this task.	(P-) ○—○—○—○—○—○—○—○	
4. While doing this task I will enjoy playing the role of a scientist who is discovering relationships between things.	(I) ○—○—○—○—○—○—○	
5. I feel under pressure to do this task well.	(A) ○—○—○—○—○—○—○	
6. This task is a real challenge for me.	(C) ○—○—○—○—○—○—○	
7. After having read the instruction, the task seems to be very interesting to me.	(I) ○—○—○—○—○—○—○	
8. I am eager to see how I will perform in the task.	(C) ○—○—○—○—○—○—○	
9. I'm afraid I will make a fool out of myself.	(A) ○—○—○—○—○—○—○	
10. I'm really going to try as hard as I can on this task.	(C) ○—○—○—○—○—○—○	
11. For tasks like this I don't need a reward, they are lots of fun anyhow.	(I) ○—○—○—○—○—○—○	
12. It would be embarrassing to fail at this task.	(A) ○—○—○—○—○—○—○	
13. I think everyone could do well on this task.	(P) ○—○—○—○—○—○—○	
14. I think I won't do well at the task.	(P-) ○—○—○—○—○—○—○—○	
15. If I can do this task, I will feel proud of myself.	(C) ○—○—○—○—○—○—○	
16. When I think about the task, I feel somewhat concerned.	(A) ○—○—○—○—○—○—○	
17. I would work on this task even in my free time.	(I) ○—○—○—○—○—○—○	
18. I feel petrified by the demands of this task.	(A) ○—○—○—○—○—○—○	

(C): Challenge

(I): Interest (Items have to be adapted to the task)

(P): Probability of success

(A): Anxiety

Translated version used for students:

	Oneens	Eens
1. Ik vind raadsels en puzzels leuk.	<input type="radio"/>	<input type="radio"/>
2. Ik denk dat ik deze opdracht kan.	<input type="radio"/>	<input type="radio"/>
3. Ik kan deze opdracht waarschijnlijk niet.	<input type="radio"/>	<input type="radio"/>
4. Ik ga het leuk hebben om bij deze opdracht een wetenschapper te spelen.	<input type="radio"/>	<input type="radio"/>
5. Ik voel druk om deze opdracht goed te maken.	<input type="radio"/>	<input type="radio"/>
6. Deze taak is echt moeilijk voor mij.	<input type="radio"/>	<input type="radio"/>
7. Nadat ik heb gelezen over de opdracht klinkt de opdracht interessant.	<input type="radio"/>	<input type="radio"/>
8. Ik ben benieuwd hoe ik het ga doen op deze opdracht.	<input type="radio"/>	<input type="radio"/>
9. Ik ben bang dat ik mezelf voor schut zet.	<input type="radio"/>	<input type="radio"/>
10. Ik ga echt mijn best doen op deze opdracht.	<input type="radio"/>	<input type="radio"/>
11. Ik ben geen beloning nodig voor deze opdracht, het is gewoon leuk.	<input type="radio"/>	<input type="radio"/>
12. Het zou beschamend zijn als ik deze opdracht niet haal.	<input type="radio"/>	<input type="radio"/>
13. Ik denk dat iedereen deze opdracht kan.	<input type="radio"/>	<input type="radio"/>
14. Ik denk dat ik deze opdracht niet goed zal doen.	<input type="radio"/>	<input type="radio"/>
15. Als ik deze opdracht kan doen ben ik trots op mezelf.	<input type="radio"/>	<input type="radio"/>
16. Als ik nadenk over deze opdracht, ben ik een beetje bezorgd.	<input type="radio"/>	<input type="radio"/>
17. Ik zou deze opdracht ook in mijn vrije tijd doen.	<input type="radio"/>	<input type="radio"/>
18. Ik ben bang voor de eisen van deze taak.	<input type="radio"/>	<input type="radio"/>

Appendix 2:

Link to lesson (With gamification elements)

<https://graasp.eu/s/3odbjk>

Link to lesson (Without gamification elements)

<https://graasp.eu/s/pw1cdn>