Gamification of high school Machine Learning education

Exploring Gamification to enthuse Young Students

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Abstract

The rapid advance of AI and ML asks for better and earlier education on these topics. However, research on teaching AI and ML topics is relatively underdeveloped. Especially applying the teaching method gamification has not yet been thoroughly tested. This research aims to explore the effectiveness of gamifying ML education in high schools. An experiment was designed based on previous research. This experiment revolves around a computer game where students learn to train a car to drive itself. Despite small sample size, results show increased motivation and low anxiety.

1 Introduction

The topic of machine learning (ML) education is relatively new, but is rapidly gaining importance as more and more machine learning is being incorporated into our daily lives [5]. Furthermore, the age at which people become exposed to machine learning is dropping fast with the rise of advanced social media algorithms and generative AI models such as ChatGPT [1]. This paper will examine different teaching methods used in general education and how well these methods translate to teaching ML topics. More specifically, this paper will explore the effectiveness of gamification of ML education as a tool to motivate students.

1.1 Motivation

A recent analysis of the research in general Computer Science education in high schools calls for the need for more research into deep-learning education [3]. Some research has been done into teaching ML concepts to high school students [5]. Most of this research focuses on applying previously verified teaching methods to teaching ML. However, the method of gamification is unfortunately not yet explored thoroughly. A notable attempt was made, but the researchers admitted to some flaws in their study, which is probably why their paper was called "a postmortem" [7]. The game was considered too hard and too confusing.

Gamification does show promising results in other fields. Mainly in the areas of motivation and academic performance [6; 10]. This is why this topic should be researched further in the field of ML education.

1.2 Research Questions

A research question arises from this knowledge gap: To what extent does gamification as a teaching method work to improve the motivation among high school students for machine learning topics? To form an hypothesis, two sub-questions must be answered:

- To what extent do other teaching methods from general education translate to machine learning education?
- To what extent does gamification work as a teaching method in general education and what are its limitations?

The answer to these questions can be used to devise an experiment to try and prove the hypothesis of the of gamification being an effective teaching method for teaching machine learning topics to high school students.

2 Previous Work

To answer the two sub-questions of this paper, it is important to look at previous work in other fields of study. The conclusions of this analysis will directly influence the experiment design. The question of to what extend other teaching methods translate to machine learning education can help understand the need for research into gamification and can help form an hypotheses on the effectiveness.

Problem-based learning, collaborative learning, hands-on learning, and visual environments all positively influence student performance and motivation, as concluded by Martins and von Wangenheim [5]. As gamification is closely related to these learning strategies, it is likely that it will have a similar effect. The aforementioned elements should therefore be included in the experiment design.

One of the unknowns for the experiment setup is what aspects of gamification to focus on and what results to expect. According to a 2022 analysis of other studies on the effectiveness of gamification in education, gamification has the most effect on students' motivation and academic achievement achieved by puzzle games and reasoning strategy games respectively [10]. Gamification elements are also shown to increase motivation in language learners [6]. For that reason, the hypotheses of the experiment is that a game to teach machine learning will produce positive results when measuring motivation of students.

The earlier attempt at using gamification in machine learning mentioned in the introduction noted some pitfalls to avoid when applying the concept. Two of the most prominent pitfalls are confusing instructions and unclear goals [7]. This was due to the absence of a teacher and sub optimal level design.

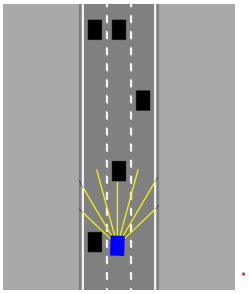
Based on these findings, the experiment should contain a game with puzzle and strategy aspects. To test the hypothesis, a questionnaire should be used to measure the motivation and attitude of the students towards machine learning. To avoid the pitfalls noted by ViPER, the game should have clear explanations at the beginning of each level and a clear goal to achieve before moving on to the next level.

3 Methodology

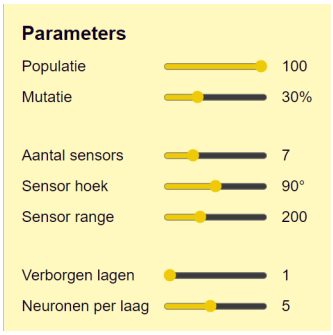
The devised experiment is centered around a game where the player (student) is challenged to train a neural network to control a car. There is no winning condition, but instead the goal is to get the car to travel the furthest without bumping into traffic or crossing the road borders. The expectation is that upon the training of a network that is able to make the first couple of turns, the student will feel joy and be motivated to experiment further and try to make their network even better.

3.1 Participants

The target group of this study is high school students. The study was therefore performed on a Dutch school in the class



(a) Car (blue), Traffic (black), Sensors(Yellow)



(b) Parameters to be changed

Figure 1: Preview of the game used to enthuse students about machine learning. Visual representation (left) and the parameters (right).

VWO 4. To total number of participants was three. As access education should not be restricted, neither should the study of education. Therefore the inclusion and exclusion criteria are very simple.

Inclusion criteria:

- Is in dutch high school
- Has *"informatica"* in chosen classes
- Willing to play game about self driving cars

Exclusion criteria:

- none

3.2 The Game

The core of the game (the car, the road and neural network) is based on the code by gniziemazity who provided their code under the MIT licence [4]. The GUI, levels and parameters are created by the author of this paper and can be found on GitHub, also under the MIT licence[1].The game is consists of multiple levels, where each level starts with a quick explanation about the available options and notes the goal of the level. The first level explains the rules of the game and allows the student to familiarize themselves with the controls by driving the car with the arrow keys. Each subsequent level unlocks a parameter or feature to fine tune the network the student is challenged to train. The student can progress to the next level at any point. The parameters and actions unlocked per level are denoted in the the table 1. A preview of the game is shown in figure 1

Once the student has progressed to the final level, they have unlocked all available parameters and should be able to train a functioning network. The final level also gives some hints for the best settings of some of the parameters. After the student is done playing the game, they move on to the questionnaire about their experiences.

[1]https://github.com/JalmarvdH/RP-Game2

Parameter	Unlock	Options	Description
Reset	Level 2	Click	Restart level
Population size	Level 3	1 - 100	Amount of networks tried at once
Sensor count	Level 4	1 - 25	Amount of sensors on the car
Sensor angle	Level 4	0° - 180°	Spread angle of sensors
Sensor range	Level 4	50 - 500	Detection range of sensors
Save	Level 5	Click	Save current best network for next generation
Delete	Level 5	Click	Delete saved best network
Mutation	Level 6	0% - 100%	Mutation between generations
Hidden layers	Level 7	1 - 5	Amount of hidden layers
Neuron count	Level 7	1 - 10	Neurons per hidden layer

Table 1: Parameters of the ML model that can be changed, at what level they are unlocked and what the possible values are.

3.3 The Experiment

The execution of the experiment consists of three parts. The first part is meant to measure the motivation and interest into machine learning before playing the game. This is to set a baseline to compare to later. The second part is playing the game. As mentioned before, the game is meant to spark interest and motivation to further study machine learning topics. The last part is supposed to measure the motivation and interest once more after the students have completed the game.

Part One

To assess the current motivation of students towards machine learning, the experiment starts with a plenary session with all students. The students are asked if they know what machine learning is and if they can name any examples. This is to refresh the memory of the students.

After the plenary session, the students are asked to individually fill in a questionnaire on their current attitude towards machine learning. This is done with the help of a short form of *the Questionnaire on Current Motivation* (QCM) [2]. This questionnaire assesses four factors of current motivation towards a topic, namely anxiety, challenge, interest, and probability of success. This short form version was chosen in to reduce the total time spent on filling in questionnaires as students already had to fill it in twice.

The short version did show some differences in outcomes compared to the original test. However, this should be mitigated by the students filling in the questionnaire twice, as the

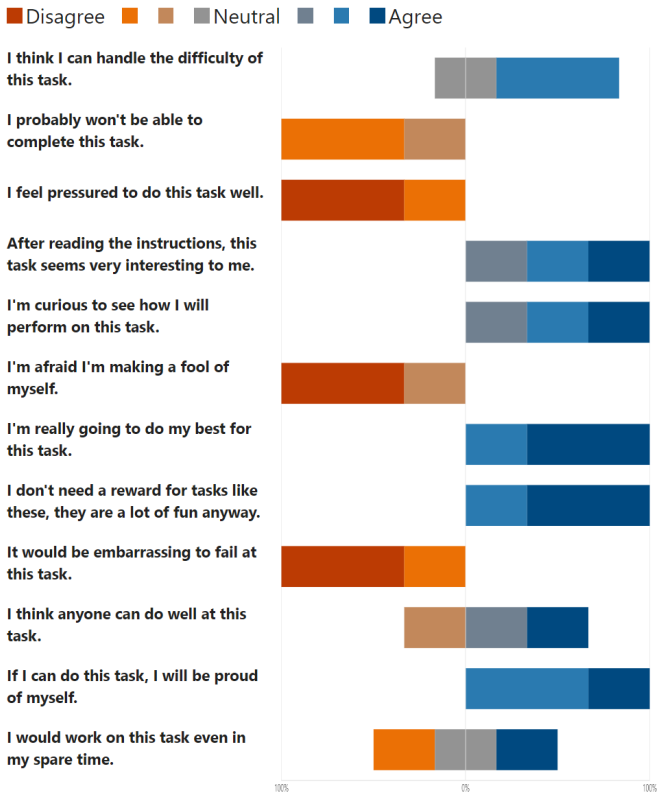


Figure 2: Questionnaire responses before playing game

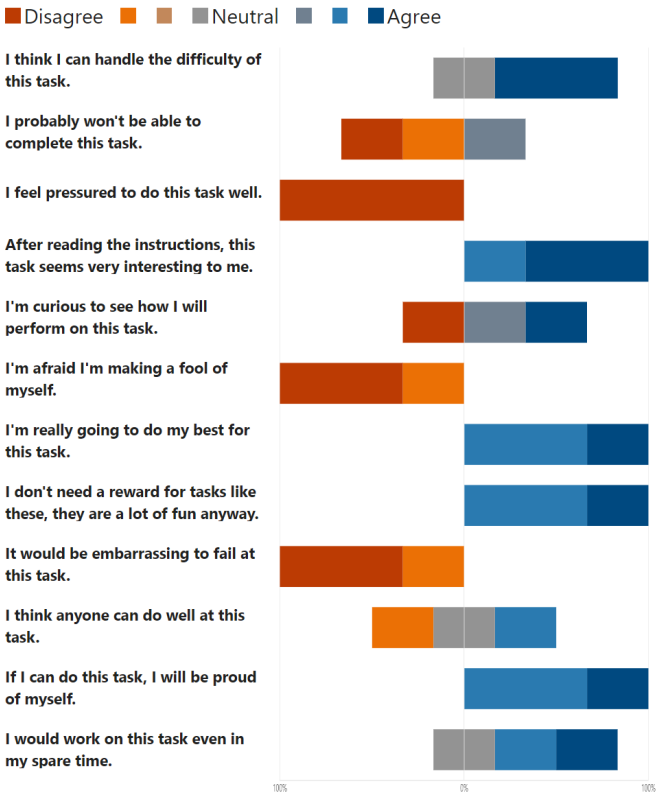


Figure 3: Questionnaire responses after playing game

differences will probably persist in the second questionnaire and only the difference between the results is of interest in this study.

Part Two

To hopefully excite the student about machine learning, they are tasked to play the game from earlier. This is done individually, with each student having access to their own instance of the game. They are however encouraged to discuss and compare the performance of their network while playing the game. This will hopefully spark even more competitive behaviour and motivate the students further.

The game is designed to last anywhere between 5 and 20 minutes, where 5 minutes is just enough to go through all the levels and 20 minutes should result in a network that can make the first couple of turns. The students are allowed to progress through the levels as fast as they like and can quit whenever they like. The idea behind this is that if someone is not interested in playing the game, the game will probably not spark interest in machine learning either and forcing play will not change that.

Part Three

The final step of the experiment is for the students to fill in the short form QCM one more time. This is once again done individually. After filling in the final questionnaire, the students are asked to leave the room.

4 Results

As mentioned before, the total amount of participants in this study was three. Therefore these results can only be used in speculation. The full set of responses from before and after playing the game can be seen in figure 2 and 3 respectively. The questions in the QCM are grouped per factor, therefore the results are split in the corresponding subsections [2]. The experimenter additionally recorded other observations during the experiment.

4.1 Questionnaire Results

Anxiety

The QCM shows very low anxiety among participants both before and after playing the game. The results show slight reduction in pressure to perform and fear of making a fool of themselves in two of the participants after playing the game.

Challenge

The participants experienced a reduction in challenge after playing the game. With one student now no longer being curious about their performance. There was no perceived change in pride and only a slight reduction in effort.

Interest

The students noted high interest in the game after the introduction but before playing. After playing the game, participants reported increased interest in the task. One participant even switched not wanting to work on the task in their free

time to wanting to work on it. This factor showed the largest change.

Probability of Success
Most participants started out quite confident in their ability to complete the task and noted they were probably up for the difficulty. The responses were more divided about whether anyone could complete this task. These results remained mostly the same after the game, with the belief that anyone could complete this task slightly decreasing.

4.2 Other Observations

Before the experiment while still waiting for other participants, the experimenter talked to some of the participants. The students all seemed to have a preexisting interest in computers and programming. One student noted to want to study at TU Delft themselves after completing high school. Another student noted to have programmed a poker game.

During the experiment, it was observed that participants spent more time in the earlier levels than expected. This was resolved after once more explaining to the students that they could continue to the next level whenever they liked. Perhaps this was not clear enough yet.

It should be noted that all students managed to get their car past the first couple of obstacles in the designed time frame of 5 to 20 minutes. Which is a good indication for the difficulty of the game. It was also observed that all students went back to playing the game after filling in the final questionnaire. Which is a good indication for the fun factor of the game.

5 Responsible Research

To ensure that this research adheres to all modern ethical research guidelines, the outline of this research was submitted to the TU Delft Human Research Ethical Committee [8]. This includes a risk analysis, a data management plan and the consent form all participants of the study had to sign. As this study focuses on a higher risk participant group in the form of high school students who are likely to be under the age of 18, extra risk mitigation techniques are required.

For the aforementioned reasons, no Personally Identifiable Information of participants was collected during the experiment. This means that the data gathered is less specific, but that is a sacrifice worth making to protect the privacy of the participants. The participants will be in the final years of high school and thus of age 16 or over. This means participants are able to sign consent themselves.

To ensure the experiment in this study is reproducible, a playable version of the game is available online[2]. Furthermore, the source code of the game is also available on GitHub[3]. The publication of the code, together with the risk mitigation mentioned above are in compliance with The Dutch Code of Conduct for Academic Practice [9].

6 Discussion

The obtained results indicate an increase of motivation among the participants. This was the expected result when comparing to related studies. The high interest/motivation before playing the game is also expected as this experiment took place on a high school as an extracurricular activity. The students willing to join did so because they found it interesting as no reward was offered.

One of the major limitations of this study is in the nature in which the study had to be executed. Just like all ethical studies with human participants, participation is voluntary. As this study is aimed to enthuse students about machine learning and students know this, the most likely group of voluntary participants are students with prior interest in machine learning.

Furthermore, the stereotype of teenage students is to dislike education and this study was conducted on a high school as an extracurricular activity. This will most likely have narrowed down the willing participants who are really interested in machine learning or education in general.

The increase in academic performance as the result of gamification suggested by other literature could also not be measured with this experiment setup.

7 Conclusions

This study aimed to answer the question of to what extent gamification works as a motivational tool for machine learning education in high schools. Previous work suggested that gamification should have a positive influence on motivation. Therefore an experiment was devised to measure the motivation of students for a gamified machine learning lesson.

As the sample size of this study was relatively small and only conducted in one class on one school as an extracurricular activity, it is hard to draw definitive conclusions about our hypothesis. It can however be noted that gamification of machine learning education in high schools shows preliminary signs as an effective way to motivate and students.

Furthermore, the game seemed appropriately challenging and fun to play. All students managed to get the car past the first couple of obstacles and enjoyed the game enough to go back to playing after completing the final questionnaire. After completing the goal of the game, students started to try and break the game. They wanted to increase the population to the point the school computer started to lag. This shows curiosity and motivation to experiment further. Perhaps these students could expand upon the code of the game in a next lesson to learn more about machine learning.

8 Future Work

To draw definitive conclusions, this experiment and the game should be slightly altered and repeated with a larger sample size.

Proposed changes to game
To prevent the students remaining in one of the earlier levels, it should be made more clear that progression to the next level is allowed at any time. To satisfy the curiosity of the most enthusiastic students, bonus levels could be added in which parameters can be changed to unreasonable values. This allows students to explore the limits of the algorithms and their computer themselves. One final suggestion is the addition of

[2]https://jalmarvdh.github.io/RP-Game2/
[3]https://github.com/JalmarvdH/RP-Game2/

multiplayer in which the best network among all students is shown on screen. This will encourage even more competitive behaviour.

Proposed changes to experiment

To hopefully get students who are less intrinsically motivated about machine learning to participate in the experiment. It should be considered to perform this experiment during a lesson on a school as part of the curriculum. In that case an alternate assignment should be prepared by the school for students not willing to join.

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