

Why do girls score less than boys in the Physics Olympiad?

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ABSTRACT

In the Dutch Junior Physics Olympiad, a gender gap in the scores and number of participants in the second round can be noticed. Previous research shows that the gender gap in Physics education, and Physics competitions can be due to gender differences in interest, motivation, confidence, sense of competitiveness, external support and encouragement, or even gender discrimination. The first part of this research aims at determining how students are selected for the second round and at proposing an inclusive selection method. Results show that selecting the best scoring boy and girl from every participating classroom leads to the most gender equal pool of participants for the second round. The second part aims at understanding the differences in motivation, perception of the Physics Olympiad and personality traits between male and female participants. This is done by sending a questionnaire to past participants of the Junior Physics Olympiad. 49 participants completed the questionnaire, revealing that boys and girls have different reasons for participating, more girls doing it for fun and more boys doing it for a chance to win. Results also show that girls have a lower sense of self-efficacy than boys, which may explain their lower performance in the Physics Olympiad. Suggestions are made to encourage girls more and help them improve their self-efficacy and self-confidence.

Key words: gender gap, physics, physics competition, motivation, attitudes.

INTRODUCTION

Every year, the Netherlands participates in the International Physics Olympiad, sending their best physics students to countries such as Portugal, Israel and Indonesia, giving them the chance to visit new places, experience enriching excursions and compete against students from all over the world. Each year, five students are selected to compete in the International Physics Olympiad, to represent the Netherlands. No girl has been selected since 2011 (Universiteit Utrecht, 2021).

This is not the only example of an existing gender gap in the Physics Olympiad. In both the Junior Physics Olympiad (NOJ) and the upper secondary Physics Olympiad (NOB), girls tend to obtain lower scores than boys (Mooldijk & van der Laan, 2019). The Physics Olympiad occurs in three rounds, the best students of the previous round getting invited to the next one, in order to progress towards the final round, and potentially winning the NOJ, or getting sent abroad for the International Olympiad (Universiteit Utrecht, 2021). It has been noted that there are fewer and fewer female participants as we progress in the Olympiad rounds, leaving little opportunity for a female winner.

Unfortunately, the issue of the gender gap in physics education is not specific to the Physics Olympiads. It can indeed be found that studies and careers in physics, engineering and computer science tend to attract much fewer girls than boys (UNESCO Institute for Statistics, 2020). Many studies have been conducted to try to understand this gender gap, and many methods now exist to try to combat this issue. These include the increase of female representation in the classroom, designing lessons more specifically for girls, and training teachers to avoid gender bias (Little & Leon de la Barra, 2009). However, these solutions are for specific contexts, and are not necessarily applicable to the Physics Olympiads.

Although this issue is widely known, the methods which have been developed and implemented do not always yield positive results. Each situation and context are different and the causes and solutions for the gender gap are varied and complex. In the case of the Dutch Physics Olympiad, the reasons of the gender gap are still unknown, making it very difficult to find effective solutions. For these reasons, it is important to focus on the causes behind the problem, with the goal of moving forward and looking for solutions to this problem. In the context of the Physics Olympiads, it is important to determine why, on the one hand, there is a lower number of female participants compared to male participants, especially as the

participants progress in the later stages of the competition, and on the other hand, why girls tend to obtain lower scores than boys.

For the purpose of this research, the focus is primarily on the gender gap in the Junior Physics Olympiad (NOJ) and the aim is to identify the reasons for this gap. The research includes questions on gender bias within the NOJ organisation and the selection process, motivation and societal pressure in relation to gender, performance of boys and girls in competitive environments, and personality differences between boys and girls. All this research is made with the goal of answering the research question:

What are the organisational, sociological and psychological reasons for the lower scores of girls in the Physics Olympiads compared to boys?

This research is conducted in two stages, by first analysing the scores obtained in the NOJ in the past few years, and then by questioning past participants of the NOJ on their experience. By analysing the scores of the NOJ, the goal is to understand the distribution of the scores for boys and girls, look for patterns that would explain why fewer girls participate in the second and third rounds of the NOJ, and investigate the effects of different selection methods on the gender balance of the NOJ.

The second stage aims at understanding psychological and sociological reasons for the gender gap. With the use of a questionnaire targeting past NOJ participants, the goal is to understand the differences in motivation, personality and perception of the NOJ experience, between boys and girls. Both stages of the research will help answer the research question and identify the causes of the gender gap in the NOJ.

THEORETICAL BACKGROUND

The gender gap in physics

Many reasons have been given over time for the apparent lack of interest of girls in fields such as physics, mathematics and computer science. These include biological, historical, cultural, psychological, and sociological explanations, amongst others, each shedding a little bit of light on this issue. In this section, previous research on the gender imbalance in physics education will be reviewed, with the goal of determining possible reasons for the gender gap in the NOJ.

First of all, one reason that might come to mind is the possibility of a biological difference between men and women that would naturally make men better at physics than men. However, studies have been made to assess girls' performance in physics, finding that girls perform just as well or even better than boys in both practical and theoretical physics tests (Klainin et al., 2007; Mutjaba & Reiss, 2014). It is therefore assumed that the difference in boys' and girls' scores in the NOJ is not caused by a biological difference which would affect their ability.

Nevertheless, some research defends that there may be a biological factor which can influence girls' interest in science. Indeed, it can often be seen that girls, even when attaining high scores in physics, choose to pursue other topics, including scientific subjects such as Biology and Chemistry (Baram-Tsabari & Yarden, 2008; Mutjaba & Reiss, 2014). Miller et al. (2000) explains this by suggesting that women are more attracted to subjects and careers which are people-oriented and would allow them to help others, whereas men tend to choose object-oriented subjects such as physics. However, it is uncertain whether this difference in interest and choice of studies is due to a biological difference or to a difference in how girls' and boys' interests are influenced by cultural and sociological factors.

Let us now investigate some cultural reasons which may impact girls' interest in science. Mutjaba and Reiss (2014) found that, in the United Kingdom, a student's heritage can influence their willingness to study post-compulsory physics in school. For example, students of Black heritage were found less likely to continue physics after the age of 16, compared with students of White heritage. On the other hand, students of Asian heritage were more likely to pursue post-compulsory physics than students of White heritage (Mutjaba & Reiss, 2014). This is explained by the fact that one of the key factors in choosing to pursue post-compulsory physics is extrinsic motivation, more specifically in the form of home support of science learning and pressure to study physics from the parents, which may be influenced by the culture of the students' family (Mutjaba & Reiss, 2014).

On an international level, Stoet and Geary (2017), found that the gender gap in science also depends on the level of gender equality in a country. Indeed, this is described as the gender-equality paradox: "countries with lower levels of gender equality had relatively more women among STEM graduates than did more gender-equal countries" (Stoet & Geary, 2017, p.590). This paradox is explained by the fact that students' decisions do not only depend on their abilities and interests, but also on their socioeconomic context (Stoet & Geary, 2017).

Another factor which may have an impact on girls' choice to pursue physics are gender stereotypes. Already at the age of five years old, gender stereotypes have been shown to influence girls' perception of their future careers (OECD, 2021). Furthermore, many women suffer from "stereotype threat" which is described as the fear of confirming a negative stereotype (Francis et al., 2016). In the case of women in physics, women get scared that they will confirm the stereotypes of females being less smart or professional than men. This leads women to put a lot of pressure on themselves, and to end up with worse results because of this pressure (Francis et al., 2016).

Gender stereotyping can also lead to the idea that women do not belong in studies or careers in physics. This is reinforced by the lack of female representation in this field. This has been identified as a main reason for the imbalance in the field of physics. Kerkhoven et al. (2016) shows that, in primary school books, women are more often depicted as teachers, whereas men are depicted as scientists. This has shown to have an impact on girls' perceptions of themselves and their own future. This is also a leading factor in this imbalance, as it can be seen as a vicious cycle. The less girls are represented, the less girls are inspired to pursue studies and careers in male-dominated fields, the less girls there are to use as examples to inspire future generations.

Another consequence of stereotyping women in physics is that it can lead to gender discrimination. Unfortunately, acts of sexism are quite common in the fields of physics and astronomy (Barthelemy et al., 2016). Women suffer from microaggressions, sexual harassment, discouragement and other hostile forms of sexism in those fields (Barthelemy et al., 2016). This may be a source of discouragement for women to choose physics in school or at university. In the case of the NOJ, no sign of gender discrimination has been found in previous research (Mooldijk & van der Laan, 2019). Nevertheless, it is important to make an active effort to limit gender bias within the organisation to a strict minimum, more specifically in the selection process for the second and third rounds of the NOJ.

The gender gap in science competitions

As mentioned previously, the gender gap in the NOJ may be explained by reasons similar to those explaining the gender gap in physics education. However, it is also important to note that there is a notable gender gap in science and mathematics competitions, and the specific context of science competitions should also be considered as a possible cause for this gender gap. Indeed, it has been found that, on an international level, there is a notable gender difference in the participation and achievement in chemistry, physics and mathematics Olympiads (Steeh

et al., 2019). One of the explanations given is that the role of gender in student learning and performance depends on the environment, showing different gender patterns in informal and formal educational contexts (Steeh et al., 2019). Research on the gender gap in science competitions is therefore reviewed in this section.

First, a possible explanation for the lower performance of girls in science competitions compared with boys, is that the types of questions asked in these competitions may favour male participants over female participants. Research shows that the content, the presentation and the context of a question can influence the gender gap in students' achievement (Wilson et al., 2016).

For instance, it was found that, for questions including graph or diagram interpretation, especially when two or more spatial dimensions are involved, the gender gap widens in favour of male participants (Wilson et al., 2016). This phenomenon can also be found in a study by Gorska et al. (1998) which concludes that men have a higher ability for spatial visualization than women. One theory explaining this is that the difference in men and women's parietal lobe structure may impact their ability to perform mental rotation tasks, which come into play when solving certain physics exercises and questions (Halpern, 2007).

The context of a question has also been shown to have an impact on the gender gap in physics assessments. For example, male participants can achieve higher scores on questions with more concrete contexts compared to female participants (Wilson et al., 2016). Additionally, stereotypically male or female contexts can affect whether the student feels familiar and comfortable with the question, and this can also impact the gender gap in physics assessments (McCullough, 2004). Previous research on the gender gap in the NOJ was conducted and no evidence of a link between the types of questions and the gap in the scores was found.

Second, an important determining factor in students' performance during a competition or science assessment is their sense of self-efficacy and self-concept in physics. A student's self-efficacy can be described as their sense of self-confidence, and it has been shown that the difference in male and female's confidence levels differ largely for subjects such as Mathematics (Di Tommaso et al., 2018). Mutjaba and Reiss (2014) also found that confidence was one of the determining personality traits in choosing to study post-compulsory physics. One's sense of self-concept, on the other hand, is related to a person's belief in their own ability (Di Tommaso et al., 2018). This can be influenced by past experiences, the belief in stereotypical ideas that boys are better at science than girls, or by the support or expectations of

one's surroundings (Halpern et al., 2007). Self-concept, as well as self-esteem and self-efficacy are crucial factors in developing intrinsic motivation (Ryan & Deci, 2000). This can impact students' decisions to pursue subjects such as physics in school, and their performance during events such as the NOJ.

Another element of the NOJ context which might impact the gender gap in achievement, is the competitive pressure found in such an environment. Iriberry and Rey-Biel (2019) have studied the effects of competitive pressure on students' performance in the context of a mathematics competition. This study reveals that competitive pressure affects female participants in a negative way compared to male participants, resulting in a wider gap between their results (Iriberry & Rey-Biel, 2019). Furthermore, this negative effect of competitive pressure on girls' performance is even found to be worse in male-dominated environments, such as mathematics competitions (Iriberry & Rey-Biel, 2019) or even the NOJ. This is explained by the difference in girls' and boys' personality traits, being that girls tend to be more risk-averse and less confident in their own capabilities than boys (Iriberry & Rey-Biel, 2019).

This idea of competitive pressure influencing boys and girls in different ways can already be found at a young age. In running, competitive pressure seems to improve the performance of boys, whereas it does not for girls (Gneezy & Rustichini, 2004). One theory which may explain this is Darwin's sexual selection theory (1998). This theory states that, in many reproducing species, males tend to compete with each other to mate with the other sex, whereas females tend to be more discriminating in selecting a mate (Vandermassen, 2004). Following evolutionary reasoning, this could result in behavioural differences between men and women, such as men being more competitive and risk-taking than women (Vandermassen, 2004).

Lastly, some key factors influencing students' performance in science competitions are the students' motivation and attitudes towards the topic. The attitudes of a student towards a subject, such as mathematics, have been found to be one of the key differences between male and female students (Di Tommaso et al., 2018). Factors such as students' enjoyment of science learning or students' sense of self-efficacy in science assessments differ considerably with the student's gender (Di Tommaso et al., 2018). Furthermore, Mutjaba and Reiss (2014) also find that attitudes and motivation towards science learning are very important determinants of their willingness to pursue post-compulsory physics.

Motivation can be defined as a multidimensional construct, as motivation is dependent on other variables, and can be considered as a combination of various factors. Variables such as

attitudes, perceived value, perceived goal and perceived need, all influence one's motivation, which Mubeen and Reid (2014) describes as "a process that elicits, controls, and sustains certain behaviours" (p.131). A student's motivation is also dependent on their environment and can have a direct impact on their performance (Ryan & Deci, 2000). Tuan et al. (2005) explain the concept of motivation by breaking it down into a combination of six measurable dimensions. These dimensions are defined as follows:

1. Self-efficacy. Students believe in their own ability to perform well in science learning tasks.
2. Active learning strategies. Students take an active role in using a variety of strategies to construct new knowledge based on their previous understanding.
3. Science learning value. The value of science learning is to let students acquire problem-solving competency, experience the inquiry activity, stimulate their own thinking, and find the relevance of science with daily life. If they can perceive these important values, they will be motivated to learn science.
4. Performance goal. The student's goals in science learning are to compete with other students and get attention from the teacher.
5. Achievement goal. Students feel satisfaction as they increase their competence and achievement during science learning.
6. Learning environment stimulation. In the class, learning environment surrounding students, such as curriculum, teachers' teaching, and pupil interaction influenced students' motivation in science learning."

(Tuan et al., 2005, p.643)

All of these factors can impact a student's motivation towards learning science or towards participating in events such as science competitions.

In this research, the focus will be put on certain types of factors which may influence boys and girls differently and affect their performance in the NOJ. These factors include possible gender bias the selection method for rounds two and three of the NOJ, differences in motivation towards physics, differences in personality traits such as confidence and competitiveness, and

variance in perceptions of the NOJ experience. Overall, the aim will be to answer the following research sub-questions:

a) How do different selection methods affect the gender balance of participants in the second round of the NOJ?

b) What different factors affect girls' and boys' attitudes towards the NOJ?

METHODS

As aforementioned, this study takes place in two stages. The first stage is an analysis of the scores obtained in the NOJ in 2018, 2019 and 2020 with the goal of answering the first research sub-question. The second stage consists of a survey on the participants' attitudes towards the NOJ and their perception of the NOJ experience.

PART I: Analysis of the NOJ selection method

The first research sub-question is answered through an analysis of the scores obtained in the NOJ of 2018, 2019 and 2020. The selection method used to choose the participants of the second round of the Physics Olympiad is to invite the students who obtained the Top 200 scores during the first round of the Olympiad. This selection method was used for the 2018 and 2019 Olympiads and the years before that. Since, the system has changed with the goal of including more girls in the second round of the Physics Olympiad. This new system consists of inviting the best girl and boy from every participating school and completing the available spots with students who obtained top scores in the first round. This system is being put in place in 2021 for the first time, as the second round of the 2020 Physics Olympiad was cancelled due to COVID-19.

The data

The data used for this analysis was obtained by collecting the scores of all participants over the past three years. This set of data includes the names, genders, class, school and scores of the participants.

In 2018, a total of 2708 students participated to the first round of the NOJ, of which 34% are boys, 33% are girls and 34% have an unknown gender. In the second round, 105 students

participated, including 14 girls, 71 boys and 20 students of unknown gender. This shows a clear decrease in the proportional number of girls in the second round.

In 2019, 2606 students participated to the first round, of which 90% have an unknown gender. For this reason, the genders of the participants are assumed based on their first names. It is important to note that this may lead to some errors in the results, as genders are guessed for all gender binary first names. Participants with gender neutral first names are left in the unknown category. The proportions found for the participants of the first round are 47% male, 41% female and 12% of unknown gender. These proportions become 59% male, 19% female and 22% of unknown gender for the 101 participants of the second round.

In 2020, because of COVID19 regulations, there were only 700 participants in the first round, of which 41% are male, 42% are female and 17% have an unknown gender. The genders for this set of data are also assumed, based on the participants' first names, as the initial data did not include the gender of the participants. There was no second round of the NOJ this year.

The procedure

In this research, an analysis of how the previous system had an impact on the number of female participants in the second round of the Physics Olympiad is conducted. This is then compared with the new selection method and the differences in gender gap in both cases will be studied. This is done to assess whether the new selection method is appropriate and can decrease the gender gap in the Physics Olympiad. Lastly, a third selection method is proposed and analysed. This method would consider the top 400 scores, rather than just the top 200 scores.

The aforementioned data is used for the calculation of the mean and standard deviation of the distribution of the scores obtained in the first round of the NOJ, for all three years. These values are compared for male and female participants. Lastly, the different selection methods are applied to find the proportion of male and female participants which would be selected for the second round of NOJ, for each of the three methods.

PART II: The NOJ experience questionnaire

The second part of the research consists of a questionnaire which aims to assess which societal and psychological factors have an impact on girls' scores in the Physics Olympiad. The answers to the questionnaire are analysed with the aim of answering the research sub-question:

What different factors affect girls' and boys' attitudes towards the Physics Olympiad?

The participants

The targeted participants for this section of the research includes present and past participants of the NOJ. The questionnaire is therefore sent to the schools who often participate to the NOJ and to the physics teachers in those schools. The questionnaire is then transferred to the students and a total of 49 participants completed the questionnaire, of which 27 are girls, 21 are boys and 1 is of unknown gender. This is quite a low number of responses, relative to the large number of participants to the NOJ.

The questionnaire

In order to encourage as many students as possible to complete the questionnaire, the questions are kept short, and the full questionnaire takes approximately 5 minutes to complete. For this same reason, the questionnaire mainly contains multiple choice questions, some statements to rate on a 5-point Likert scale and a few short open questions. The full questionnaire can be found in the Appendix.

The questionnaire is split into three sections, the first one focusing on the Physics Olympiad experience, the second, on motivation, and the third, on personality traits. Some initial questions regarding gender and age are also asked at the beginning of the questionnaire. This is mainly done to help organise and sort the collected answers, as gender is one crucial variable to analyse, and age will give us an idea of the school year and year of participation in the NOJ. The choice of the questions and creation of the questionnaire was made after a literature analysis of previous research on the gender gap in science.

The first section of the questionnaire focuses on the Physics Olympiad experience itself. In the first instance, some questions are asked to try to understand the specific trajectory of the person answering the questions: their score, which year and which rounds they participated in and the basic reason for their participation. This allows for a better understanding of the context of this person's experience and can be used to classify the rest of the data. In the second instance, the questions aim at identifying factors specific to the NOJ environment and experience which may have influenced the participants' performance such as their emotional state and preferences during the NOJ. This is also done to investigate the impact of the environment on the students' performance.

The second section of the questionnaire aims at measuring the students' motivation towards the NOJ. Motivation is quite a complicated construct, and even more complicated to measure.

Previous questionnaires such as the Science Motivation Questionnaire II (SMQ-II) (Glynn, 2011) and the Student Motivation Towards Science Learning Questionnaire (SMTSL) (Tuan et al., 2005) are used as a base to create this portion of the questionnaire. By combining the motivation factors used in both questionnaires and selecting the ones that apply to the NOJ context best, six scales are chosen to measure motivation: intrinsic motivation, self-efficacy, self-determination, grade motivation, career motivation and learning environment stimulation (Glynn, 2011; Tuan et al., 2005). Two to three statements are selected for each scale, modified to fit the context of the NOJ and arranged as a Likert scale questionnaire. The choice of multiple statements per scale was made to improve the reliability of the data collection.

The third section of the questionnaire aims at identifying personality traits which may influence the NOJ results. Previous research finds that traits such as competitiveness, level of self-direction and level of extroversion play a role in determining students' willingness to study post-compulsory Physics (Mujtaba & Reiss, 2014). This section aims at investigating whether these personality traits could also play a role in students' willingness to participate to the NOJ or even on their performance during the NOJ. This portion of the questionnaire is based on the Understanding Participation rates in post-16 Mathematics and Physics (UPMAP) survey used for year 8 as this the closest to the target group's age (Institute of Education, 2008). Three to four statements are chosen for each of the three selected personality traits and arranged as a Likert scale questionnaire, keeping enough statements to ensure consistency, while remaining short enough to encourage participants to complete the questionnaire in full.

The procedure

After completion of the questionnaires, the answers are collected and sorted in preparation for a statistical analysis.

The answers to the first section of the questionnaire are mainly categorical variables, whether they be from multiple choice questions or from open questions. When few answers are given for a specific question, the answers are analysed qualitatively. When more are given, the answers to open questions are categorised using open coding in order to facilitate further analysis.

Various hypotheses are then stated, each exploring the relation between the different variables and gender. Examples of hypotheses include:

Gender affects participants' mood during the NOJ.

Gender affects participants' initial reason for participating to the NOJ.

Gender affects participants' preference of location for the NOJ.

Gender affects participants' goal when participating in the NOJ.

These hypotheses are then tested statistically, using Pearson Chi-square tests.

The answers to the second and third sections of the questionnaire are in the form of Likert-scale scores. The answers are translated to numerical values and then added for each measurable variable: intrinsic motivation, self-efficacy, self-determination, grade motivation, career motivation and learning environment stimulation for the motivation section; and competitiveness, self-direction and extroversion for the personality-traits section.

Similar hypotheses are stated, exploring the relation between gender and the variables listed. As these variables are measured on a continuous scale, the hypotheses are tested using independent-samples t-tests.

RESULTS

PART I: Scores and selection methods

The NOJ scores

First, for each set of scores of the first rounds of the NOJ, for the years 2018 to 2020, the mean and standard deviation were calculated for male and female participants. These can be found in Table 1.

Table 1

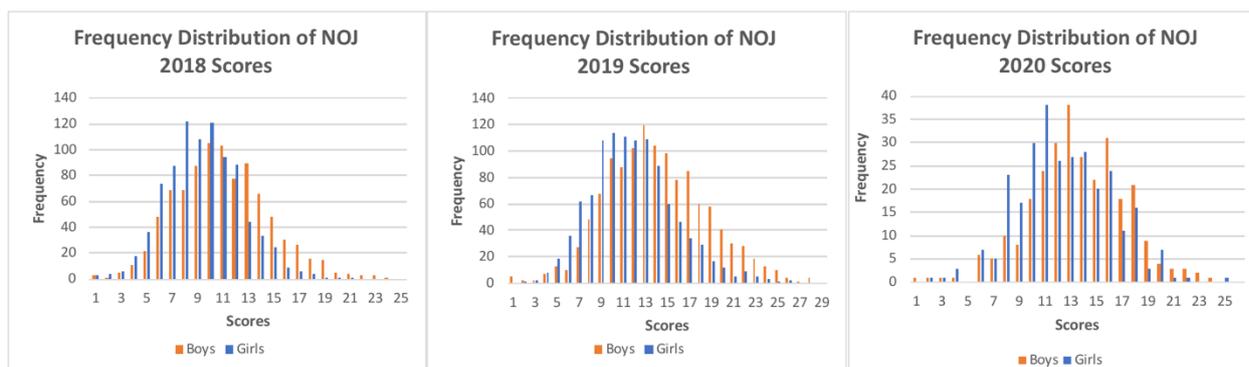
Data NOJ round 1

	2018			2019			2020		
	Gender ratio (%)	M (%)	SD	Gender ratio (%)	M (%)	SD	Gender ratio (%)	M (%)	SD
Total	100	33	3.5	100	40	4.4	100	43	4
Female	33	32	3.0	41	37	3.8	42	42	3.7
Male	34	37	3.7	47	43	4.6	41	45	4
Unknown	34	35	3.5	12	40	4.8	17	42	4.3

From this first table, it can be seen that, for each of the three years that are analysed, the mean score for girls is slightly lower than the mean score for boys. It can also be noted that the standard deviation is higher for boys than girls in all three years. This can also be seen in the frequency distribution graphs of the scores. These were plotted for the first round of each of these years, both for girls and boys. They can be seen in Figure 1.

Figure 1

Frequency Distributions of NOJ round 1 scores



By analysing these graphs, it can be noted that more female participants tend to obtain scores close to the mean score and that more male participants obtained high scores, for example, noticeably fewer girls obtained scores over 15/30 in 2019. The distribution of scores for boys is a lot more spread out than for girls in the cases of 2018 and 2019. Not only is the average higher for boys, but the distribution for boys is flatter than for women (see Figure 1), leaving much of the top scores to the boys. It can also be seen from the 2018 and 2019 graphs that the gender gap widens for higher scores.

The distribution graph for the 2020 NOJ is slightly different to the distribution graphs of previous years. Indeed, the difference between male and female participants' scores distributions is not as noticeable in the graph and the standard deviations for girls and for boys are closer to each other.

The NOJ selection methods

The second part of this NOJ scores analysis is a comparison between three different methods for the selection of the second-round participants. The first method consists of selecting the students who obtained the top 200 scores in the first round. The second method consists of picking the top scoring boy and girl from each school and then filling out the remaining spots

with the best scoring students. The third method consists of selecting the top 400 scoring students, as a way of including more female participants who may not have obtained top scores.

Two other selection methods were considered for this comparison. The first one would be to select the top scoring boy and girl from each participating class, as this may become the selection method in future years. However, data relating to students' classes was not available, making this analysis impossible. The second method was based on the top 400 selection method. It would consist of selecting 200 of the top 400 students, while trying to keep the proportions as gender equal as possible. For example, in 2018, one could select 70 girls, 76 boys and 54 of unknown gender. These numbers were calculated by keeping a maximum number of girls and then keeping the male-to-unknown ratio constant. One issue with this method is that it may lead to protests of unfair selection, positive discrimination and gender-bias towards boys. The hypothetical number of selected boys and girls for each of the three chosen selection methods were calculated and can be seen in Table 2.

Table 2.

Comparison of three selection methods for the second round of NOJ

	2018			2019			2020		
	Top 200	Best per school	Top 400	Top 200	Best per school	Top 400	Top 200	Best per school	Top 400
Total	200	200	400	200	200	400	200	200	400
Female	29	47	70	37	52	81	77	75	147
Male	105	111	192	142	127	267	93	95	189
Unknown	66	42	138	21	21	52	30	30	64

For 2018, the “best per school” method yielded the best results, with a selection of 55.5% boys, 23.5% girls and 21% of unknown gender. Although this gender gap is still significant, it is an improvement to the 13.3% of actual female participants in the second round.

For 2019, it is also the “best per school” method which led to the most gender balanced pool of participants. The participants invited to the second round would be composed of 63.5% boys, 26% girls and 10.5% of unknown gender. This is also an improvement compared with the real situation, yet 26% of girls is still quite a small amount.

In 2020, the best results were obtained with the top 200 selection method. The participants selected would have been 46.5% boys, 38.5% girls and 15% of unknown gender. This is the

most balanced selection of all, and this makes sense as 2020 was the year with the most similar distributions of scores for boys and girls.

The second round of the NOJ

Lastly, a comparison between these hypothetical selections and the actual number of round 2 participants was made. Since there was no round 2 in 2020, this comparison is only made for 2018 and 2019. For these years, the Top 200 selection method was used. The proportions of participants for round 1, the top 200 selection method and the actual round 2 participants are listed in Table 3.

Table 3

NOJ Participants in 2018 and 2019

	2018			2019		
	Round 1	Top 200	Round 2	Round 1	Top 200	Round 2
Total	2708	200	105	2606	200	101
Female	887	29	14	1059	37	19
Male	911	105	71	1223	142	60
Unknown	910	66	20	324	21	22

From Table 3, we can see that, in 2018, only 105 students actually participated in the second round, which is 52.5% of the invited 200. Indeed, 14 girls participated, out of the predicted 29, and 71 boys out of the predicted 105. This is equivalent to only 48% of the predicted girls, and 68% of the predicted boys. In 2019, 101 attended the second round, which is 50.5% of the total invited. These 101 are composed of 19 girls, 59 boys and 22 of unknown gender. This means that, from the total amount of invited participants, only 51.4% of the girls and 41.5% of the boys attended the second round. Contrary 2018, the difference between the predicted and actual participants is more important for the boys in this case.

PART II: Answers to the questionnaires

As the questionnaire is designed in three sections, the answers to these sections are analysed in three parts.

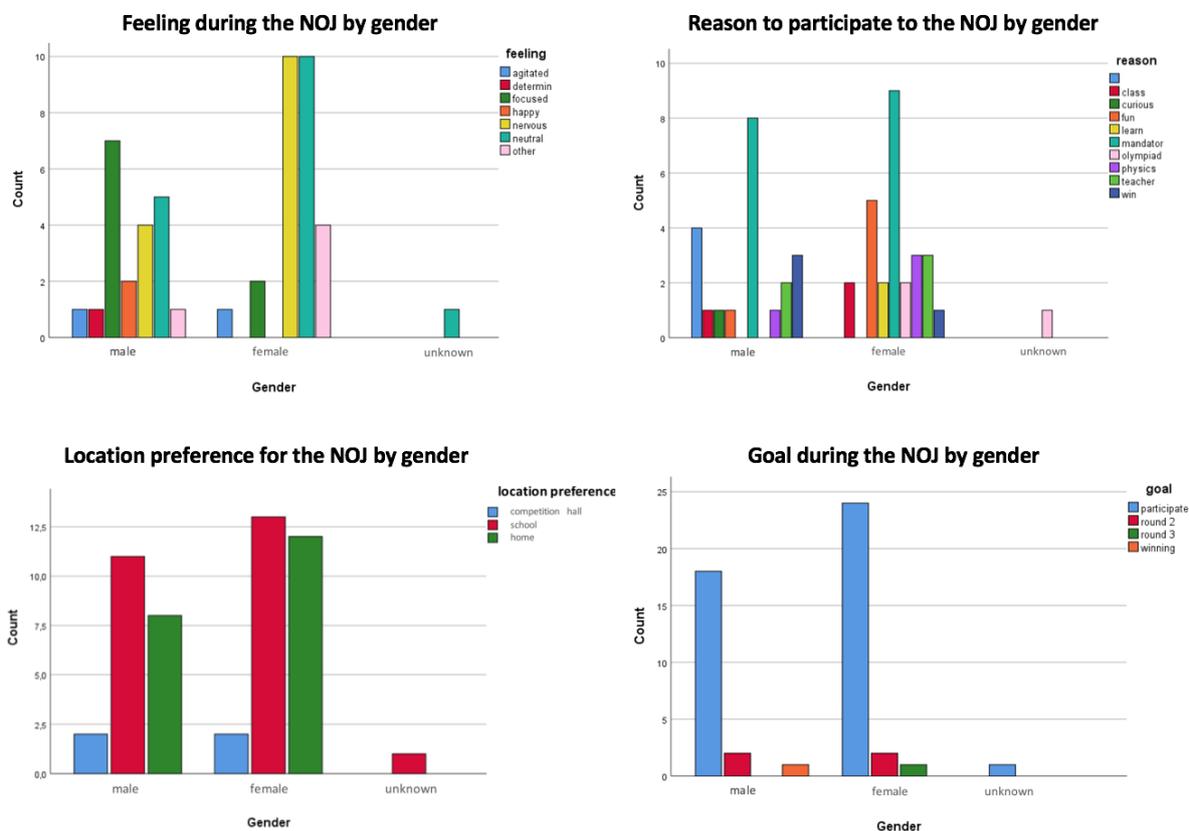
The NOJ experience

The first part includes the answers to the first section of the questionnaire, about the NOJ experience. Let us first note that questions such as “What score did you obtain in Round 1 of

the NOJ?” and “Why did/didn’t you participate to the second round of the NOJ?” yielded very few answers. Most students stated that they did not remember their score in the first round in the NOJ and most students were not invited to the second round of the NOJ. The answers to this last question were therefore analysed quantitatively and only one participant was invited to the second round but did not participate. This was the case of a female participant who justified her choice by stating that second round participation was not mandatory. On the other hand, most students who were invited did accept and they indicate that they did so because it was either fun, a good challenge or because they were excited for the practical activity in round 2.

Figure 2

Bar charts of the answers given to section 1 of the questionnaire by gender.



Note. The first graph represents the answers to the question “Which word would best describe your mood when you participated in the NOJ?”. The second graph represents the answers to the question “Why did you participate to the NOJ?”. The third graph represents the answers to the question “Where do you prefer taking the NOJ test?”. The fourth graph represents the answers to the question “What was your goal in the NOJ?”.

The more complete sets of answers are analysed statistically to test the different hypotheses, by use of Pearson Chi-square tests and some results can be seen in Figure 2.

The graphs shown in Figure 2 show that the two answers to the questions about feelings during the NOJ and reasons for participating are quite different between boys and girls, whereas the two other questions yielded similar responses for boys and girls. The first graph in Figure 2 shows that more girls stated they felt nervous during the NOJ and more boys stated they felt focused. The second graph in Figure 2 shows that more girls stated that their reason for participating in the NOJ was because it was fun or because they enjoyed physics compared to boys. However, only one of these results was found to be statistically significant. Indeed, there was a significant effect of gender on the reasons for participating to the NOJ at the $p < .05$ level [$\chi^2(18, N = 49) = 29.13, p = 0.047$].

Motivation factors

The answers to the second section of the questionnaire are analysed statistically and the results obtained can be seen in Table 4.

Table 4.

Scores and t-tests of answers on motivation factors by gender

Variable	Girls (n = 27)		Boys (n = 21)		t-test
	M	SD	M	SD	
Intrinsic motivation	6.52	1.50	6.48	2.06	0.82
Self-efficacy	5.11	1.42	6.19	1.75	2.36*
Self-determination	4.67	1.47	4.00	1.48	1.55
Grade motivation	4.48	1.60	4.33	1.71	0.31
Career motivation	4.48	1.53	4.71	1.77	0.49
Environment stimulation	4.99	1.87	5.33	1.26	0.73

* $p < .05$

The results in Table 4 show that, for most motivation factors, boys and girls obtained similar scores on average. This is confirmed by independent-samples t-tests which find that, for most motivation factors, the effect of gender is insignificant.

However, there is a significant difference in the scores for girls' self-efficacy and boys' self-efficacy at the $p < .05$ level [$t(46) = 2.357, p = 0.023$].

Personality traits

The answers to the third section of the questionnaire are analysed statistically and the results obtained can be seen in Table 5.

Table 5.

Mean scores of answers on personality traits by gender

Variable	Girls (N = 27)		Boys (N = 21)		t-tests
	M	SD	M	SD	
Extroversion	9.07	2.62	9.05	3.01	0.03
Competitiveness	11.78	1.40	12.57	2.70	1.32
Self-direction	9.59	1.89	10.43	2.36	1.37

Independent-samples t-tests were run to determine if there is a difference in personality traits for boys and for girls and there was no significant difference found in the results, in all three personality trait scales.

DISCUSSION

The goal of this research project is to determine the organisational, sociological and psychological factors which may cause the gender gap in the scores of the NOJ and the low proportional number of female participants in the second round of the NOJ. The goal is that, by identifying these factors, we can gain a better understanding of the reasons for the issue of the gender gap in the NOJ. Once these causes are clear, it will be easier to further research opportunities for bettering the situation and tackle the problem at its root. This is a relevant issue, as it affects all the girls that may be facing barriers to studying physics. Furthermore, in the case of gender discrimination, it is important to identify the issue quickly and stop it before it affects any more people.

Conclusions

The first focus is to identify organisational factors which are specific to the Dutch Physics Olympiad organisation, and to answer the first research sub-question:

a) How do different selection methods affect the gender balance of participants in the second round of the NOJ?

This is done by analysing past scores of the NOJ and comparing different selection methods for the second round of the NOJ. The first result is that the frequency distributions of the NOJ scores are very different for boys and girls in 2018 and 2019 (see Figure 1). They show that top scores are more likely to be obtained by boys and may explain why more boys are selected for the second round of the NOJ. Similar results were also obtained by Iriberry and Rey-Biel (2019) in their analysis of frequency distributions of scores from a mathematics competition. They explain this by a difference in self-confidence and risk aversion between genders, stating that boys tend to be more confident and more likely to take risks than girls in such competitions (Iriberry & Rey-Biel, 2019).

In 2020 however, the frequency distributions of scores for girls and boys were a lot more similar. It is important to note that, because of the COVID-19 pandemic, the total number of participants was much smaller in 2020 than in previous years. The context of the first round of the NOJ was also different in 2020 compared with other years, as the students would participate online from home rather than from school. This difference in environment may explain this change in scores distributions. This explanation is in line with the conclusions of Iriberry and Rey-Biel (2019) that girls are more negatively affected by competitive environments. In 2020, not only was the environment more familiar to the students as they could participate from home, but the competitive pressure may have been decreased by the fact that there were fewer participants and therefore, fewer competitors to beat. Indeed, Iriberry and Rey-Biel (2019) find that girls tend to feel less competitive pressure when there are fewer competitors, and that they feel even more comfortable when competing with other girls rather than with boys. This may spark the idea of having separate competitions for boys and girls, which can be another option to explore in the future.

The comparison of selection methods for the second round of the NOJ reveals that, for both 2018 and 2019, the method yielding the most gender balanced selection for the second round is the “best boy and girl per school” method. However, it is crucial to note that this method solely depends on the number of participating schools. In 2020, for example, only 14 schools participated to the NOJ, because of COVID-19. This means that, for that year, there is no advantage to this selection method. Another selection method which was mentioned is the “best boy and girl per class” method. Although this method was not analysed because of lacking data, by extending the conclusions on the “best boy and girl per school”, it can be suspected that this method may lead to more inclusive results. Further research on this selection method should be conducted, especially as this may be the selection method used by the NOJ in future

years. It is also important to consider that, any inclusive selection method which favours gender balance over the achievement of top scores may lead to criticism against positive discrimination. Furthermore, it is crucial that this method also be adapted to gender non-binary students, to avoid discrimination against them or any other gender identities.

The second focus is to understand how girls' and boys' experience, motivation and personality traits differ from each other and how they may affect their performance in the NOJ and to answer the second research question:

b) What different factors affect girls' and boys' attitudes towards the NOJ?

In this portion of the research, the first main result obtained is that girls' and boys' initial reason or motivation to participate to the NOJ are significantly different. In the questionnaire, more girls stated that their initial motivation to participate to the NOJ is to have fun, to learn or just because they enjoy physics. In contrast with this, more boys stated that their initial motivation was because they thought they had a chance of winning. Although it is difficult to draw a clear conclusion from these answers, they can be related to the idea of boys having a higher sense of self-concept and more confidence in their own ability to succeed in physics competitions.

This idea is also found in the results of the motivation section of the questionnaire, which conclude that girls have a significantly lower sense of self-efficacy than boys. Additionally, this reason can be found in previous research on the issue of the gender gap in science competitions (Di Tommaso et al., 2018; Steegh et al., 2019; Halpern et al., 2007). Many reasons are given for the difference in self-efficacy and self-concept between boys and girls, including the gender stereotypes that girls are less capable than boys in physics (Steegh et al., 2019) and the influence of expectations and beliefs of a students' surroundings (Halpern et al., 2007). According to Ryan and Deci (2000), self-concept and self-efficacy are also important in building intrinsic motivation, which can in turn affect performance. This may be an explanation of how these factors can affect girls' and boys' scores in the NOJ. Ryan and Deci (2000) also state that intrinsic motivation is crucial, not only for improving performance but also for building self-confidence and general well-being. This shows how crucial developing girls' sense of self-efficacy is, in decreasing the gender gap in the NOJ.

Limitations

Considering these conclusions, it is also important to note the various limitations to this study. Indeed, this research was conducted specifically for the Dutch Junior Physics Olympiad, and

the conclusions are limited to the country and age group of the participants. Further research is needed before applying these same conclusions to any other physics competitions.

It is also important to note that, in the NOJ, most participating schools make participation to the first round mandatory for the whole class. This may differ in other countries, where participation is a free choice, which may lead to different proportions in the first round of physics competitions. In those cases, motivation for signing up would have to be investigated and an analysis of the gender ratio in the first round would have to be conducted.

Other limitations of this study include the low number of participants to complete the questionnaire and the simplification of the questionnaire. When creating the questionnaires, some questions were deleted from the original questionnaires that were used as reference. This was done to keep the questionnaire short, so as to encourage as many students to complete it. Because of this, the results may include some errors and a study involving a more complete questionnaire may lead to more reliable results. Unfortunately, even with this short questionnaire, many schools decided not to participate to the study, as they had limited time due to COVID-19.

Lastly, as mentioned in the methods section, the genders of past participants of the NOJ were assumed in some of the data sets. This may lead to slight errors in the results. This may be avoided in the future if more consideration is taken for recording the gender of participants during the NOJ.

Suggestions

In the future, more research should be conducted to see if these conclusions are applicable, for example, to the upper-secondary Physics Olympiad (BOJ). Research should also be conducted to analyse the actual effects of different selection methods on the gender balance of the second round participants of the NOJ. From this study, the recommended selection method is to invite the best boy and girl from each classroom to the second round. If this method is used in the future, an analysis of how it affects the gender gap in practice should be made.

In addition to this, this research suggests that, by increasing girls' sense of self-efficacy, the gender gap may be decreased. Recommendations for the NOJ organisation, as well as for teachers and parents of girls, include trying to build up their self-confidence and belief in their own abilities. This may be done through encouragement, exposure to female representation in Physics, by believing in them, or simply by rejecting damaging gender stereotypes.

Furthermore, more research could analyse which parallels could be drawn for issues of gender gap in other fields such as Computer Science or Engineering. Another parallel which may be drawn in further research is the issue of the lack of women of colour in science, or the barriers related to ethnicity or religious backgrounds (Avraamidou, 2019). Hopefully, this can shed some light on the issues that women from various backgrounds face in many scientific fields and contribute to solving these issues.

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APPENDIX: Questionnaires

(English version) Understanding the gender gap in the Physics Olympiads

This questionnaire aims at understanding the Dutch Physics Olympiad's (NOJ) participant's attitudes, motivation and personalities. Please answer the following questions as truthfully as possible, with your NOJ experience in mind.

General Information

How old are you? (*open*)

What is your gender? (*MCQ: male, female, other/rather not say*)

Section 1: The Physics Olympiad

When did you participate in the NOJ? (*MCQ: 2018, 2019, 2020, 2021*)

Why did you participate to the NOJ? (*open*)

What round(s) did you participate in? (*MCQ: Round 1, Rounds 1+2, Rounds 1+2+3*)

What score did you obtain in Round 1 of the NOJ? (*MCQ: Number from 1 to 30*)

What is/was your goal in the NOJ? (*MCQ: participating, getting to round 2, getting to round 3, winning the NOJ*)

Were you invited to the second round of the NOJ? (*MCQ: Yes, No*)

If yes: did you participate? (*MCQ: Yes, No*)

Why? Why not? (*open*)

Where do you prefer taking the NOJ test? (*MCQ: at home, in school, at the competition site*)

Which word would best describe your mood when you participated in the NOJ? (*MCQ: determined, excited, nervous, neutral, scared, focused, happy, other (open)*)

Section 2: Motivation

The following statements aim at understanding your motivation. Please respond to each of them with your NOJ experience in mind. (*each statement will be followed by a 5-point Likert scale, from “strongly disagree” to “strongly agree”*)

A. Intrinsic motivation

1. I think that participating to the NOJ will help me get better in physics.
2. I enjoy participating in physics competitions.

B. Self-efficacy

3. Whether the NOJ questions are difficult or easy, I am sure that I can understand them.
4. I am confident that I can do well in the first round of the NOJ.

C. Self-determination

5. I put effort and study(ied) hard to prepare for the NOJ.
6. When the NOJ questions are too difficult, I give up or only do the easy parts. (-)

D. Grade motivation

7. Getting to the second round of the NOJ matters to me.

8. Getting a good result in the NOJ is important to my parents/family.

E. Career motivation

9. Participating to the NOJ will help me get a good job.

10. Having the NOJ experience will benefit me in my career.

F. Learning environment stimulation

11. I am/was willing to participate to the NOJ because my teacher encourages me to.

12. I am/was willing to participate to the NOJ because my family encourages me to.

13. I am/was willing to participate to the NOJ because I feel pressure from other people.

Section 3: Personality traits

The following statements describe different personality traits. Please respond to each of them as truthfully as possible. *(each statement will be followed by a 5-point Likert scale, from “strongly disagree” to “strongly agree”)*

Extroversion:

1. I feel comfortable around people.

2. I don't like to draw attention to myself. (-)

3. I start conversations easily.

Competitive:

4. I like to challenge myself.

5. I think it is more important to participate than to win. (-)

6. I want to be successful, even if it's at the expense of others.

7. I can easily get stressed when competing with others. (-)

Self-direction:

8. When I make plans, I am almost certain to make them work.

9. When I get what I want, it's usually because I worked hard for it.

10. I am sure of myself.

The questionnaire can be found using this link:

<https://forms.office.com/Pages/ResponsePage.aspx?id=oFgn10akD06gqkv5WkoQ52uZoD54Vc5IqBX8ZIadTKVUOFIzTDIDNjRQMUJaVDcwU01EQkdBVTVMWi4u>

(Dutch version) Studie en analyse van de genderkloof in de natuurkunde-olympiade

Deze vragenlijst dient om inzicht te krijgen in de attitudes van de deelnemers aan de Nederlandse Natuurkunde Olympiade (NOJ), met een bijzondere focus op houding, motivatie en persoonlijkheid. Beantwoord de volgende vragen zo nauwkeurig mogelijk, rekening houdend met je NOJ-ervaring.

Algemene Informatie

Hoe oud ben je? (*Open vraag*)

Wat is je geslacht? (*Meerkeuze vraag: jongen, meisje, anders, wil ik niet zeggen/liever niet weergeven*)

Sectie 1: De Olympiade

Wanneer heb je aan de NOJ deelgenomen? (*Meerkeuze vraag: 2018, 2019, 2020, 2021*)

Waarom heb je aan de NOJ deelgenomen? (*Open vraag*)

Aan welke ronde(s) heb je deelgenomen? (*Meerkeuze vraag: Ronde 1, Ronde 1+2, Ronde 1+2+3*)

Welk resultaat heb je behaald in ronde 1 van de NOJ? (*Open vraag*)

Heb je een uitnodiging ontvangen voor de tweede ronde van de NOJ? (*Meerkeuze vraag: Ja, Nee*)

Zo ja, heb je deelgenomen aan de tweede ronde? (*Meerkeuze vraag: Ja, Nee*)

Waarom heb je deelgenomen? Waarom heb je niet deelgenomen? (*Open vraag*)

Waar leg je het liefst de NOJ-test af? (*Meerkeuze vraag: thuis, op school, in een wedstrijdzaal*)

Wat is/was je doel bij de deelname aan de NOJ? (*Meerkeuze vraag: deelname, ronde 2 bereiken, ronde 3 bereiken, het winnen van de NOJ*)

Welk woord beschrijft het best je stemming bij de deelname aan de NOJ? (*Meerkeuze vraag: vastberaden, opgewonden, nerveus, neutraal, bang, gefocust, gelukkig, andere*)

Sectie 2: Motivatie

De volgende uitspraken dienen om je motivatie te begrijpen. Geef op elke vraag het antwoord dat het best past bij je persoonlijke ervaring.

1. Ik ben van mening dat deelname aan de NOJ mij zal helpen om beter te worden in natuurkunde.

2. Ik doe graag mee aan natuurkundewedstrijden..
3. Hoe moeilijk de vragen ook zijn, ik weet zeker dat ik ze kan begrijpen.
4. Ik had er vertrouwen in dat ik goed kan presteren in de eerste ronde van de NOJ.
5. Ik heb veel moeite gedaan om me goed voor te bereiden voor de NOJ.
6. Als de vragen te moeilijk zijn focus ik me alleen op de makkelijke onderdelen.
7. Doorgaan naar de tweede ronde is belangrijk voor mij.
8. Een goed resultaat behalen is belangrijk voor mijn ouders en familie.
9. Door mee te doen aan de NOJ kan ik aan een goede baan komen.
10. Mijn ervaring met de NOJ zal me later helpen in mijn carrière.
11. Ik was bereid deel te nemen aan de NOJ doordat mijn leraar mij aanmoedigde.
12. Ik was bereid deel te nemen aan de NOJ doordat mijn familie mij aanmoedigde.
13. Ik was bereid deel te nemen aan de NOJ door druk van andere mensen.

Sectie 3: Karaktereigenschappen

De volgende uitspraken dienen beschrijven enkele karaktereigenschappen. Gelieve op elk een zo nauwkeurig mogelijk antwoord te geven.

1. Ik voel me op mijn gemak rond andere mensen.
2. Ik hou er niet van om de aandacht te trekken.
3. Ik begin gemakkelijk een gesprek.
4. Ik daag mezelf graag uit.
5. Aan iets meedoen is voor mij belangrijker dan winnen.
6. Ik zou graag succesvol willen zijn, al is dit ten nadele van anderen.
7. Ik kan gemakkelijk gestrest raken in een competitieve omgeving.
8. Ik ben er bijna zeker van dat ik al mijn plannen uit zal voeren.
9. Als ik krijg wat ik wil, is dat meestal omdat ik er hard voor heb gewerkt.
10. Ik ben zelfverzekerd.

The questionnaire can be found using this link:

<https://forms.office.com/Pages/ResponsePage.aspx?id=oFgn10akD06gqkv5WkoQ52uZoD54Vc5IqBX8ZIadTKVURDINOUBMTFTNDhUU1NUNE85MUIyRlgxNC4u>