The German Physics Olympiad—identifying and inspiring talents

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The German Physics Olympiad—identifying and inspiring talents

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Abstract
Student competitions can act as potent enrichment measures and complement formal schooling in fostering students’ motivation as well as promoting their skills. This article presents the German Physics Olympiad, the national precursor to the International Physics Olympiad, in the general context of student competitions in Germany and its integration with the so called Science Olympiads in Germany. To put the German Physics Olympiad into an international context its structure and some of its features are compared with data on Physics Olympiads in other countries. As an outlook we elaborate on some of the challenges the Physics Olympiad in Germany is facing and present two research projects that further support the development of the competition.

Keywords: Physics Olympiad, German Physics Olympiad, talents, Science Olympiads, student competitions, gifted education

(Some figures may appear in colour only in the online journal)

1. Introduction—competitions as potent enrichment measures

It is often proclaimed that the development of modern societies largely depends on people’s knowledge potential, in particular in the field of science, technology, engineering and mathematics—or STEM for short [1, 2]. The promotion of students’ interest and skills is therefore of particular importance to lead them to a future career choice in this field. Empirical findings, though, provide a rather sceptical view on the success of this endeavour. The
existing knowledge potential still remains largely untapped [3] and also those students that exhibit high potential in science and mathematics often divert their professional interest away from STEM subjects [4]. These findings necessitate additional efforts to counteract the precarious situation in STEM.

School itself is limited in the time it can devote to single subjects and thus in the depth of content it can achieve. Schools therefore often fall short when it comes to fostering talented students [5]. In effort to support STEM education a plethora of so called enrichment measures have therefore been initiated over the last decades. These aim at interesting students in the field of STEM, at developing their skills and abilities and at sustaining this motivation in order to influence future career choices [6]. Enrichment measures come in a large variety such as extra classes and workshops (in-school activities) or out-of-school laboratories, science camps and competitions (out-of-school activities). Consequently, they target different groups and pursue different aims. The, often positive, effects of enrichment measures on cognitive abilities are well documented (e.g. [7–10]). Empirical evidence on effects in the affective domain that describes students’ attitudes is less conclusive, though [11–13]. Nevertheless, enrichment activities are seen as very promising measures in terms of promoting talented students.

A special type of enrichment are student competitions that provide opportunities to evaluate one’s performance and compare it with others [14]. Despite this obviously competitive nature, competitions also support nurturing students’ interests and abilities [15]. The objectives of competitions are therefore usually twofold: on the one hand, they aim to identify talented students and to further develop their skills. On the other hand, they seek to arouse interest in students and to sustain a long-term engagement in the area under consideration. This interplay between cognitive and affective objectives forms the basis of the majority of student competitions. Student competitions in the STEM areas have been found to be especially effective when it comes to influencing later career choices. Successful participants in STEM competitions are far more likely to take up a study in a STEM subject than their peers and show above average accomplishments [10, 16–22]. Student competitions in the field of STEM can therefore be considered as a potent enrichment measure that complements formal schooling in fostering students’ motivation as well as promoting their skills.

2. Finding the way out of a labyrinth—student competitions in Germany

In the preceding section we argued that student competitions foster and challenge students’ interest and talent. They thus form a valuable supplement to school activities. But for those who seek to engage themselves in competitions, difficult decisions await. Students, teachers, parents and schools have to find a competition that fits to their interests and goals. In Germany alone, there are more than 400 activities that address themselves as competitions. Even if one deducts activities that primarily serve the purpose of promoting a certain company or initiative, roughly 150–200 competitions remain. Finding the right competition can therefore be a difficult task in itself. A pragmatic approach for those seeking orientation is to try and classify competitions according to certain characteristic features. Table 1 provides a non-exhaustive overview of such features that can be used for rough orientation.

This checklist might provide some initial guidance in the labyrinth of student competitions. But it is based on superficial features of competitions that do not easily allow assessing the quality of competitions.

To this end the main authority for schools in Germany, the Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany
KMK, compiled a set of criteria competitions should meet in order to be considered pedagogically valuable competitions [24]. According to these criteria, a ‘good’ competition should put the participants at the focus of its activities. It should therefore …

* … nurture students’ individual potential and interests regardless of success.
* … incite innovative teaching and learning thus furthering teachers’ professional development.
* … stimulate students’ and teachers’ commitment and establish a culture of recognition for this dedication.
* … facilitate educational aims of schools and trigger processes to improve quality of schooling.

These aspects address the pedagogical and educational aims of competitions. In addition to the above criteria, the KMK document [24] also gives concise recommendations regarding the organisation of ‘good’ competitions. The document is supplemented by a list of competitions on a national level in Germany that are endorsed by the KMK. This framework sets the stage for the activities of many student competitions in Germany.

### 3. Science Olympiads—internationally and in Germany

#### 3.1. International Olympiads in STEM subjects

The International Olympiads in Mathematics (IMO), Physics (IPhO), Chemistry (IChO), Informatics (IOI) and Biology (IBO) as well as the International Junior Science Olympiad (IJSO) are prestigious annual competitions in which students from all over the world take part and, similar to the Olympic Games in Sports, strive for Olympic medals. During the Olympiads the participants solve challenging theoretical and, in most cases, also experimental tasks. The number of participating countries ranges from around 50 (IJSO) to more than 100 in the IMO. The national delegations are selected by means of national selection procedures that vary widely from country to country but also from competition to competition. In the following we will elaborate on the national Science Olympiads in Germany and elucidate how the German IPhO-selection procedure is tied in with these.

Before going into detail it is important to note that the International Olympiads each target a small number of exceptional students and focus on their (individual) performance.
The nurturing of interest and skills naturally plays a rather marginal role during the competition. The students are already enthusiastic about STEM and, since the training takes place prior to the competition, they line up for the Olympiads already well prepared. The situation is somewhat different in the national precursors in Germany and probably in most other countries. Here, components of performance assessment and training as well as the objectives of identifying the best students versus interesting a larger number of students in STEM subjects are intimately connected to each other.

3.2. The German Science Olympiads

Germany’s participation in the above mentioned Olympiads is largely funded by the Federal Ministry for Education and Research. The practical organisation of the national selection procedures, though, is in the hand of different organisations. The Leibniz Institute for Science and Mathematics Education at Kiel University (IPN) is responsible for the national competitions leading to the IBO, IChO, IPhO and the IJSO. Furthermore, the IPN organises the BundesUmweltWettbewerb (BUW), an environmental project competition, and the national qualifying competition for the European Union Science Olympiad (EUSO). At the EUSO students up to the age of 17 participate in teams of three to solve interdisciplinary, practical problems (see [25] for further details).

Together, these six national competitions comprise the so called Science Olympiads in Germany. The Science Olympiads are listed as national competitions recommended by the KMK and a central service and transfer activity of the IPN. The initial function of the Science Olympiad was primarily to identify and train the national teams for the ensuing international Olympiads. The achievements of the German students at the international competitions in the last years indicate that the Science Olympiads serve this purpose very well. The vast majority of the members of the national teams received a medal with approximately one third of the students being even awarded a gold medal, ranking them among the top 10% in the respective competition. In addition to focussing on the national teams, the motivation of a much larger group of interested students to develop a sustained motivation in science activities has become of increasing importance for the Science Olympiads in the last years. A strong interconnection between the Science Olympiads yet distinct profiles of each of the

Figure 1. Targeted age groups for the German Science Olympiads. The eligibility for participation is also linked to the class level. The ordering by age therefore only serves as a rough orientation. Note that the BUW is differentiated into two distinct age categories (BUW I & II).
competitions provide favourable conditions for achieving this aim. The difference in the targeted age groups allows for a promotion of students’ interest and skills throughout all of their secondary education (see figure 1).

The candidates for the German EUSO teams, for example, are chosen from successful participants of the national competitions leading to IJSO, IBO, IChO and IPhO. The EUSO thereby acts as an additional incentive for younger students aiming at IBO, IChO or IPhO and also bridges the gap between the IJSO and the subject specific Olympiads. This strategy, together with various other activities aimed at a long term commitment to science effected a strong increase of participations in the Science Olympiads in Germany. From roughly 2500 annual participants in 2005 the number has increased to more than 8000 participants in the Science Olympiads in 2016. A remarkable increase. As a cautionary note, this number should be compared with the number of students attending the highest academic track of secondary education, roughly 3.6 million [26]. This means that approximately only one out of 400 students takes part in the Science Olympiads in Germany. While this figure clearly allows for future improvement the development of the number of participants gives rise to an optimistic look ahead.

In line with the criteria for pedagogically valuable competitions detailed above, the German Science Olympiads not only address individual students. They aim to affect different levels within schools. For the students, the competitions obviously offer challenges and opportunities to be recognised for their efforts and achievements. The activities of the competition also support the building of networks beyond school. Teachers, on the other hand, may use competitions and the accompanying learning materials as individualised learning opportunities for their students that provide incentives for a sustained engagement in science topics. Adequate support and a recognition of teachers’ efforts within the competitions also support their professional development. Schools themselves can use competitions to strengthen their profile [27]. By incorporating competitions into a school culture they
provide supportive conditions for individual development of students and teachers. The Science Olympiads have initiated several activities to facilitate this aspect [28].

The following sections concentrate on the German Physics Olympiad as one of the six German Science Olympiads.

4. The German Physics Olympiad as part of the Science Olympiads in Germany

The national selection procedure for the German teams attending the International Physics Olympiads, the German Physics Olympiad, was devised for the IPhO 1981 and has remained largely unchanged since then. The annual German Physics Olympiad commences at the beginning of April in the year preceding the IPhO and culminates in the international competition in the following year. It consists of four stages and an additional training phase for the team members. The general layout of the competition is depicted in figure 2.

Naturally, the different stages of the competitions have different foci. While the first stage primarily serves the purpose of motivating students to participate in the competition, the subsequent stages put a stronger emphasis on the selective character and the training of the students. This change in character entails a stronger orientation towards the school curricula in the first and a stronger orientation towards the syllabus of the IPhO in the later stages.

4.1. First and second stage of the German Physics Olympiad

At the beginning of the first stage advertisement material is send out to all roughly 4500 public schools in Germany that lead to a university entrance qualification. The material includes general information on the competition and the tasks for the first stage. Interested students and teachers register electronically for participation in the first stage of the competition. During the following months, the students individually work on the given set of tasks at home. Usually four theoretical tasks are provided in the first stage that span a wide range of topics relevant to the IPhO. An additional task, the so called junior challenge, especially addresses the younger candidates of the competition, who are not yet in their final two years at school. This additional task is intended as an opportunity to earn bonus points thus alleviating disadvantages these students might have due to their younger age. As a support to the teachers, we have this year begun to provide additional training material. The teachers may use this material to bridge the gap between contents covered at school and the requirements of the competition. Until the beginning of September, the students hand in their work to their teacher who corrects their solutions and transmits the results to the person responsible for the competition on the level of federal states. Based on these results about 50%–70% of the participating students are invited to take part in the second stage.

In the second stage the students again have to solve tasks individually and at home. The three tasks provided in the second stage are far more advanced than the tasks in the first stage, the level being comparable to the IPhO itself. One of the tasks is an experimental task. The list of material allowed for this experimental task is rather restricted and usually contains almost exclusively things that would be found in the students’ home. The time for working on these tasks is four to six weeks. Due to the possibility of using textbooks and internet resources great care is taken to provide unique tasks to which solutions are not readily found. Due to the high demands of this stage and the given time constraints only about 40%–55% of the students qualified for this stage actually hand in solutions to the tasks. To ensure fairness of the grading process and to improve the validity of assessment each student solution is graded at least twice in the second and all subsequent stages.
The topics for the first and second stage of the competition are chosen in such a way that they are mostly relevant to school but often require a deeper knowledge of the subject. The format of these initial stages with the rather long time for solving the tasks allows the students to get acquainted with topics that are not yet familiar to them. This provides a good preparation for the later stages of the competition.

4.2. Final stages of the German Physics Olympiad and training for the IPhO

The third and the fourth stage of the German Physics Olympiad are organised as one week camps in cooperation with renowned research institutions in Germany. About 50 students are invited to the third and roughly 15 students to the fourth and final stage of selection. As a preparation for the camps the students are provided theoretical tasks. They are encouraged to work on these tasks and to hand in their solutions to receive feedback prior to the camps. During each camp the students take two theoretical and two practical examinations of three to four hours each. The tasks in these stages cover the major areas of the IPhO syllabus [29]. Since many German students have little experience with carrying out experiments, a short training phase is provided at the beginning of the third stage. The change of procedure for the exams between the second and third stage causes a rather low correlation between the results of these stages. From a test theoretical perspective this could be considered problematic. We believe, though, that this disadvantage is balanced by the positive motivational and training effects achieved by the current modus in the first stages. Surveys among former participants support this view. They stress the value of the extended periods available for learning new topics and for solving the tasks in the second stage.

Apart from the examinations the students of the third and fourth stage experience a rich programme of talks, exercises and excursions that allows for exchange among the students but also between the students and researchers at the host institutions. The involvement of former participants of the competition in the correction of the test papers and the supervision of the students furthers this interaction. Meeting one's peers and being in close contact to researchers both act as a valuable source of motivation to the students and are seen as very attractive characteristics of the third and fourth stage.

At the end of the fourth stage, around Easter, the five students for the German IPhO team are selected. They are then provided with additional training opportunities: a voluntary theoretical training with competition tasks of former years via email and a three-day experimental training seminar. Directly prior to the International Physics Olympiad, the team meets with the Danish delegation alternatingly in Germany and Denmark for final preparations. This activity also intends to give the students a first impression of the international atmosphere they encounter at the IPhO.

4.3. Additional information on the German Physics Olympiad

The way of organising the German Physics Olympiad has proven quite successful. This is evidenced on the one hand by the performance of the German students at the International Physics Olympiad. Since the IPhO 1981 German students won 29 gold, 66 silver and 61 bronze medals. 21 students received an honourable mentioning, the fourth award category at the competitions. Only three of the 180 German Olympians in these years did not receive an award. While the results usually do not rank Germany among the top ten nations of the competition the teams usually achieve a placement within the top third of the participating countries. This is a very satisfying result especially if one compares the level and duration of
training with the most successful countries at the IPhO which mostly provide much longer and more intense training.

The other evidence for the success of the German Physics Olympiad is the number of students participating in the competition. This number has increased considerably during the last years (see figure 3) and is this year, for the first time ever, close to a thousand students from about 350 schools. This increase is most likely an effect of strengthened efforts to make the first stage of the competition more accessible and of additional activities to make the competition better known among schools, teachers and students.

5. Tasks in the German Physics Olympiad

At the heart of the International Physics Olympiad are the theoretical and experimental tasks. This also holds true for the German Physics Olympiad, where the tasks serve different purposes: first of all, they are a means of motivating interested students to take part in the competition. They are also required for a differentiated assessment of student performance. Finally, the tasks help students to train their skills and thus prepare for the international competition.

In the following, we present two sample tasks from the German Physics Olympiad—one theoretical and one experimental. For another example of an advanced experimental task see [30]. Additional tasks (in German) are available on the website of the German Physics Olympiad at www.ipho.info.

5.1. Example of a theoretical task—cooling of a whale

One of the tasks set for the first stage of the German Physics Olympiad 2014 concerned the cooling of a stranded whale.
5.1.1. Task. In autumn 2011 a sperm whale stranded at a beach on the island Pellworm. Even though the whale had been dead for several days already, the measured body temperature of the whale on 21 November was 20 °C. Three days later it had sunk to 15 °C. The cooling of an unheated body in air can be modelled by a temperature curve as shown in figure 4. To take into account the different dimensions and temperatures of different bodies the axis need to be scaled appropriately.

Using the given information, make an estimate of the time of death of the sperm whale. Assume that the outside temperature remained constant at around 0 °C during the cooling and that the body temperature at the time of death was 37 °C.

5.1.2. Solution. Several methods are possible for solving this task. One might, for example, use a mathematical formulation of the exponential decay depicted in figure 4. A more direct
approach that involves less mathematics uses a second set of time and temperature axis that are scaled differently (see also the forensic task for the EUSO 2010 in [25] were a similar approach was used). The initial temperature and the ambient temperature define the scale for the new temperature axis. The time axis then needs to be scaled in such a way that the two given data points lie on the cooling curve. Figure 5 shows the resulting axes that allow to determine the time of death at 170 h or roughly seven days before the first temperature measurement.

It should be noted that the given model does not capture all features of the cooling of a real body. It assumes quasi-stationary conditions throughout the process. This assumption is violated in particular directly after the death of the whale when no stationary temperature
profile has yet been established. Furthermore, biological degradation processes might produce additional heat. Despite these weaknesses, the task was considered very interesting, allowed students to apply knowledge of physical processes and was accessible also to those students with a weaker background in mathematics.

5.2. Example of an experimental task—collision times

The second example was used as an experimental task in the third stage of the German Physics Olympiad 2014. The students were to determine the collision times of two steel balls as a function of the impact velocity. Since the collision times are of the order of a hundred microseconds [31] they are not directly accessible to measurements. Therefore, a setup was used that allows to determine the collision times by monitoring the discharge of a capacitor. Figure 6 shows the experimental setup.

The two steel balls were suspended by conductive metal threads which were connected to an electrical circuit. They acted like a switch that was closed during the collision. The capacitor in the electrical circuit was charged by a voltage source that was then disconnected with another switch. A voltmeter allowed to monitor the voltage across the capacitor and thus to determine the collision time. The impact velocity was varied by moving one of the steel balls to a certain height and letting it swing. Directly after the collision, the second steel ball needed to be caught to prevent additional collisions. Figure 7 shows sample data for the voltages across the capacitor as a function of time before and after the collision.

The gradient in the voltage readings before and after the collision are due to the discharge of the capacitor via the voltmeter. The jump in the logarithmic voltage during the collision is directly proportional to the collision time. Repeating the measurement for several impact velocities leads to a graph similar to the one in figure 8.

Theoretical considerations for elastic bodies predict a proportionality between the collision time and the impact velocity to the power of $-1/5$. The presented results are in good agreement with this prediction. This can be checked by plotting the logarithm of the collision time versus the logarithm of the impact velocity.
In contrast to the rather simple first example, this task was quite demanding for the students in terms of the required data acquisition and the mathematical requirements.

6. Comparison of the German Physics Olympiad with national Physics Olympiads in other countries

More than 80 countries participate in the annual International Physics Olympiads. The students entering the national teams of the participating countries are usually selected via elaborate selection processes, the national Physics Olympiads, that identify and support highly skilled students in physics. There are close similarities between countries’ selection processes and also huge differences. Some national Physics Olympiads are one staged, others have several stages. Some are organised by universities others by ministries or other organisations. Some use mainly multiple choice questions in the first stage while others employ a combination of theoretical and experimental formats. In order to shed some light on the similarities and differences between the national Physics Olympiads, a questionnaire was distributed to all team-leaders at the IPhO 2015 in Mumbai, India. Questionnaires from 31 different countries were returned. This section presents some of the findings from this survey. As a cautionary note it has to be kept in mind that many countries (sometimes roughly) estimated the numbers of participants. Some might have chosen to average the participation numbers over the last couple of years, others might have chosen numbers from the recent Olympiad. The reported data therefore only serves to give a broad impression on the national IPhO selection procedures in different countries.

First, we were interested in the general organisation of the selection procedures and the number of selection stages that eventually lead to the selection of the national teams. In most of the countries the national Physics Olympiad is organised either by a ministry or another organisation. Only in about 10% of the countries universities are responsible for the organisation. On average, the participating countries have 3.1 (SD = 1.2) selection stages. The numbers ranged from 1 to 5. Table 2 shows the different number of stages within the countries.

The first stages of the selection procedures are mostly decentralised, i.e. taking place at local schools or regional centres. Towards the advanced stages, however, the selection processes in different countries get more and more centralised. Multiple-choice questions are administered only in the first and to a lesser extent, second stage. Not surprisingly, there is a tendency towards a higher proportion of experimental tasks in the higher stages. This mirrors the relevance of the experimental tasks at the International Physics Olympiad, where the experimental part carries 40% of the total marks.

Table 2. Number of selection stages in the national Physics Olympiads of different countries.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Canada, Liechtenstein, Sri Lanka</td>
</tr>
<tr>
<td>2</td>
<td>Cyprus, Finland, Greece, Iceland, Sweden, Switzerland, Thailand</td>
</tr>
<tr>
<td>3</td>
<td>Australia, Belgium, Bulgaria, Denmark, Poland, South Korea, United Kingdom</td>
</tr>
<tr>
<td>4</td>
<td>Armenia, Austria, Belarus, Georgia, Germany, Hong Kong, India, Italy, Portugal, Turkey</td>
</tr>
<tr>
<td>5</td>
<td>P. R. China, Israel, Romania, Singapore</td>
</tr>
</tbody>
</table>
The number of participants in the first stages differs largely among the countries and ranges from classroom sizes to 500,000 students in P.R. China. The numbers are much more similar in the final stages where 5 to some hundred students participate. Figure 9 illustrates the number of students in the different stages.

7. Challenges await

In the preceding sections we elaborated on the aims and the structure of the German Physics Olympiad. We illustrated how it is embedded into the landscape of competitions in Germany and how it compares to the national Physics Olympiads in other countries. As an outlook, we will close with presenting some of the challenges that the German Physics Olympiad faces and mention two ongoing projects that address these challenges.

While the number of participants in the German Physics Olympiad has increased considerably in the last years, many schools, teachers and students are still not aware of the Physics Olympiad. There thus remains potential for a further increase of the number of participating students. Together with the other Science Olympiads in Germany different measures are developed and initiated that aim to increase the awareness of the competition and to better connect them to formal schooling. Within the German Physics Olympiad, the introduction of additional teacher material provides one example of these activities.

Another striking finding about the participants of the German Physics Olympiad is the underrepresentation of female students. There is no convincing reason why they should not be able to excel in the competition in the same way as their male counterparts. Nevertheless, we find that in the first stage only about 18%–27% of the participants are female. Even more striking is the fact that the percentage of females steadily decreases towards the higher stages until it reaches a level of approximately 5% in the final stage of the national competition. Internationally, the situation is not much different. The percentage of female students at the
IPhO averages at around 7%. In an effort to better understand the reasons for this imbalance and to devise measures that can help alleviate this situation IPN has initiated the project identi|j. Interviews with female participants of the third stage of the German Physics Olympiad revealed several well-known factors that had an effect on their engagement within the Physics Olympiad [32]. The discussion of female under- or misrepresentation in quantitative domains, like mathematics, engineering, and physics, is under constant debate. The influential cognitive scientist Elizabeth Spelke argues from her vast empirical evidence that girls and boys share an equal set of ‘biologically based cognitive capacities’ that lead them to develop a talent for math and science [33]. Large meta-analyses buttress this claim. They show, for example, that spatial perception, that was hypothesised by Wilson et al [34] as one factor effecting different performances in physics competitions of boys and girls, can be trained [35]. Female underrepresentation to a great extent thus seems to be an issue of social stereotypes (e.g., girls lack talent for physics, girls don’t belong in physics) that constrain female engagement in physics. This holds for science competitions like the Physics Olympiad as well. In line with this literature low female participation in school physics and science competitions can be attributed to a lack of agency [36]. Agency can be described as the capacity to act meaningful or to institute new practices within a social setting. In other words, especially female students see a mismatch between their perceived identity and environments like the Physics Olympiad. Therefore, efforts to increase the level of female participation should aim at increasing the agency of women in the competition. To achieve this aim, an intervention is currently being developed taking into account design features that are known to have a positive effect on young women’s agency.

The intervention will consist of two short seminars and an accompanying online course. The participants will thus experience a higher level of immersion in a learner community. It is important to note that the intervention is not exclusively open to women. We aim at a balanced group composition also in terms of gender. This way it is hoped that the intervention will not only strengthen the level of female participation but will, more generally, act as an additional source of motivation to all participating students.

Finally, there still is a demand for a deeper knowledge of the effects of competitions on participating students. As detailed in the introductory section, successful participants of STEM competitions perceive their participation as positive and even attribute their later successful careers, at least in parts, to their participation. But what remains largely unknown are the immediate effects of success and failure in a competition on participating students and how this will influence a possible future participation. Will a student that failed to reach a certain stage of a competition turn away from the competition or even from science itself? Will he or she be better equipped for a future participation? The IPN Project ‘WinnerS’ aims to fill this knowledge gap by conducting a longitudinal study with current participants of all Science Olympiads in Germany (see the project webpage www.ipn.uni-kiel.de/en/research/projects/winners?set_language=en for additional details). Using an adaption of the expectancy-value model of Wigfield & Eccles the project seeks to answer the following questions: (1) What are the determinants of success and failure in a competition? (2) What effects do success and failure have on cognitive and affective person characteristics? The results of the study will be valuable for the future development of the competitions that may help to counteract negative effects that participants may experience.

The list of challenges presented is, of course, far from exhaustive. There exist other areas that offer developmental perspectives for the German Physics Olympiad and help to make student competition an even more potent measure of identifying and inspiring talents.
Acknowledgments

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