# Executive summary of the evaluation study of the World Robot Olympiad in Germany during the 2019-20 season "SMART Cities"

## 1. Introduction

The World Robot Olympiad (WRO)[1] is an international educational robotics competition with the aim to get students aged 6 to 9 years enthusiastic about science, technology, engineering, and mathematics (STEM). In teams of 2 or 3, the students assemble, design and program robots to accomplish tasks, which are associated with real-world problems regarding annually changing tasks (e.g. "SMART Cities" in 2019). Each team is accompanied by a team coach. Teams use *LEGO* robotics kits to build their robots (in the categories Regular and Football) or develop a robot model using also other robotics kits such as *RaspberryPi* or *Arduino* (in the Open category). Starting at regional competitions, where the teams compete against each other in the respective categories for the first time, they can qualify for advanced rounds of the competition, i.e. the national final or even the world final, which takes place in different countries each year (e.g. in Győr, Hungary in 2019).

The overall aim of the WRO is to tackle the lack of specialists in technological industries. Thus, on the one hand, the WRO aims at sparking the students' interest in STEM, and, on the other hand, it wants to foster the skills they need for their future working life. This addresses especially *21st century skills*. This phrase describes skills, which are indispensable for a future, which is shaped by an increasing digitalization, automation, and globalization. Examples of 21st century skills are advanced communication, collaboration, and problem solving skills as wells as digital literacy.

Beneath the international organization of the WRO Association, the competition is organized by national partners. In Germany, The WRO is organized by the organization TECHNIK BEGEISTERT e.V. Since the organization started their work in 2012, the number of participants in WRO Germany has been growing continuously, from 32 teams in 2012 to 683 teams in 2019 (Regular Category: 573 teams, Football Category: 43 teams, Open Category: 67 teams). 693 teams correspond to 2298 students, who participated in WRO Germany in 2019. Moreover, further surveys show that WRO Germany even reached up to 4138 students through their programs in 2019. For example, students participate in educational robotics afterschool-classes but did not yet participate in the WRO Germany competition itself. Apart from the number of participating teams, the number of regional competitions has also been growing continuously, from 2 regional competitions in 2012 to 34 in 2019.

This ongoing trend is a first indicator that WRO Germany is a promising educational program. Regardless, to measure the impact of the WRO, the organizers of the WRO in Germany, the organization TECHNIK BEGEISTERT e.V., conducted an evaluation study in cooperation with the University of Würzburg during the season of 2019-2020 "SMART Cities". Even though WRO Germany has been collecting feedback by participants via online surveys regularly in recent

[1] Further information on the WRO can be found online here:
International: https://wro-association.org/home, Germany: https://www.worldrobotolympiad.de/

years[2], no scientific program evaluation has been conducted yet. This evaluation is necessary to measure the impact of the program on, for example, students' skill development and career choices in the field of STEM.

## 2. Research questions

The research questions for the evaluation study were the following:

1. **What is the impact of the WRO on students' skill development in terms of**
   a. **Building a robot (digital literacy)**
   b. **Programming a robot (digital literacy)**
   c. **Teamwork/collaboration**
   d. **Communication**
   e. **Problem solving?**
2. **What is the impact of the WRO on students' self-concept and interest regarding STEM[3] (as indicators of future career choices)?**

## 3. Study design and methodology

To answer these research questions, two studies have been designed (Fig. 1):

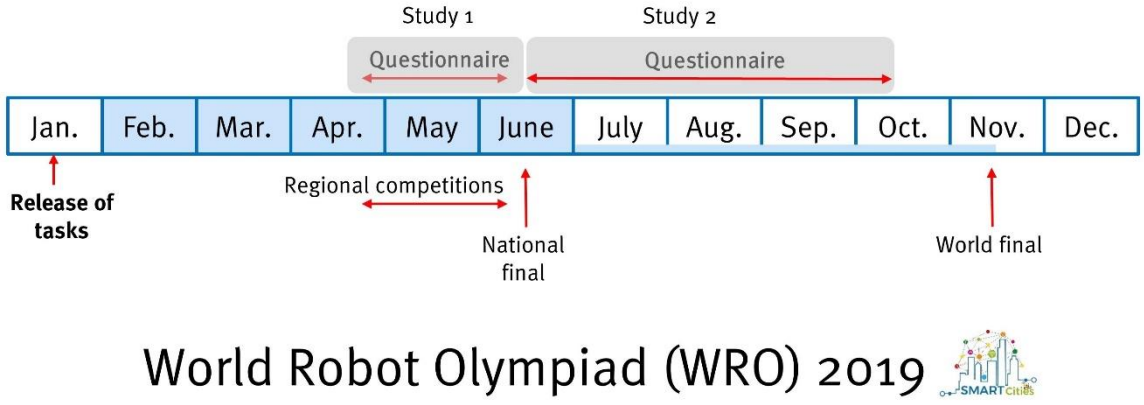


*Figure 1: Study design of the evaluation study*

The first study was a paper-pencil-questionnaire study at the teams' respective regional competitions with the team coaches. The study started at the first regional competition on 4th May 2019 (in Leonberg) and continued until the last regional competition on 8th June 2019 (in Menden (Sauerland)). In addition to general questions regarding demographic information or questions on the current WRO season, the questionnaire asked the team coaches to externally assess students' skill development in a pre-post design (using "then-data", i.e. pre-values in

[2] Selected results of these surveys can be found online in the annual reports by TECHNIK BEGEISTERT e.V. here (in German):
https://www.worldrobotolympiad.de/technik-begeistert-ev/transparenz

[3] Especially regarding Computer Science (CS) and technology.

retrospect). For each skill (e.g. problem solving), multiple questions were grouped as scales. One example question from the problem solving scale is available in Fig. 2.

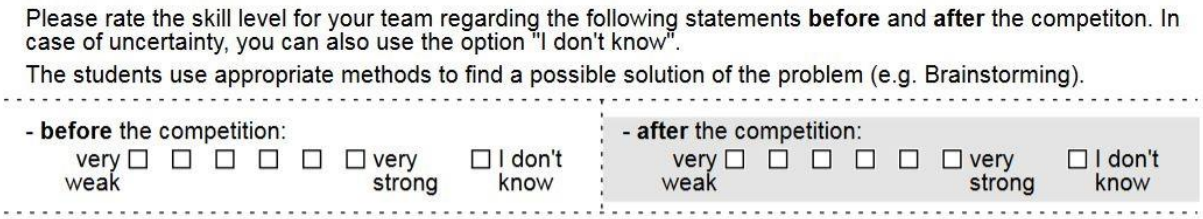


*Figure 2: Example question from the problem solving scale*

Using the pre- and post-values allowed the researchers to construct values for skill development.

The second study was conducted with former participants (alumni) of WRO Germany using an online questionnaire. Participation in this study happened on a self-selective basis and the data collection started on 25th June 2019 (first day of the national final in Germany) and continued until mid-September. This questionnaire study focused on the impact of the WRO on the alumni's career choices. Regardless, this impact was not measured directly but indirectly using the impact on their self-concept and interest regarding STEM as indicators of their future career choices. Self-concept and interest are regarded as relevant indicators for future career choices in occupational psychology.

Data analysis was conducted using descriptive and inferential statistical methods. To convey the meaning of the results from the inferential statistical analysis comprehensibly, effect sizes were used. In general, effect sizes are a measure of the strength of the impact of a trait (e.g. the WRO as educational program) on a variable (e.g. the students' problem solving skills). The higher the effect size, the higher the impact of the trait on the variable. To report effect sizes, multiple units are available. In this report, we use a unit called *Common Language Effect Size* (CLES). As the name indicates, this unit aims at reporting effect sizes in a non-technical way. CLES is the probability that a sample from one group (e.g. *after* the competition) is greater than a sample from another group (e.g. *before* the competition). Effect sizes, which are reported in the CLES unit, can be divided into small (>53%), medium (>58%), and large (>62%) effects.

## 4. Key findings

Key findings from the evaluation study are reported in the following.

### 4.1 Study 1

A total of 60% of teams (413 of 683) participated in this study. This corresponds to 1053 students.

Tab. 1 presents a summary of the five investigated skills with effect sizes (in CLES) and their interpretation.

*Table 1: Summary of skill development with effect sizes (in CLES) and their interpretation*

| Skill | Effect size (CLES) | Interpretation |
|---|---|---|
| Building a robot | 0,79 | Large effect |
| Programming a robot | 0,77 | Large effect |
| Teamwork/collaboration | 0,74 | Large effect |
| Communication | 0,74 | Large effect |
| Problem solving | 0,79 | Large effect |

The results show, for example, a positive skill development regarding the students' problem solving skills in 79% of the cases. On a positive note, both building and programming a robot as *hard skills* and teamwork/collaboration, communication, and problem solving skills as *soft skills* are influenced positively.

In addition to the comparison of pre- and post-values for all participants, further analysis was conducted to compare key subgroups.

- Category (Regular, Open und Football category)
- Age group (Starter, Elementary, Junior and Senior)
- Experience (number of participations at regional competitions of WRO Germany)
- Gender (all-boys, all-girls, and mixed teams)
- Success (percentage of solved tasks at the regional competition of WRO Germany)

When comparing different subgroups, they are compared based on their relative skill development (i.e. normalized gain, in contrast the absolute skill development). Using the relative values, skill development can be calculated excluding prior skill level.

- **Category**: The digital literacy skills (building and programming a robot) show the greatest impact in the Regular category compared to the Open category (CLES = 0,55 (building a robot) or 0,59 (programming a robot), i.e. small to medium effects) and the Football category (CLES = 0,57 (building a robot) or 0,56 (programming a robot), i.e. small effects). Communication skills are most influenced in the Open category (CLES = 0,56, i.e. small effects). Regarding the category, CLES is the probability that a sample from one group (e.g. Regular category) is greater than a sample from another group (e.g. Open category). The interpretation of CLES is similar for the comparison of the following subgroup comparisons.
- **Age group:** The comparison of different age groups does not show any differences regarding the relative skill development of participants. Regardless, differences can be observed in the prior skill level. Younger age groups (Starter and Elementary) show a lower prior skill level than older age groups (Junior and Senior) (CLES = 0,58-0,62, i.e. medium effects).
- **Experience:** Similar to the comparison of different age groups, differently experienced teams do not show any differences regarding the relative skill development but in their prior skill level. Less experienced teams show a lower prior skill level than more experienced ones (CLES = 0,54-0,64, i.e. small to large effects).

- **Gender:** To compare the teams based on their gender, the teams were divided into all-boys, all-girls, and mixed teams. Again, they do not show any differences regarding the relative skill development but in their prior skill level. Teams with a higher proportion of boys, i.e. all-boys teams or teams with mostly boys, show a higher prior skill level compared to their female counterparts regarding their digital literacy skills (building and programming a robot) and problem solving skills (CLES = 0,55-0,59, i.e. small to medium effects). No differences were found for teamwork/collaboration and communication skills.
- **Success:** Differently successful teams differ in terms of their skill development of communication skills (CLES = 0,57, i.e. small effects). Regarding their prior skill level, more successful teams show higher values for their problem solving skills (CLES = 0,54, i.e. small effects).

### 4.2 Study 2

62 former participants (alumni) participated in the second study.

The results of the descriptive analysis of the second study show that alumni rate problem solving skills as significantly higher than the other investigated skills regarding the skills' relevance for their future working life. They rate problem solving skills as 15% more important than the average of the other skills. Subsequently, teamwork/collaboration skills are rated as 14% and communication skills as 12% more important than the average of the other skills. All in all, especially the relevance of soft skills is emphasized.

Moreover, they rate the influence of the WRO on general school motivation as rather weak to neutral (average of 3,4 of 7). The school motivation regarding STEM is rated as rather high to high (average of 5,2 of 7) by contrast.

In occupational psychology, the self-concept, i.e. the collection of beliefs about personal traits, skills, etc., and interest regarding STEM are important indicators of future career choices in the field. Interests are developed in reference to boundaries, which are defined by the self-concept, and career decision making happens within these boundaries. The inferential statistical data analysis shows a great positive impact on the alumni's self-concept (CLES = 0,81, i.e. large effect) and interest (CLES = 0,84, i.e. large effect) regarding STEM. Thus, the WRO influences the career choices of participants indirectly by having a great impact on their self-concept and interest regarding STEM as indicators for future career choices.

## 5. Conclusion

In summary, the WRO proves to have a great impact on students' learning and future career choices. On the one hand, WRO positively influences the (former) students' self-concept and interest regarding STEM as indicators for future career choices and, on the other hand, the students' skill development of 21$^{st}$ century skills in terms of digital literacy skills (building and programming a robot), teamwork/collaboration, communication, and problem solving skills. More interestingly, the first study indicates that there is no *ceiling effect* in the students' skill development and students can develop their skills independent of their age, experience, gender, or success.

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