Facts, Figures, Remarks and Conclusions about the Austrian Bebras Challenge with Regard to Computational Thinking and Computer Science Domains

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Abstract. The interest in the Bebras movement and the number of participants increases every year. Participants of this international contest have to solve Informatics related tasks, requiring no specific education in that field. Each of the tasks covers one or more categories of Computational Thinking (CT) and can be assigned to special domains of Computer Science (CS). Although the practical definition of CT is still a moving target, this challenge can be seen as a measurement tool for CT competencies.
In this paper, we present an analysis of different aspects of the Austrian Bebras competition over the last three years. Accumulated statistical datasets are compared and analyzed as well as detailed task solutions. Moreover, the data provide information about CT skills and CS domains mastered by the pupils and, conversely, about difficulties in certain task categories. Accordingly, the evaluated data provided by the automatic testing system can be used to draw conclusions about the development of tasks.

Keywords: Bebras Challenge, Austria, Findings, Computational Thinking.

1 Introduction

The Bebras Challenge is an international initiative, aiming at promoting Informatics among teachers and pupils of all ages. Established in 2004 in Lithuania [6], the Bebras movement developed very well since then. The increase from 29 participating countries and 0.7 million pupils in 2013 up to 54 countries and 2.7 million of pupils in 2018 impressively demonstrates this phenomenon.

In the wake of this encouraging development a considerable scientific accompanying research and documentation work is growing, including this contribution as a further mosaic stone among Bebras-related publications.

This paper must be seen as a compromise between exemplary cumulated statistical data, collected and provided by the Bebras testing system and exemplary task specific considerations and results with regard to a well-accepted classification scheme.

The paper starts with hard facts about Austrian participation numbers in various contexts, taking into account some idiosyncrasies due to the diverse Austrian school system. The underlying raw data have been collected by the international Bebras website [6] and by the (Dutch) Bebras testing system. These findings are complemented by empirical results of a survey among the local Bebras organizers in 2016.

The next chapter begins with some considerations on the limits of Beaver tasks in view of a wider perspective on Computational Thinking in general, and represents a widely accepted two-dimensional approach to classify Beaver tasks with regard to Computational Thinking aspects and Computer Science domains.

Chapter 4 is dedicated to the Austrian selection of tasks and its alignment to an existing classification scheme, followed by a discussion about exemplary results of pupils' proficiency in various domains.

2 Facts, Figures and Remarks about the Austrian Participation

2.1 The Last Three Years

In the year 2018, the Bebras Challenge in Austria took place for the 12th time in succession, with celebrating the 10th anniversary in 2016 and the first participation in 2007, together with Latvia and Slovakia as the 8th country, after Estonia, Germany, The Netherlands, and Poland joined the forerunner Lithuania in 2006 [6].

Within 14 years, the Bebras challenge developed rapidly, currently encompassing 54 member countries from all continents. The last Bebras challenge attracted about 2.7 millions of pupils all over the world. Table 1 shows the top ten list of these countries and its specific development of participation within the last three years, considering its population in total and the estimated number of pupils. In this list Austria ranks in 10th place. It is striking that there was a big increase from 2016 to 2017 whereas the growth from 2017 to 2018 is moderate. About 3 out of 100 Austrian pupils have participated in the past year 2018, which indicates that there is still much room for expansion. Even the leader Slovenia attracts not more than about 11% of all the potential pupils.

Table 1. Top Ten List with the Rank of Austria Among the Participating Countries

		Development of Number of Contestants							
	Country	**Year 2016**	**Inc.**	**Year 2017**	**Inc.**	**Year 2018**	**Inhabitants**	**Pupils est.**	**Perc.**
1.	Slovenia	29.083	3%	29.993	12%	33.590	2.078.246	300.000	11,2%
2.	Belarus	70.753	58%	111.554	35%	150.237	9.452.514	1.350.000	11,1%
3.	Lithuania	33.006	26%	41.708	6%	44.136	2.780.446	350.000	12,6%
4.	Slovakia	62.981	18%	74.216	5%	77.928	5.455.014	750.000	10,4%
5.	France	474.901	26%	598.869	14%	682.053	65.060.120	9.300.000	7,3%
6.	Czechia	71.792	4%	74.518	7%	79.988	10.677.443	1.500.000	5,3%
7.	Serbia	35.554	20%	42.539	18%	50.168	8.787.495	1.250.000	4,0%
8.	Taiwan	60.744	84%	111.560	6%	118.332	23.750.168	3.400.000	3,5%
9.	Germany	290.802	17%	341.241	9%	373.406	83.320.732	11.000.000	3,4%
10.	**Austria**	**21.191**	**46%**	**31.034**	**5%**	**32.675**	**8.923.245**	**1.200.000**	**2,7%**

Table 2 shows clearly the very inhomogeneous distribution among different types of schools, age-groups and grades. The Austrian High Schools (Academic Secondary Schools), hosting about 200.000 out of about 1.200.000 Austrian pupils, cover dispro-portionally many 2/3 of all participants. Almost 50% of them have taken part in the Bebras challenge within the last years, with the actual number of 132 out of about 330 schools of that type.

Table 2. Distribution of participation regarding school types.

	Contestants			Schools		
	Year 2016	Year 2017	Year 2018	Year 2016	Year 2017	Year 2018
High School(s), Grades 1-8	**15.429**	**20.402**	**21.397**	**124**	**137**	**132**
Vocational School(s), Grades 9-13	2.076	1.823	2.067	20	18	16
Lower General School(s), Grades 5-8	3.053	5.565	6.391	61	98	95
Primary School(s), Grades 1-4	613	1.026	1.033	24	38	46
Other Schools, Grades 9-11	23	2.202	1.789	2	35	23
	21194	31018	32677	231	326	312

About 2/3 of all participants are covered by pupils aged between 13 and 16 years. In Austria the categories are named Meteor and Junior. As table 3 shows, primary schools are still playing a marginal role (not even 1 of 300 pupils took part in 2018), and so do senior students in grade 11 to 13. The data showed that some primary schools offered the Bebras challenge even at grade 2 with 8-years old pupils.

Table 3. Distribution of participation regarding Bebras levels.

	Year 2016	Year 2017	Year 2018
Little Beaver (Grades 2/3/4)	636	1163	1146
Benjamin (Grades 5/6)	5311	8948	8785
Meteor (Grades 7/8)	6401	9465	10129
Junior (Grades 9/10)	7101	9056	10333
Senior (11/12/13)	1745	2386	2284
	21194	31018	32677

Regarding the development of the overall performance over the last three years, there are comparatively little deviations without significant statistical outliers. The numbers in Table 4 indicate (but do not prove) a good annual task selection with a stable level of difficulties. The column labelled with “n.a.“ represents the not answered questions which has significantly decreased in the year 2018 except the category Senior.

Table 4. Distribution of participation regarding wrong and correct answers.

	Year 2016			Year 2017			Year 2018		
	wrong	n.a.	correct	wrong	n.a.	correct	wrong	n.a.	correct
Benjamin (Grades 5/6)	43%	9%	48%	40%	16%	44%	47%	6%	46%
Meteor (Grades 7/8)	44%	15%	42%	37%	16%	47%	44%	9%	48%
Junior (Grades 9/10)	48%	17%	36%	35%	10%	55%	36%	9%	55%
Senior (11/12/13)	39%	17%	44%	35%	12%	53%	34%	18%	49%

2.2 Exemplary Results of a Survey among School Coordinators and Pupils

In January 2017, the Austrian Bebras school coordinators of the challenge 2016, the key persons and drivers of Bebras at school level, were asked to take part in an online survey regarding organizational aspects, the competition platform and the tasks. 97 of 231 Bebras coordinators responded. A rough quantitative analysis shows that

- over 70% (of the coordinators) have organized the Bebras Challenge three times or more,
- more than 2/3 prefer the temporal extension of the competition to two weeks,
- during the challenge the pupils were strictly supervised in more than 80% of cases,
- the offer to work in teams of two was not recommended in 85% of the cases and less than half of the coordinators would be interested in this option in the future,
- in about 1/3 of all participating schools the Bebras challenge was also offered in classes without formal computer science lessons,
- the used (Dutch) competition platform was over 90% technically well-functioning and there were only little technical problems (less than 10%) at the schools,
- more than 90% of the Bebras tasks (2016) were found to be good,
- about 30% found the tasks on average too difficult and about half would want more easier tasks and less text,
- about 90% of the coordinators are in favor of interactive tasks,
- almost everyone stated that the competition was taken seriously by students,
- only 6% of the coordinators stated that they had ideas for Bebras tasks and less than 10% are willing to contribute to the Bebras task collection,
- finally, about 40% stated that the number of 21,000 Bebras participants (2016) in Austria is seen to be comparatively satisfactory.

3 The Bebras Challenge and Computational Thinking

3.1 Are Bebras Tasks Solvers Real Computational Thinkers?

Since the last year, Computational Thinking (CT) is an explicit, but not dominating part of the new Austrian curriculum for Basic Digital Education for lower secondary education (grades 5-8) within other domains, ranging from Computer Literacy to Media education. Within this CT related part of the curriculum pupils should be able to name and describe everyday processes, to use and build codes, to reproduce distinct instructions (algorithms) and carry them out, to formulate distinct instructions verbally and in written form and to program in one computer language [11]. This is one (Austrian) definition of CT which has become a buzzword with a multitude of definitions.

In a broader definition, CT shall be seen as „a cultural technique consisting of a set of skills needed to complete a task in a responsible, sustainable manner including problem solving, evolutionary and reflection steps. These steps encompass logical reasoning, algorithmic thinking, abstraction, generalization, decomposition, design/solution patterns, evaluation techniques, and as computers might be involved in the solution process, different representation forms. It also includes knowing about related disciplines like computer science and software engineering. As such, it should be thought to its fullest extent, but in an age-appropriate manner, at secondary level in Austria.“ [2]

The most comprehensive definition of CT is given by Denning/Tedre where „CT is the mental skills and practices a) for designing computations that get computers to do jobs for us and b) explaining and interpreting the world as a complex of information processes.“. Moreover, the authors distinguish clearly between „CT for beginners“ (K-12 education) and „CT for professionals“ with a very rich skillset with six dimensions: machines, methods, computing education, software engineering, design, and computational science.

„If you try to understand what Computational Thinking *is from media accounts (and many publications) you will hear a story of problem solving with algorithms, along with the ability to think at the many levels of abstraction needed to solve problems. But the K-12 education insights and debates barely scratch the surface of CT”* [5].

In view of these multifaceted perspectives on CT, and the fact that our brains do not naturally think computationally and must be developed and trained, it is up to discussion if Bebras tasks should be so strongly and almost exclusively associated with CT as it is outlined in many publications. If we agree on CT as a set of trained and broad skills and look at the assertion that Bebras tasks can be solved at every level without prior Informatics education, we should see the Bebras challenge less as a role model for CT, but more as a valuable initiative for transmitting many Informatics concepts.

Since the Bebras’ start in Lithuania 2004, about - roughly estimated - one thousand Bebras tasks and their solutions, developed in a cooperative effort by enthusiastic Informatics educators worldwide, are publicly available. These tasks constitute their own reality with an unique character and increasing influence on Informatics teaching, and on the perception of what the core of „computing“ is about. The key idea behind these tasks is not to assess already learned factual and procedural computing knowledge, but to expose pupils to problems with a strong background of Informatics and CT concepts.

3.2 Categorizing Bebras Tasks

In different countries the Bebras tasks are published in form of booklets including the correct answers and descriptions of the computer science topics they deal with (e.g. United Kingdom [14], Australia [1] or Switzerland [13]). Some additionally categorize the tasks into given categories for computer science or Computational Thinking (e.g. United Kingdom, Australia). The booklet from United Kingdom [14] provides a categorization system based on the work of Dagienė et al. [8]. Dagienė et al. present a two-dimensional system to categorize the Bebras tasks. As a first dimension they use five computer science concepts as domains and connect them with a set of keywords to clarify their meaning (in this paper we include only a snippet of the keywords).

1. **Algorithms and programming:** Algorithm; Binary search; Boolean algebra; Breadth-first search; Brute-force search; Bubble sort; Coding; …
2. **Data, data structures and representations:** Array; Attributes; Graph; Binary representations; Binary tree; Character encoding; Databases; …

3. **Computer processes and hardware:** Deadlock; Image processing; Memory; Peripherals; Priorities; Scheduling; Turing machine; …
4. **Communication and networking:** Client/server; Computer networks; Cryptography; Encryption; Parity bit; Protocols; Security; Topologies; …
5. **Interactions, systems and society:** Classification; Computer use; Ethics; Graphical user interface; Legal issues; Robotics; Social issues; … [8]

Computational Thinking skills build the second dimension. Based upon the work of Selby and Woollard [12] Dagienė et al. define five categories, adding notes how the use of the particular CT-skills can be assigned.

1. **Abstraction:** Removing unnecessary details; Spotting key elements in problem; Choosing a representation of a system
2. **Algorithmic thinking:** Thinking in terms of sequences and rules; Executing an algorithm; Creating an algorithm
3. **Decomposition:** Breaking down tasks; Thinking about problems in terms of component parts; Making decisions about dividing into sub-tasks with integration in mind, e.g. deduction
4. **Evaluation:** Finding best solution; Making decisions about good use of resources; Fitness for purpose
5. **Generalization:** Identifying patterns as well as similarities and connections; Solving new problems based on already-solved problems; Utilizing the general solution, e.g. induction [8]

This two-dimensional approach represents a possible categorization system for Bebras tasks describe them in more detail. In the Australian booklets comparable categories are used. With the help of the computer science concepts a mapping to the Australian Digital Technologies Curriculum is shown [1].

4 Results Regarding Computational Thinking and Computer Science Domains

4.1 Methodology

To categorize the Bebras tasks of the Austrian challenges the two-dimensional approach by Dagienė et al. [8] was used due to the fact that data of categorized tasks was available. So, in a first step the tasks of Austria and the United Kingdom were compared and mapped, considering language discrepancy. If a mapping could be found, the categorization was adopted. In the year 2016 18 out of 41, in 2017 22 out of 39, and in 2018 24 out of 39 tasks from the Austrian challenge could be mapped to tasks from UK. The tasks without a mapping were discussed and categorized by the authors following the instruction from the UK booklet:

- Each task is assigned to one or more Computational Thinking skills
- Each task is assigned to one Computer Science domain [14]

First, in the following section the results concerning category frequency are presented. Subsequently, the results of the Austrian challenge are discussed with regard to the distribution of correct answers within the categories.

4.2 Category Task Frequency

The results for the Computational Thinking categories show that the Bebras tasks contain a lot of 'algorithmic thinking' topics rising from 76% from 2016 up to 87% from 2018. In the year 2017 the number of tasks from the category 'abstraction' appeared more often compared to the other two years. The category 'decomposition' occurs most rarely in 2017 and 2018. Only in 2016 tasks including an aspect of 'evaluation' occurred more rarely. These results can be seen in Figure 1.

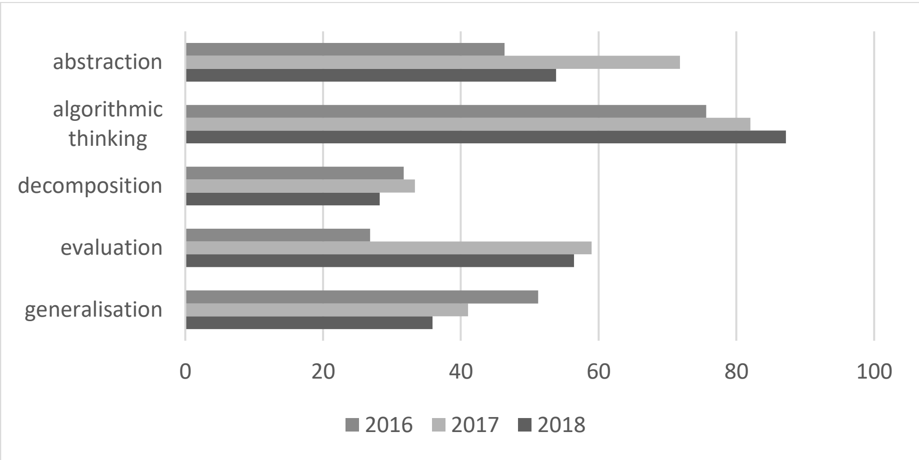

Figure 1. Relative distribution of Computational Thinking tasks

Regarding the Computer Science domains, the two categories 'algorithms and programming' and 'data, data structures and representations' occur very frequently over all three years, as Figure 2 shows. The other three domains are not represented as often. This trend increased from 2016 to 2018: Domains which are represented frequently in 2016 and 2017, are represented in 2018 even more frequently, domains which occur rarely in 2016 and 2017, occur even more rarely in 2018. For instance, in the year 2018 there was no task in the Austrian Bebras challenge that belonged to the category 'communication and networking'.

A comparison of all levels of the Bebras challenge shows the same picture. At all levels 'algorithmic thinking' for Computational Thinking and 'algorithms and programming' and 'data, data structures and representations' for Computer Science occur very frequently. However, the level two for grade 5 to 6 shows one exception. Figure 3 indicates that in this level the relative frequency of tasks from the category 'decomposition' is the highest. This is true for all three years, leading to the assumption that this was intended by the task selection.

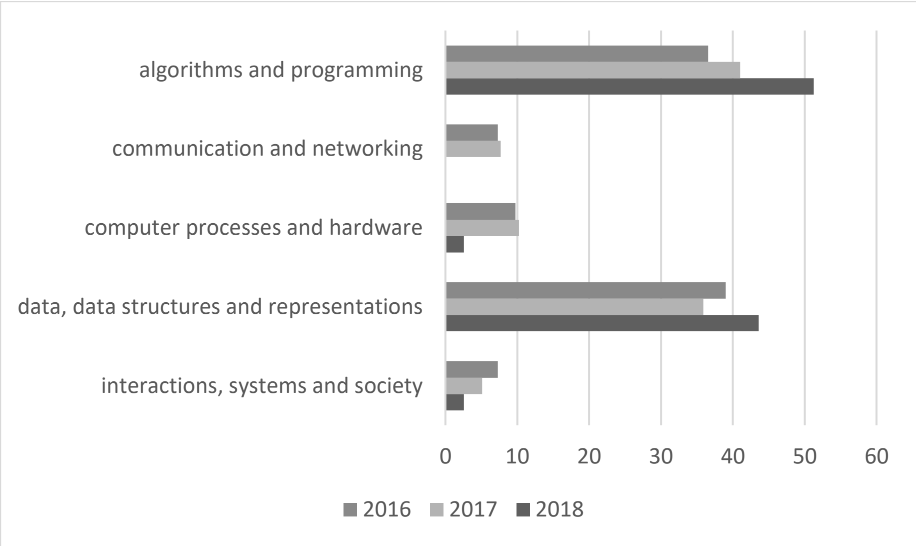

Figure 2. Relative distribution of computer science domain tasks

The results presented in this section shows that among the Computational Thinking categories tasks which demand algorithmic thinking skills are significantly prevalent. Among the Computer Science domains most tasks can be assigned to ‘algorithms and programming’ and ‘data, data structures and representations’. These distributions of tasks may have different reasons, as the tasks can be selected from an international pool of tasks but also can be invented by the (national) organizations. It may also be the case, that the particular task selection is intended. This would imply that the categorization system should be revised (at least) for the Austrian Bebras challenge.

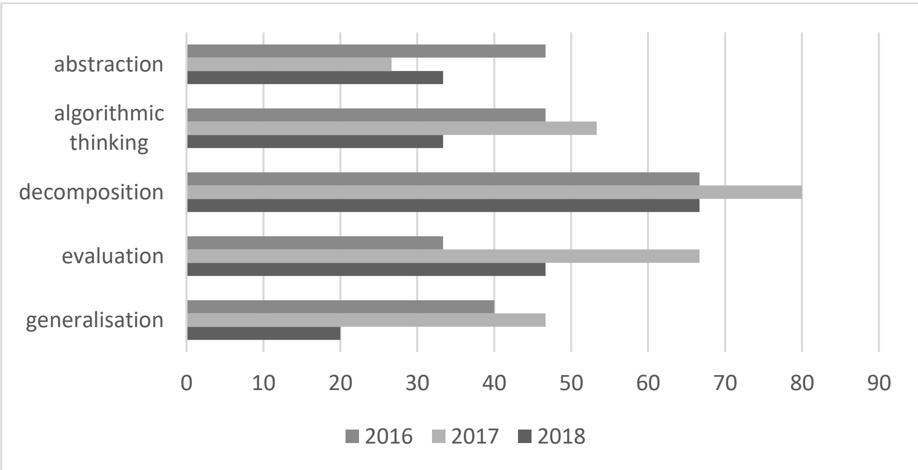

Figure 3. Relative distribution of Computational Thinking tasks for grades 5 to 6

4.3 Answers within Categories

In this section the (correct) answers of the Austrian Bebras challenges over the years 2016, 2017 and 2018 are investigated. Obviously, the tasks are different from year to year which makes it difficult to compare the annual performance of Austrian pupils. Many other variables have to be considered, like the difficulty of selected tasks, the number of tasks within the categories or the fluctuation of participants. So, the comparison of the results over three years offers limited interpretation possibilities.

Figure 4 shows the relative student results regarding the years 2016-2018 for the Computational Thinking domain. Despite the aforementioned limitations, trends are visible over the three years. For example, in the category ‘abstraction’ the percentage of correct and wrong answers differs by 5% over all three years. In the category ‘decomposition’ the number of correct answers is at least 49% (2016), where the maximum of wrong answers is 42% (2016). 2017 nearly 57% of the answers within this category were correct, only 33% were wrong and 10% were not answered. Over all three years the number of correct answers is for at least 7% higher, compared to the number of wrong answers. For the category ‘evaluation’ also a trend over all three years is visible, as the ratios of the relative numbers of correct and wrong answers are very similar. In the two categories ‘algorithmic thinking’ and ‘generalization’ no trend can be recognized. However, the distribution follows the same pattern: in 2016 there were more wrong than correct answers, in 2017 there were far more correct than wrong answers, and in 2018 there were a bit more correct than wrong answers. This indicates that the national Bebras organizers aim at a task selection which yields a balance between correct and wrong answers.

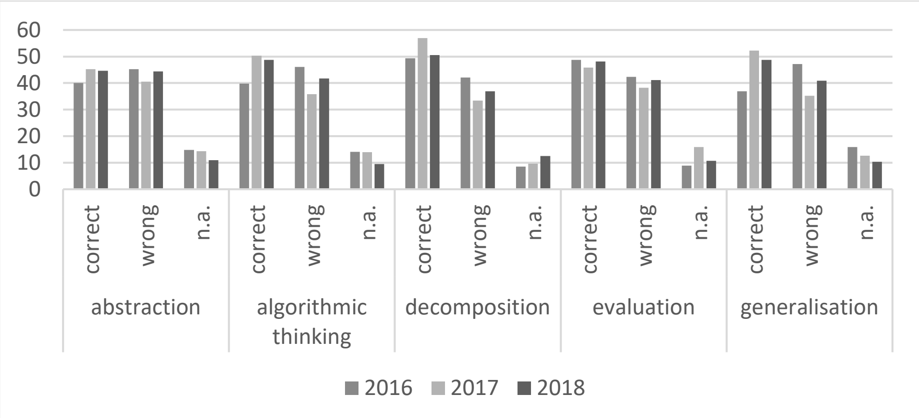

Figure 4. Relative distribution of the answers for Computational Thinking tasks

Additionally, the results for the Computer Science domains show also interesting findings as it can be seen in Figure 5. Like in the Computational Thinking domain, again trends are visible in several categories. In the very frequently appearing category ‘algorithms and programming’ over all three years the ratio of correct and wrong answers is similar. All three years show a slightly higher percentage of correct answers.

The tasks from category ‘communication and networking’, which only occurred in 2016 and 2017, were answered correctly far more often (at least 20% more in 2017) than incorrectly. It has to be considered that each year only three tasks belonged to this category.

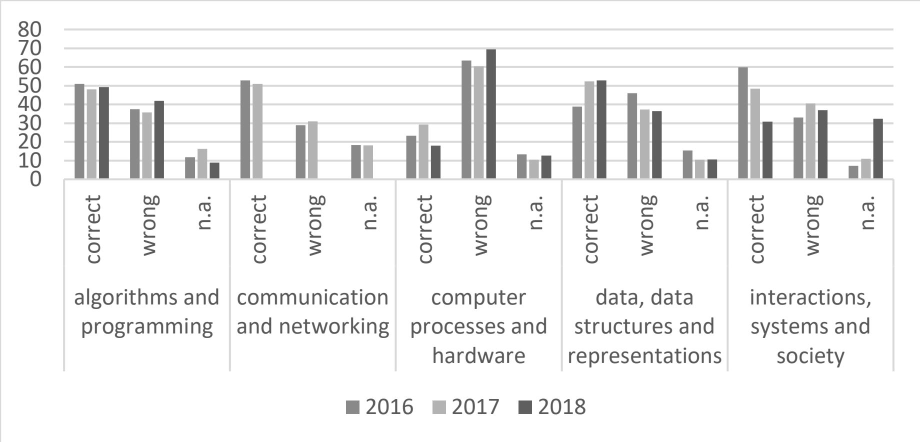

Figure 5. Relative distribution of the answers for computer science domain tasks

The category ‘computer processes and hardware’ represents an unusual result, as there are over all three years significantly more wrong (at least 31% more in 2016) than correct answers. Here a very low number of tasks may bias the results as in the years 2016 and 2017 only four tasks and in 2018 only one task belonged to this category. In the category ‘data, data structures and representations’ which is the second most frequent category in the Computer Science domain, the number of correct answers was only in 2016 less, compared to the number of wrong answers. The years 2017 and 2018 were similar in the ratio of correct and wrong answers.

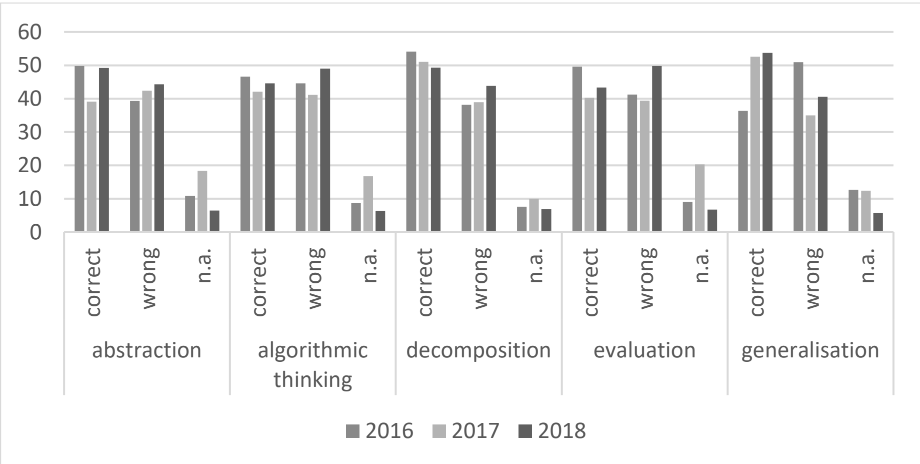

Figure 6. Relative distribution of the answers for CT tasks for grades 5 to 6

Taking a look at grades 5-6, the Computational Thinking category is of interest. Figure 6 shows that over all three years a trend is visible in nearly all categories: The ratios between correct and wrong answers are more or less balanced.

Despite the limitations of measuring the development of the pupils' performance and the difficulties of tasks over the period of three years, due to the lack of taking into account other influential preconditions and variables, it can be stated that the process of task selection works accurate and satisfactorily.

5 Concluding Remarks and Future Work

The Bebras challenge has a comparatively long tradition in Austrian schools and the numbers of participating pupils are still increasing from year to year. However, it seems that the growth from 2017 to 2018 has flattened out. So it will be interesting to observe the development of the Austrian Bebras challenge in the next years. It will take additional information and conviction effort from the Austrian Computer Society and the Ministry of Education among all schools and teachers to improve Austria's 10th rank in the country table. The evaluation of test data with regard to different types of schools and the participating age-groups reveals clearly where to target the promotion for the next Bebras challenge in 2019.

Due to the page limit some other valuable statistical analyses have been omitted in this contribution (at the expense of a classification-related task study), such as the fluctuation of participating schools, the (average) percentage of participating pupils of schools including gender-specific evaluations, the correlation with formal Informatics education, and last but not least the pupils' performances. It is planned to publish these facts and figures, together with new empirical data provided by a follow-up survey among the Bebras organizers at schools.

Regarding the categories provided by Dagienė et al. [8], the Austrian Bebras challenge includes a comparatively balanced number of tasks considering each of the categories from the Computational Thinking domain. However, some more tasks in the categories 'decomposition' and 'generalization' could even improve this balance. In contrast, the situation differs significantly in terms of the computer science domains. Only the two categories 'algorithms and programming' and 'data, data structures and representations' are very frequently represented in tasks. Tasks assigned to the categories 'communication and networking', 'computer processes and hardware' as well as 'interactions, systems and society' are exceptions for all examined three years. One conclusion might be that it is hard to find tasks fitting in the Austrian Bebras challenge for these three domains. Does the categorization system need a revision to be applied for the Austrian task selections?

The combination of the categories and the answers of the participants gives additional insights into the Austrian Bebras challenge. Although there are several limitations of the study due to different Bebras tasks over the years, the results indicate that in some categories the (performance) results are similar and relatively stable. Considering all variable conditions leading to these results, this is a remarkable finding about continuity and in task generation and selection by the Bebras community involved.

We propose further accompanying evaluation of Bebras data and even more scientific research in order to refine and expand the Bebras challenge in Austria and in other countries involved in the Bebras movement. And finally, we think of mutually agreed, comparable and desirable cross-national evaluations as well as of a revised classification scheme, or conversely, of an improved alignment of the Beaver tasks to the existing categorical framework referred to in this paper.

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