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Primary Education Student Teachers' Perceptions of Computational Thinking through Bebras Tasks

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Abstract. This paper describes an investigation of primary education student teachers' perceptions of computational thinking (CT) who participated in a course 'Digital Technologies in Primary Education', and explores what these students consider difficult when developing primary school pupils' CT. In the academic year 2021/22, a revised curriculum will be introduced into Czech primary school education. Instead of 'ICT', 'Informatics' is to be introduced into the curriculum as a new subject at all school levels. Pupils' digital literacy will be formed and developed across all subjects, so all faculties of education in the Czech Republic have paid great attention to the development of primary education student teachers, to prepare them for the planned changes in school practice. Using qualitative methods, the study findings of 66 primary education student teachers (who analysed the Bebras contest for primary school pupils) were that (1) for better understanding of CT, student teachers are required to have sufficient Informatics' knowledge to be able to think computationally, (2) student teachers reported CT is close to mathematical thinking, but these two concepts are not the same, and (3) CT development in primary education requires logical thinking, reading literacy and counting abilities.

Keywords: Primary school student teacher, computational thinking, informatics in education, Bebras contest

1 Introduction

Since 2005, the Czech Republic's curriculum for primary and secondary school education has included 'ICT' as a compulsory subject, intending to develop pupils' ICT skills using a computer, working with basic software applications, and searching for information on the Internet. Until now, in most schools, the teaching of 'ICT' is still governed by the curricular document. Many Czech schools have, however, realised the need to prepare pupils for more advanced IT skills, and have thus included topics in informatics (programming, robotics, etc.) into 'ICT'. Such schools understand that the future of society will depend heavily on digitisation and artificial intelligence applications in most areas of the economy, industry, services, health, education, and citizenship. Therefore, for these developments, the young generation can no longer be educated according to the 2007 curriculum.

Under the Government's Digital Education Strategy [12], the Ministry of Education, Youth and Sport of the Czech Republic (MoEYS) decided to revise the curriculum content for ICT. In co-operation with the faculties of education over three years, textbooks and teaching guidelines were developed to introduce the new subject of informatics, and the development of digital literacy across all subjects at all levels of education. In January 2021, the MoEYS published a revised curricular document with two major changes: (1) improving pupils' digital literacy development at all educational stages, and (2) the subject of 'ICT' is replaced by 'Informatics' with new educational content aimed at computational thinking (CT) development. Both changes are radical and are to be put into practice in pre-school, primary and secondary schools by 2021/22, and no later than 1.9.2023 [13].

For faculties preparing teachers, the task is to prepare student teachers for these changes within undergraduate education; especially, to prepare primary education student teachers to develop pupils' CT in the 'new' subject of 'Informatics'. The key topics of this subject are (1) data, information and modelling, (2) algorithmisation and programming, (3) information systems, and (4) digital technology.

At Charles University's Faculty of Education, two consecutive obligatory courses, 'Digital Technologies in Primary Education' and 'Didactics of Digital Technology', were included in the second year of the full- and part-time five-year MA study in Primary Education. The first is organised as a set of interactive lectures focused on Papert's constructionist theory, a concept of algorithmisation (searching algorithms, code pictures, the principle of recursion, etc.) and examples of how to develop CT (CSUnplugged activities, Bebras tasks, etc.). The second is organised as a set of practical exercises in robotics (LegoWeDo kit), and programming in Scratch.

This paper reports how primary education student teachers who participated in the course 'Digital Technologies in Primary Education' perceive CT through the Bebras contest tasks' analysis, and what these students identified as difficult, when developing primary school pupils' CT using Bebras tasks, is presented.

Based on the above aims the following research question was formulated:

RQ: How does the analysis of Bebras tasks contribute to better student teachers' understanding of computing and computational thinking in primary school education?

2 Literature Review

Seymour Papert originated the idea of CT when he stated that "certain uses of very powerful computational technology and computational ideas can provide children with new possibilities for learning, thinking, and growing emotionally as well as cognitively" [14, pp.17-18]. Wing [20, p.33] followed up on his idea when she introduced the concept of CT as an educational approach that "builds on the power and limits of computing processes, whether they are executed by a human or by machine". Wing [21] states the most important elements are abstraction (the "mental" tool of computing) and automation (using a computer, the "metal" tool of computer scientists) and that "computing is the automation of our abstractions".

Considering that CT has become a prerequisite skill of 21st century learners, Hemmendinger [6, p.6] argued that the goal of teaching CT to students “to teach them how to think like an economist, a physicist, an artist, and to understand how to use computation to solve their problems, to create, and to discover new questions that can fruitfully be explored”. On the other hand, Lu and Fletcher [9] highlighted the importance of teaching CT as in early school education with an emphasis on understanding “computational processes, and not on their manifestations in particular programming languages” and “skills for abstracting and representing information” [9, p.24]. Wing [20] also stressed that “to reading, writing and arithmetic, we should add computational thinking to every child’s analytical ability” [20, p.33].

Developed countries, such as the USA, Italy, Slovakia, Ireland, UK and including the Czech Republic, have integrated computing in primary school education. There is an increasing need not only for teachers, but also for student teachers to be prepared to integrate CT into their classroom practices. For example, Switzerland recently introduced a national curriculum, “Lehrplan 21”, mandating Computer Science Education, the new common curriculum for compulsory education in the 21 German-speaking cantons. To discover how practical the CS Education course organised for student-teachers was, Lamprou and Repenning [8] conducted a study collecting data from more than 600 students who took the course. The research showed that even though pre-service teachers can quickly learn basic programming, the question about learning CT remains open.

With regard to studies focusing on developing primary school student teachers’ competence in CT, Jaipal-Jamai and Angeli [5] investigated the effect of robotics on the learning of 21 primary school student teachers’ CT in a semester-long course on science education methods. Findings from that study revealed that student teachers showed increased interest and knowledge in robots, and in self-efficacy for teaching robotics. Sadik et al. [15] investigated 12 student teachers’ understanding of CT when planning and implementing a fifth-grade activity focusing on CT, robotics, and coding. The findings of the study were that student teachers showed increased awareness of CT. Some misconceptions, such as defining CT as equal to algorithm design and suggesting a trial-and-error approach to computational problem-solving did, however, persist. Similarly, Chang and Peterson [2] examined how 59 primary school student teachers’ perceptions and CT conceptualisations in their teaching practices. In line with Sadik et al. [15], the findings of Chang and Peterson [2] were that student teachers increased their understanding of CT and teaching applications. Moreover, student teachers improved their attitudes to including CT in their course and workshops. A study by Ma et al. [10] focused on exploring student teachers’ field experience in a pedagogical laboratory designed to challenge teacher candidates’ beliefs of teaching and learning in the context of CT. After 12-hours’ training in programming activities on robotics and practice facilitating those activities with children, student teachers reflected that they increased knowledge and skills to facilitate learning CT. Another study focusing on primary school education student teachers by Kim et al. [7] investigated STEM engagement and learning and teaching via robotics. The authors suggested that robotics can be used as a technology in activities designed to enhance student teachers’ STEM engagement and teaching through improved STEM attitudes.

3 The Study

In autumn 2020, primary school student teachers at the Faculty of Education attended a 12-hour compulsory course, ‘Digital Technologies in Primary Education’, to understand CT. The course aimed to introduce student teachers to teaching Informatics in primary school education. It was designed as a set of six interactive lectures. At the end of this course, the student teachers were allowed to choose one of the following four activities (see Table 1) to complete the course:

Table 1. List of final activities for completing the course ‘Digital Technologies in Primary Education’

Activity 1	Activity 2	Activity 3	Activity 4
Code.org	Bebras contest tasks (MINI category)	Informatics Textbooks for Primary Education	Hello Ruby (books)

3.1 Participants

The course was attended by 138 second year student teachers on the 5-year MA study for Primary Education (71,7% full-time and 28,3% part-time). During their study at lower or upper secondary school, they did not have a computer science (CS) or computing subject, only the ‘ICT’ subject (which, in schools, was unfortunately called ‘Informatics’). Among them, a few students had participated in the Informatics Bebras contest while pupils at lower or upper secondary schools. Several of them, mainly the part-time student teachers, work in primary schools and teach the subject ‘ICT’ to children. In the course, ‘Digital Technologies in Primary Education’, which introduced them to the topics and requirements for the new school subject ‘Informatics’, they found many interesting examples and ideas for working with pupils in primary education.

The majority of student teachers 116 chose Activity 2 in which they had to analyse Bebras tasks [1] saved in the archive (<https://www.ibobr.cz/test/archiv>) of Bebras contest tasks (Informatický bobřík) since 2008 for pupils from the Czech Republic.

For the Bebras task analysis, the student teachers could choose any year for the MINI category, established in 2012. Some student teachers decided to analyse tasks from different years of the Bebras contest (MIX).

The study focused on n=66 participants (female = 97,0%) who analysed the Activity 2 related to 2019 Bebras tasks. In this study, we therefore looked at the results reported for 2019. The student teachers were allowed to do the Activity 2 individually or to collaborate in groups (Table 2).

Table 2. How student teachers worked and collaborated in Activity 2 Bebras contest 2019.

Number of student teachers (Activity 2)	Working individually	Working in pairs	Working in threes
66	29 (43,9%)	34 (51,5%)	3 (4,5%)

3.2 Bebras Tasks' Analysis

The student teachers had to decide which Bebras tasks they consider are simple or difficult and the reason why. The following scheme (see Table 3) illustrates the key steps in how to complete the given task:

Table 3. Partial steps in solving Activity 2.

Step 1	Step 2	Step 3	Step 4
To choose a year of Bebras contest	To assess Bebras tasks and to decide which of them are easy/difficult	To justify the opinion as to why the Bebras task is easy/difficult	To design a teaching situation for three selected Bebras tasks as CSUnplugged activities (didactics approach, teaching aid, worksheet, etc.)

“Predicting the difficulty level of a task on the concepts of computer science or computational thinking, like in the Bebras contest, proves to be really hard” [18]. Each year, data obtained from Bebras contest competitors are analysed to understand better why competitors are more successful in some tasks, or why in some cases they were not able to solve the task, which could help Bebras task authors to better estimate the difficulty of the tasks next time. “The actual difficulty of the Bebras tasks will only become apparent after the competition and will often differ from the expected difficulty” [16, p.125]. Sometimes “estimating the difficulty level of a Bebras task is done merely by intuition” [17, p.138].

Some student teachers not only assessed the difficulty for selected Bebras tasks, but also assigned these tasks to their primary school pupils and found out which tasks were difficult for them. In this manner, some of them verified their understanding or expectations.

Some tasks from the Bebras contest were presented to student teachers at the lecture of the course ‘Digital Technologies in Primary Education’, some student teachers started to show interest in these tasks: in some cases they even implemented Bebras tasks to teach their pupils in schools or to activities with their children at home.

3.3 Method

In the present study, data were collected through student teachers’ reflective texts (n=66) in which they assessed the Bebras tasks for the year 2019 and explained why they assumed the difficulty level of particular tasks. The researchers utilised also the information resulting from the design of the teaching process for the three selected Bebras tasks (see Step 4 in Table 3).

In the case of student teachers, it is not a matter of agreeing on the difficulties with the Bebras tasks' authors. Their view of the task level difficulty reflects student teachers' subjective feelings, which is mixed with their own experience, as they struggled with solving the task. The Bebras task analysis is a way how to teach student teachers to think about pupil's thinking computationally.

3.4 Findings

Unlike the authors of the Bebras contest tasks who use a three-level scale to assess difficulty (*easy - moderately difficult - very difficult*), student teachers used only a two-level scale: *easy – difficult*. The two-level scale was deliberately given to student teachers since these students have practically no experience with informatics tasks and teaching computing. They are not yet able to be sufficiently clear about the thinking process about the problem nor appreciate how pupils can analyse the task, or what strategy to choose to solve it. Thus, it is not appropriate for beginners to apply *a finer scale* (see Figures 1 and 2).

In general, student teachers reported that they very much enjoyed solving the Bebras tasks. Some of them have already participated in the Bebras contest as lower secondary school pupils. Nevertheless, for many student teachers the Bebras contest was something completely new.

In some cases, student primary school teachers' opinions on the difficulty of specific Bebras tasks diverged from the Bebras task authors' views; while, in others, the vast majority of student teachers agreed with authors of Bebras tasks.

Practically all student teachers and task authors agreed that the task ***“Text editing”*** is an easy task (Fig. 3). The student's common view was based on their belief that everyone can work with a text editor, but does this also apply to primary school pupils? Student teachers' view of difficulty level of the task, ***“Magic with coins”***, coincides with expectations of the task authors, describing it as difficult (Fig. 1).

In some tasks, student teachers' opinions on the level of difficulty of the Bebras tasks differed, so it is not entirely clear whether, in general, for most student teachers the task is difficult or easy. Among them there are opinions both that the task is difficult, and opinions that the task is simple (see Fig. 1 and 2).

a) Bebras tasks considered very difficult according to their authors:

Student teachers evaluate these following Bebras tasks differently (Fig. 1). Like the authors of Bebras, the majority of students consider the ***“Magic with coins”*** task to be an extremely difficult. Nevertheless, some tasks that authors find very difficult, student teachers considered easy. That is the case with the logic task, ***“Entrance to the swimming pool”***, and the task, ***“Shields and swords”***, (see Appendix 2).

According to the authors, the difficulty of the task ***“Entrance to the swimming pool”*** lies in the fact that pupils work with logical conditions, while the student teachers saw its difficulty only in pupils' ability to focus on reading comprehension, associating the success of solving this task mainly with reading literacy. Only very rarely did a few student teachers comment that “in this task, pupils are required to realise what exactly the rules for entering the swimming pool say (what are the conditions for entry to the swimming pool: if - then - else) and realise what conditions are fulfilled in the given case (how old is who to whom, and who can go to the swimming pool with whom)” (Student teacher 59).

The task, ***“Shields and Swords”***, has been described by some student teachers as easy. It is enough to carefully select individual swordsmen and realise what equipment swordsmen should have at the beginning and at the end of the row. Some student teachers also reflected their views in their teaching design for working with this task with

pupils in a classroom: groups of five pupils equipped the same way as in the picture (see Appendix 2) and solved this task through a drama performance.

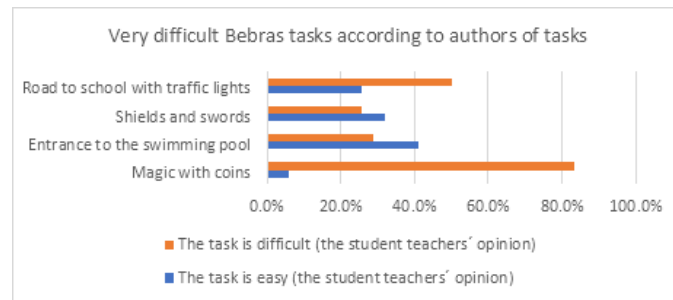


Fig. 1. Student teachers' opinions on Bebras tasks, which the authors of the Bebras contest consider very difficult.

b) Bebras tasks considered moderately difficult according to their authors:

In the case of moderately difficult tasks, the views of student teachers and authors of tasks on the task difficulty also vary (Fig. 2). Differences in the perception of difficulty were manifested mainly in the evaluation of tasks, *“Candy vending machine”* (see Appendix 1) or *“Cloudy weather forecast”*.

One student teacher justified the difficulty of the task *“Candy vending machine”* as follows: “I think that pupils will apply a “trial and error” method. They will try to apply this method until the required number (for 44 candies) appears on the display. Pupils will not understand why this happened or how to look for a more general strategy to solve this task” (Student teacher 45). The student teachers' comments showed that none of them related this task to the triple system. “In my opinion, it is difficult for children to find their way in the machine itself. Working with numbers, in my opinion, is quite a challenging task for children” (Student teacher 12).

In the case of the task, *“Cloudy weather forecast”*, as anticipated, most student teachers described this task as easy. Problem tasks of this kind based on visual analysis are included quite a lot in the learning of primary school pupils.

A completely different type of task is *“Little worm”*. According to some students, the task is simple; according to others, the task is difficult (Fig. 2) “because there are several solutions to the paths and pupils have to find the shortest one. On twigs, the little worm can proceed in different directions” (Student teacher 47).

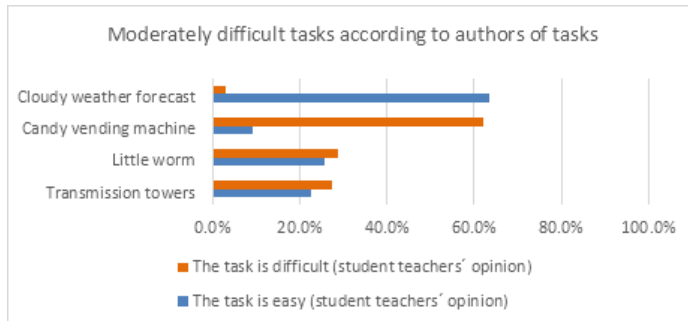


Fig. 2. Student teachers' opinions on Bebras tasks, which the authors of the Bebras contest consider moderately difficult.

c) Bebras tasks considered easy according to their authors:

For all the tasks in this group (Fig. 3), the prevailing opinion among student teachers is that these are simple tasks, corresponding to the views of the task author.

Only in case of the task, **“Park cleaning”** (see Appendix 3), according to some student teachers the task can be difficult (Fig. 3) because the pupils will not be able to visually compare distances between objects placed in the park and “to decide which of a pair of objects is closer to the cleaning robot, and the robot then cleans it up.” (Student teacher 32).

Some student teachers compared the Bebras tasks with mathematical ones used in other challenges for primary school pupils (Kangaroo, Mathematical Olympiad, etc.); they found the Bebras tasks more interesting and engaging. They appreciated the fact that the Bebras tasks usually include a picture or an interactive function, so the control of the task could be user-friendly. Student teachers also valued a theme or story of Bebras tasks –reflecting pupils' lives, interests and experiences which can be fun.

The student teachers pointed out that a significant condition for the successful solution of each task is the ability to read the assignment carefully and to concentrate on its reading with understanding. From a didactical point of view, reading and visual literacy, logical thinking and numeracy are very important for solving Bebras tasks.

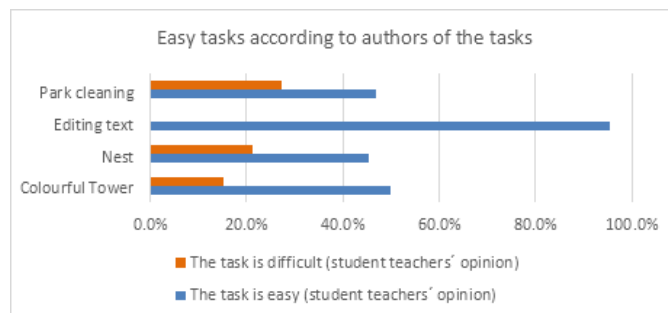


Fig. 3. Student teachers' opinions on Bebras tasks, which the authors of the Bebras contest consider easy.

The student teachers appreciated very much the opportunity they had about how a pupil could think over, and whether pupils are, indeed, capable of solving each Bebras task. They considered that to be a great contest in their initial professional development to become a primary school teacher.

As already mentioned, primary education student teachers not only assessed the difficulty of Bebras tasks, but also proposed teaching methods or approaches aimed to help pupils think about solving tasks (Step 4 in Table 3). Some student teachers created teaching aids (made of paper, wood etc.). Other teaching methods were based on pupils envisioning and enacting the whole situation as a story (something like CSUnplugged). Some examples:

Teaching aids

Cloudy weather forecast: “Together with pupils, we would first number the lines in both pictures (including the weather forecast report). Then we compare step by step in which rows and columns the data from the weather report match” (Student teacher 17).

Little worm: A teacher would explain this task to children with the use of toothpicks. “Pupils would be given a redrawn assignment on paper. The pupils' task would be to place one toothpick on each part of the branch that the little worm travels to the apple (which is bordered by a black dot for greater understanding). If the worm returns to the branch, the pupil will lay two toothpicks. Then pupils will count the toothpicks” (Student teacher 2).

Drama teaching

Park cleaning: “Various objects are placed around the class (garbage). One pupil will represent a robot, whose task is step-by-step to collect scattered objects according to the rules given in the Bebras task. Gradually, other pupils take on the role of a robot” (Student teacher 51).

4 Discussion and Conclusion

This study set out to explore primary education student teachers' perceptions of CT who participated in a course ‘Digital Technologies in Primary Education’ and explored what these students consider difficult when developing primary school pupils' CT. The finding of this study revealed that most of these student teachers completed this course successfully, analysing the required activities, especially the informatics Bebras tasks on which the study concentrated.

Based on the analysis of reflective texts of the Bebras tasks elaborated by 66 primary education student teachers, it was found that for better understanding of CT, student teachers are required to have sufficient Informatics' knowledge to be able to think computationally and to understand the informatics contexts of Bebras tasks.

During their studies at primary and secondary school, these student teachers did not have any opportunity to become introduced to computer science, as no such subject was part of the compulsory curriculum. Nor, after completing the 12-hour compulsory course ‘Digital Technologies in Primary Education’, did the primary school student teachers show convincingly that they know what computing and computational thinking are. They did not have sufficient foreknowledge of (i) what Informatics are, (ii) how

computers work, (iii) algorithms, (iv) programming, and knowledge in mathematics, but (and at the same time) they would be required to develop pupil CT.

The study's findings indicate that due to their lack of fundamental knowledge in informatics, student teachers did not differentiate greatly between CT and mathematical thinking. This conclusion concurs with Millwood et al. [11] that "mathematical concepts are clearly linked, but Computational Thinking defined as the problem solving & design to create useful solutions demands a much broader, creative and playful approach engaging children's imagination" [11, p.8].

Informatics in primary education, including CT development, requires not only logical thinking, reading literacy and counting abilities, but also a good level of abstract thinking, which - like mathematical thinking - is still developing in primary school pupils. Teaching using puzzles, quizzes and games can support and develop understanding and learning of algorithms. Such teaching has been successful in the study of other computing disciplines [4]. Most Bebras tasks are so designed.

The study showed that primary education student teachers do not yet have an idea of what it means to think computationally. It will be necessary to focus first on this in the subject, 'Digital Technologies in Primary Education', and only then to address teaching issues of how to teach computational thinking to pupils. This finding fully corresponds to the recommendations of Yadav et al. [19], that "teacher educators need first to develop pre-service teachers' knowledge and skills on how to think computationally and then how to teach their students to think computationally. It is thus imperative for pre-service teachers to understand computational thinking in the context of the subject area which they will be teaching. This requires them to have deep understanding of their own discipline and knowledge of how computational thinking concepts relate to what students are learning in the classroom."

In primary school teacher education, it is necessary to pay great attention to the evaluation of informatics tasks for pupils, so they can "grasp" the informatics content of an assessed task. The student teachers in this study evaluated the Bebras tasks as interesting tasks (such as quizzes or games); they did not have enough insight from CS to notice what and why it may be difficult for pupils working on Beaver tasks. They assessed difficulty mainly according to their ability to solve the task. They applied a certain "automated" (stereotypical) thinking procedure for solving problematic tasks which could be a barrier to gain insight into completing the task.

For primary education student teachers to really develop CT, they need a grounding in CS, otherwise "there is a real danger that Computational Thinking becomes a label for a set of enjoyable time-filling activities with little coherence and a lack of continuity and progression" [11, p.14]. To ensure primary school development of CT, initial teacher education cannot concentrate only on pedagogical issues of pupils' CT development but must also include informatics. We agree with Cutts, Connor and Robertson [3, p.26] who argue that "efforts to make computer science entirely about "computational thinking" in the absence of "computers" are mistaken".

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Appendix 1 Candy vending machine

Set the candy machine to dispense 44 candies. Use red sliders to change the setting.

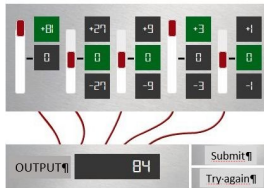


Fig. 4. Candy vending machine.

Appendix 2 Shields and swords

Drag to place masters of historical fencing (swordsmen) to apply:

- Each sword points to one of the masters (swordsmen).
- The master (swordsmen) must defend himself with a shield against each sword.

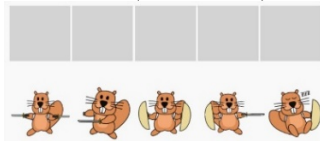


Fig. 5. Shields and swords.

Appendix 3 Park cleaning

After the concert, a lot of garbage remained in the park and the robotic waste bin has the task of collecting it. The robot works according to the following program:

As long as there is an object on the lawn, drive to the nearest object, pick it up and load it. Which of the objects will the robot load last?



Fig. 6. Park cleaning.