Algorithms Unplugged: a Card Game of the Bebras-like Tasks for High Schools Students

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Abstract. The way to ensure that students will learn informatics (computer science) concepts is focused on learner's intrinsical motivation. Informatics concepts based on tasks and puzzles raise students' interest. Teachers need diverse activities that can lead students to deeper understanding. Algorithms are very important part of informatics. Thus we need to introduce various algorithms even at school. Based on our long experience at informatics education research, we proposed an algorithm card game in particular for high school students to discover *Algorithms Unplugged*. For this purpose, Bebras-like tasks were created, by placing one task per card. An idea of the card game was originated on the ground of the Bebras tasks from the International Challenge on Informatics and Computational Thinking [1]. The *Algorithms Unplugged* are closely linked to *CS Unplugged* activities [2].

Keywords: Algorithms Unplugged, Bebras-like tasks, computational thinking, informatics education, informatics concepts, problem solving.

1 Introduction

Many countries are now moving to increase the amount of informatics taught at high school level. This is partly driven by the dramatic shortage of computer science graduates in western countries. Also a broader view of computer science beyond just programming attracts those who are interested in the bigger picture, rather than programming as an end in itself.

Focus on key concepts in informatics improve students' problem-solving skills, students become stronger critical thinkers and problem solvers [1], [2]. Thus we have analyzed the informatics key concepts and have searched for learning methods to convey the concepts. For example, binary representation has some obvious conversion skills that can be learned, but the key concepts are things such as the exponential increase in descriptive power with each bit added. Algorithms are often published as a shopping list of many different algorithms, whereas the key concepts are more about how different algorithms can have a nonlinear difference in performance, and that some problems are intractable.

[1] http://www.bebras.org
[2] http://csunplugged.org

Many of the technological innovations of recent decades have relied on algorithmic ideas and computational thinking. Algorithms not only enable to develop better programming skills, but they are the key to several recent scientific discoveries. Only because of clever algorithms used by search engines can we find desirable information in the World-Wide Web.

Algorithms describe the way how computers process information and how they execute tasks. The problems solved by algorithms have big variety, for example: How to find an exit from inside a labyrinth? How to plan a tour visiting several towns in the cheapest possible order? How to share information and keep secrets as well? Solving these challenging problems requires logical reasoning, computational imagination, and creativity, of course. The developed tasks can be understood without any particular previous knowledge about algorithms and computing.

Students learn better when they are given the opportunity to construct knowledge themselves through experience. Another key tool in supporting students' construction of mental models of these concepts is the use of analogies and metaphors for the chosen of algorithms [3].

The use of games to promote student's learning has been done in the past to capture student's interest as all of us learn better when we are motivated [4]. Student motivation can be described as a student's willingness, need, desire and compulsion to participate and be successful in the learning process [5]. Some researchers have considered the relationship between student motivation and impressions of computing subjects. Students who feel they have a strong motivation for studying a subject have a more positive perception of the subject and about the amount of practical work involved, the clarity of the subject matter and their final grades [6].

2 *Algorithms Unplugged* and *CS Unplugged*

Computer scientists emphasize problem solving in the field of informatics. A collection of learning activities called *Computer Science Unplugged* was developed by Tim Bell and his colleagues. These activities expose students to main concepts in informatics through engaging games and puzzles without requiring a computer. The *CS Unplugged activities* have become more and more popular among educators in different countries.

The *CS Unplugged* contains activities on various topics in informatics, such as how computers store information (the binary system and the representation of pictures as pixels), and algorithms (searching and sorting). Other interesting topics include cryptography and networks. The *CS Unplugged* activities demonstrate these topics using games, magic tricks, and other entertaining methods that require only the simplest equipment, primarily worksheets [7], [8]. Main goal of the *CS Unplugged* is to change students' views of the nature of informatics, so that students will have a rough idea of what informatics is. Especially important is the students understand that fundamental concepts of informatics do not focus on the computer, and that informatics is more than programming.

Also, it is important to show students that informatics requires a mathematical way of thinking and supports a computational thinking.

The *CS Unplugged* focuses on a few algorithms (e.g. sorting and searching) and presents detailed activities. However main attention is paid to various attractive informatics problems (networks, cryptography, information theory, finite automata, etc.).

Using idea of the *Algorithms Unplugged* we would like to focus only on various algorithms and help students to understand their main concepts by solving small problem based tasks.

3 Method

Students usually like problem based tasks solving activities. The *Algorithms Unplugged* cards are for informatics study. There are various studying methods. For example, students can discuss the discovered algorithms in pairs or present the learned algorithms practically by playing or using other visual tools. The card games based on Bebras-like tasks should stimulate teachers and students to deepen their knowledge in algorithms and also inspire cooperation and work together, including collaboration in decision-making, looking for the best solutions, etc. [9].

4 Examples

A set of Bebras-like cards (aimed to students age 15 to 19) is developed. Four cards are shown below. They present the following algorithms: the sieve of Eratosthenes; quick-sort algorithm; the traveling salesman problem; and binary search.

5 Future works

Informatics education should be taken seriously and combine various forces. To obtain deep understanding of algorithms, formal lessons are not enough attractive for keeping students' motivation. Attracting students to get fundamentals of algorithms is a challenge for teachers [10]. An idea to bring algorithms through developed tasks and card game is proposed. An aim is to present various algorithms in an understandable way using attractive formats and develop students' computational thinking. Algorithms are introduced by using various storytelling questions. Teachers are asked to participate in creating and testing tasks.

However, a future goal is to examine the effect of *Algorithms Unplugged* activities on different age of students' cognitive load as well as their ideas on what informatics is about.

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7 THE SIEVE OF ERATOSTHENES

The first algorithm for the computation of primes was introduced by Eratosthenes using a very simple idea:

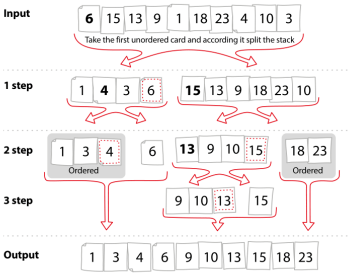
1. Create a list of consecutive integer from 2 through n.
2. Initially take 2, the smallest prime number, and strike all multiples 2, 4 ,6 ,8 , …
3. Take next not striked number, e.g. 3 and strike all its multipliers. If there are no such numbers, stop.
4. Repeat step 3 until the algorithm terminates.

The numbers remaining not marked in the list are all the primes below n.
How many primes are between 2 and 100?

Eratosthenes (276-194 B.C.) was the third librarian of the famous library in Alexandria and developer of an algorithm for collecting prime numbers, - it is known as the Sieve of Eratosthenes.

4 QUICKSORT

The Quicksort algorithm was developed in 1962 by the famous British computer scientist C.A.R. Hoare.
With the following example we demonstrate how this algorithm proceeds:



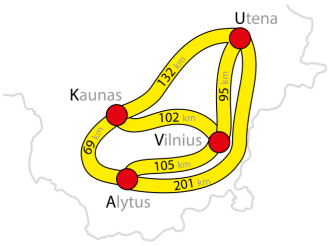
The following card set is given:

Calculate how will the Step 3 look like?

The travelling salesman problem (TSP) is one of the most famous and most studied problems in theoretical computer science. The TSP has several applications, such as planning, logistics, and the manufacture of microchips or even in DNA sequencing.

6 THE TRAVELING SALESMAN PROBLEM

Lina must travel from Vilnius (**V**) visiting 3 towns and coming back to **V**.



Applying the brute force algorithm we started to write down the routes as starting and ending at **V**.

1. V K U A V	102	+	132	+	201	+	105	=	538
2. V A U K V	105	+	201	+	132	+	102	=	538
3. V U A K V	95	+	201	+	69	+	102	=	467
4. V K A U V	102	+	69	+	201	+	95	=	467

How many routes are missing?
How long is the shortest route?

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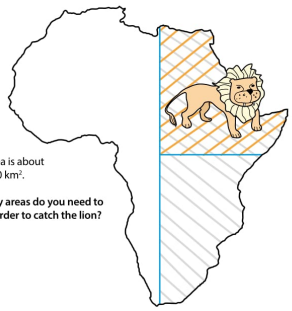
8 CATCH A LION WITH BINARY SEARCH

Informaticians know how to catch a lion in Africa!
Here is a legendary algorithm based on the binary search technique.

Step 1. Divide the area in half.
Step 2. Check the first half - if the lion is here, explore this one futher. If not, take another half.
Step 3. Check if the explored area is less than 0,5 km^2, then assume that the lion is catched, and the algorithm stops. Otherwise go to Step 1.



Africa's area is about 30 370 000 km^2.

How many areas do you need to check in order to catch the lion?

Binary search is the most commonly used techniques that is used to solve problems. The uniform binary search algorithm was published in D. Knuth's book "The Art of Programming" in 1971.

Fig. 1. Examples of *Algorithms Unplugged* cards

References

1. Duckworth, A. L., Peterson, C., Matthews, M. D., Kelly, D. R.: Grit: Perseverance and Passion for Long-Term Goals. Journal of Personality and Social Psychology, 92(6), 1087–1101 (2007)
2. Ben-Hur, M.: Concept-rich mathematics instruction: Building a strong foundation for reasoning and problem solving. ASCD, (2006)
3. Foriek, M. Steinov, M.: Metaphors and analogies for teaching algorithms. In: Proceedings of the 43rd ACM Technical Symposium on Computer Science Education, SIGCSE'12. ACM, New York, NY, USA, 15–20 (2012)
4. Bergin, S. Reilly, R.: The influence of motivation and comfort-level on learning to program. In Proceedings of the 17th Workshop on Psychology of Programming PPIG05, 293–304 (2005)
5. Bomia, L., Beluzo, L., Demeester, D., Elander, K., Johnson, M., Sheldon, B.: The impact of teaching strategies on intrinsic motivation. Champaign, IL: ERIC Clearinghouse on Elementary and Early Childhood Education. (1997)
6. Mitchell M., Shearad J., Makham S.: Student Motivation and Positive Impressions of Computing Subjects. ACM International Conference proceedings series, 189–104 (2000)
7. Bell, T., Alexander, J., Freeman, I.,Grimley, M.: Computer Science Unplugged: School students doing real computing without computers. The New Zealand Journal of Applied Computing and Information Technology, 13(1), 20–29 (2009)
8. Bell, T., Duncan, C., Jarman, S., Newton, H.: Presenting Computer Science Concepts to High School Students. Olympiads in Informatics, 8, 3–19 (2014)
9. Dagiene, V., Vinikiene, L., Stupuriene, G.: Teaching Informatics: Activities-based Model. Proceedings of ISSEP'16, 47 (2016)
10. Dagienė, V., Stupurienė, G.: Bebras a Sustainable Community Building Model for the Concept Based Learning of Informatics and Computational Thinking. Informatics in Education, 15(1), 1–20 (2016)