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Olga Kosheleva

The University of Texas at El Paso, olgak@utep.edu

Vladik Kreinovich

The University of Texas at El Paso, vladik@utep.edu

Christian Servin

El Paso Community College, cservin@gmail.com

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УДК

WHY CORE CURRICULUM? WHY ART AND NATURE ENHANCE CREATIVITY? A MATHEMATICAL EXPLANATION

Olga Kosheleva¹, Vladik Kreinovich¹, Christian Servin²

¹ *University of Texas at El Paso, El Paso, Texas, USA;* ² *El Paso Community College, El Paso, Texas, USA*

¹ olgak@utep.edu, vladik@utep.edu, ² cservin@gmail.com

Abstract Students majoring in mathematics or computer science also have to take additional classes in language, history, philosophy, etc. These classes – that all students have to take, irrespective of their major – are known as *core curriculum*. Students are often not happy with the need to study subjects outside their major – they view it as waste of time – but empirical evidence shows, surprisingly, that these classes help students be more successful in their majors. In this paper, we provide a mathematical explanation for this unexpected phenomenon. The main idea behind this explanation also helps explain why, e.g., art and nature often enhance the creativity of math and computer science students and professionals.

Keywords: *Core curriculum, Creativity, NP-complete problems.*

FORMULATION OF THE PROBLEM

What is core curriculum: a brief reminder. In addition to classes in their selected major, students also have to take classes in language, philosophy, etc. – classes completely unrelated to what they want to study.

Does core curriculum help when learning math of computer science? Many students majoring in mathematics and computer science are unhappy that they need to take these additional classes. They view these classes as a waste of time.

Of course, these classes make the students more rounded, but, honestly, since these classes are unrelated to their majors, one would not expect to see that these classes in any way help students to become better mathematicians or better computer scientists.

Surprisingly, core curriculum helps. Interestingly, empirical evidence shows that

students who got better grades in core curriculum classes get better in their major as well. One would expect the opposite: students who get better grades in core curriculum classes spend more time on these classes and thus, have less time to excel in the classes corresponding to their major.

So why? A natural question is: why core curriculum helps? In this paper, we provide a mathematical answer to this question. This answer will be based on the notion of NP-completeness.

NP-COMPLETENESS: REMINDER

Tractable and intractable problems. For some general problems, there is a general algorithm for solving all the instances of the corresponding problem. Once we learn this algorithm, we can solve any such instance. In arithmetic, such are problems of multiplying and dividing two real numbers or two fractions. In algebra, such are problems of solving systems of linear equations. In calculus, such are problems of differentiating given functions. Such *tractable* problems do not need professionals to solve them: there are computer programs that automatically solve them.

Of course, not all problems are known to be tractable, and this is why we train professionals – to solve such intractable problems. For many problems – e.g., for the problem of solving systems of quadratic equations – no general feasible algorithm is known. We still do not know for sure, with absolute (mathematical) certainty whether there exist any general problems which are not tractable. However, most computer scientists believe that such problems do exist; their existence constitutes the famous hypothesis that P is different from NP: here, NP is the class of all the problems for which we can feasibly check whether a given answer is indeed a solution, and P is the class of all problems for which there exists a general feasible algorithm; see, e.g., [1].

NP-complete problems. While we do not know whether any problem is intractable, it has been shown that there are many problems which are as hard as possible – in the sense that any other problem from the class NP can be reduced to this problem. Such problems are called *NP-complete*.

For example, it is known that the problem of solving systems of quadratic equations is NP-complete.

Important consequence of definition of NP-completeness. In general, the notion of intractable problems sounds negative: if we have proven that the problem is intractable, this means that no feasible algorithm is possible for solving this problem. However, this same definition has a (somewhat unexpected) positive consequence: since any problem can be reduced to an NP-complete problem, any feasible algorithm for solving *some* instances of an NP-complete problem automatically leads to algorithms for solving some instances of *all* other problems as well.

From this viewpoint, learning how people solve instances of one NP-complete problem can immediately lead to solutions to other NP-complete problems. This is not just a theoretic possibility: e.g., many problems in robotics and planning are now solved by reducing them to the problem of checking whether a given Boolean expression is always true (known as *propositional satisfiability problem*).

HOW THE NOTION OF NP-COMPLETENESS EXPLAINS THE USEFULNESS OF CORE CURRICULUM

For subjects studied in core curriculum topics, there are clearly no feasible algorithms – there is no general algorithm for solving all ethical dilemmas, there is no general algorithm for producing objects of art, there is no general algorithm for effective communication between people. In all these areas, there is a lot of good advice, there are many specific algorithms for solving some particular instances of the corresponding problems – but no general algorithms exist, and the consensus in each of these areas is that such an algorithm is not possible.

In terms of the above notions, this means that these problems are intractable – and, judging by the fact that they remain unsolved in spite of many efforts of genius researchers, these problems belong to the class of most hard-to-solve intractable problems, i.e., that these problems are – in a proper formalization – NP-complete.

Thus, in line with the general positive consequences of NP-completeness, once we learn techniques that specialists in this area have developed for solving their problem, we can automatically get new ways of solving problems in mathematics and/or computer science (and in any other discipline as well).

OTHER CONSEQUENCES OF THIS IDEA

As we have mentioned, art is a good example of an intractable – and possibly NP-complete – problem, so no wonder that watching objects of art – be it great paintings or wonderful music – can help us solve creative problems in our professional area.

Another example of intractable problems is nature. The fact that we have not yet succeeded in designing anything alive from scratch is a good indication that living creatures are complex solutions to a very complex problem -- of designing creatures that could survive for a long time in a dynamic environment. So no wonder that observing beautiful nature can boost creativity as well.

Religious doctrines often lead to complex ethical questions – so no wonder that religious studies can also inspire creativity: e.g., in the Middle Ages, this was one of the starting points for many creative scientific discoveries.

Mathematics itself is an example of an NP-complete problem: no feasible algorithm is known that, given a formulation of a possible theorem, would check whether this theorem is true or not. This NP-completeness provides one of the explanations of why mathematical methods are so successful in studying nature, a puzzle first formulated by the Nobel-prize winning physicist Eugene Wigner.

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Vladik KREINOVICH

PhD, Professor

University of Texas at El Paso, El Paso, Texas, USA

Email vladik@utep.edu



Olga KOSHELEVA

PhD, Associate Professor and Co-Chair

University of Texas at El Paso, El Paso, Texas, USA

Email olgak@utep.edu



Christian Servin

PhD, Associate Professor

El Paso Community College, El Paso, Texas, USA

Email cservin@gmail.com

