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UNDERSTANDING ALGORITHMS BY DESIGNING THEM IN A NEW WAY*

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The paper presents an educational solution based on the Understanding by Design (UbD) approach, aiming to improve the knowledge understanding of the Algorithms topic. The solution also offers a learning practice for creative thinking and learning-by-authoring, engaging students in more active participation in the learning process.

Introduction. The new strategies for teaching and learning point to the investigation and the deployment of workable learning methods and scenarios for better understanding, creative thinking, learning-by-doing and learning-by-authoring, engaging learners in more active participation during the perceiving of knowledge. The main questions being asked are: How could learners' creativity be activated and stimulated? What tasks could be interesting and attractive and could stimulate learners' desire to work? What learning methods can be used in order to attract learners in more active participation in the learning process? How to improve the knowledge understanding by the usage of *imperceptible* and *unobtrusive* methods—desirable for students as well as for teachers?

Having in mind the high school learners' needs and features, the educational requirements and the current teaching practices, during the Educational Leaders' Training Program (ELTP)[1] we started a long-term consideration of teaching strategies that could improve the current Bulgarian classroom experience. The key is looked out in innovative pedagogical methods with real involvement of the technologies in the learning process.

Our specific task is to produce an educational "design" plan unfolding current teaching and studying practices in the Computer Science (CS), a studied discipline with great difficulty leading often to misunderstanding. Moreover, the proposed solution has to be easyly transferable to a similar or dissimilar domain.

This paper proposes an educational solution based on the Understanding by Design (UbD) approach, aiming to improve the knowledge understanding of the *Algorithms*

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[1] ELTP brought Bulgarian secondary school educators to the Teachers College, Columbia University for a dynamic three-week professional development and training program. The goal of ELTP is to introduce program participants to the latest pedagogical innovations, as well as to foster professional collaboration between outstanding Bulgarian and U.S. teachers. ELTP's academic training component focused on fostering and implementing innovative pedagogical practices in the classroom, transforming the classroom experience by active usage of technology, tracking student progress and measuring success though proven methods.

topic. UbD provides a common language for educators who are interested in promoting student understanding rather than formulaic knowledge or recall learning. The approach also gives a framework and a toolkit of research-based best practices that have been proven effective in helping educators to promote understanding-based results for learning, expand the range of assessment tools and processes they use to monitor student achievement, and enhance their design of instructional activities to promote high levels of student achievement. The paper also discusses educational difficulties of the *Algorithms* topic and teaching problems. The paper presents shortly the UbD framework and the UbD version of the Algorithms topic.

Algorithms Studying – Difficulties and Challenges. Teaching Computer Science and Algorithms in particular follows a standard methodology of the Science education. Its main teaching problems are related to difficulties or misunderstanding of the learned content, its abstractedness, insufficiently of real-life examples, low attractiveness. The Algorithms topic is often presented using mathematical problems, assuming that students know how to solve them. In general, this conclusion can be considered as inaccurate, not because students cannot solve the problems, given to them, but because they do not distinguish the steps that lead from the "given" to the "searched". Incomprehension of the solution is often the main reason. This gap becomes bigger when the students have difficulties to understand Mathematics or don't perceive its structures, properties, relations, inferences, and conceptualization.

Students have difficulties to formalize an algorithm through natural and formal language, to distinguish the simple steps of the algorithm, the moment/s of adjudicating and the repetitive sequences (cycles) of steps, and totally to trace and describe algorithmic structures. However, understanding algorithms is essential for the Programming through procedural languages, studied at school. More general, to understand algorithms is fundamental for real life and algorithms are used for organizing the daily tasks in a certain (often) predefined way.

Understanding by Design Framework. The Understanding by Design® framework offers a planning process and structure to guide curriculum, assessment, and instruction for innovative teaching and resulting studying. Its two key ideas, contained in the title, are: 1) focus on teaching and assessing for understanding and learning transfer, and 2) design curriculum "backward" from those ends [2]. UbD framework "claims" that learning is enhanced when teachers think purposefully about curricular planning. The focus is on the curriculum and teaching on the development and deepening of student understanding and transfer of learning (i.e., the ability to effectively use/reuse content knowledge and skill). Understanding is revealed when students autonomously make sense of and transfer their learning through authentic performance (six facets of understanding—the capacity to explain, interpret, apply, shift perspective, empathize, and self-assess—can serve as indicators of understanding). Effective curriculum is planned backward from long-term, desired results through a three-stage design process (Desired Results, Evidence, and Learning Plan). This process helps avoid the common problems of treating the textbook as the curriculum rather than a resource, and activity-oriented teaching in which no clear priorities and purposes are apparent. Teachers are coaches of understanding, not mere purveyors of content knowledge, skill, or activity. They focus on ensuring that learning happens, not just teaching (and assuming that what was taught was learned); they always aim and check for successful meaning

making and transfer by the learner. Regularly reviewing units and curriculum against design standards enhances curricular quality and effectiveness, and provides engaging and professional discussions. The UbD framework reflects a continual improvement approach to student achievement and teacher craft. The results of the designs—student performance—inform needed adjustments in curriculum as well as instruction so that student learning is maximized [2].

Algorithms Topic in the Understanding by Design Template. Based on the UbD framework, a special educational template, also called *backward design template*, is developed. For a complete topic (often an unit), it specifies the desired results, the chosen evidence and assessments, and the learning plan [1].

The first stage (desired results panel) includes established goals, content standards, curriculum expectation, essential questions, and target knowledge/abilities: What should students know, understand, and be able to do? What content is worthy of understanding? What enduring understandings are desired?

The second stage (evidence/assessments) panel determines the acceptable evidence: How will we know if students have achieved the desired results? What will we accept as evidence of student's understanding and proficiency? The student's performance tasks are clearly defined.

The third stage (plan learning experiences and instruction) presents the instructional activities: What enabling knowledge (facts, concepts, principles) and skills (processes, procedures, strategies) will students need in order to perform effectively and achieve desired results? What activities will equip students with the needed knowledge and skills? What should be taught and coached, and how should it best be taught, in light of the performance goals? What materials and resources are best suited to accomplish these goals?

Following the backward design template, we developed an UbD lesson on the *Algorithms* topic.

DESIRED RESULTS Panel

Established Goals:

To present the algorithm concept, its characteristics, specifics, and types using examples from the real life; Graphical presentation of the algorithms (from the Common Core standards for Literacy in Computer Science Studies (Grades 9-10)).

Students will understand:

- Every activity of the real life has its own algorithm;
- Algorithms are used for organizing the daily tasks in a certain predefined way;
- The complexity and the type of the algorithms vary according to their nature and the problem they are solving.

Essential Questions:

What is the algorithm in my life?

Is it possible to live without algorithms?

Students will know algorithm's concept, its characteristics, specifics, and types using example/s from the real life.

Students will be able to:

- formalize an algorithm through natural and formal language;
- distinguish the simple steps of the algorithm, the moment/s of adjudicating and the repetitive sequences (cycles) of steps;

- trace and describe algorithmic structures.

EVIDENCE/ASSESSMENTS Panel

Student's Performance Tasks:

You and your team are advisors of the town's Mayer. Your main task for the next two months is to prepare a plan to optimize the street traffic in the town. A complete report of the problem and the offered solutions has to be prepared.

The first task is the traffic observation and analysis. You and your team have to find and mark on interactive map the traffic problematic places in the town. Make a picture or/and video of these places and prepare a chart, showing the rush hours.

The next task (the most important for the topic) is to determine and describe as an algorithm the important steps, needed for traffic improvement. You have to prepare a list of these steps and a graphic presentation (image) of the algorithm through a block schema/diagram, advised by an algorithm specialist (teacher).

The next task is the discussion on the created solution (block schema), advised by a real traffic specialist or an algorithm specialist (the teacher). The discussion is executed online through social network tool. The main discussed questions are: what are the main steps of the algorithm and are they properly determined? What are the input data and the results of the algorithms? What are the base and additional tasks that the algorithms solve? What are the moments of adjudicating and the repetitive sequences (cycles) of steps? What is the algorithm type?

The last task is the rich-media report preparation and presentation. You have to develop an interactive multimedia document (or presentation) by use of textual, graphical, visual and interactive elements to enhance understanding of the problem and the offered solution (algorithm).

Other Evidence: Interactive town map with images and video marking the problematic places (zones); Rush hour chart; Flowchart illustrating the proposed algorithm; Saved on-line discussion in the social network showing the activities, opinions, arguments, and proposals of the students; Rich-media report.

LEARNING PLAN Panel

Learning Activities:

Period 1:

Exploring, gathering materials; data analysis; visual summarization and presentation through a chart diagram.

Period 2:

Preparation and formalizing of an algorithm for optimizing the traffic in the town.

The traffic specialist is invited to aid the problem observation and the preparation of the traffic optimizing solution. A specialist on algorithms (the teacher) presents the components of the flowchart language and some illustrative examples.

Period 3:

On-line discussion for the prepared algorithm; algorithm optimization and improvement.

Period 4:

Preparation of a complete media project demonstrating the problem and the proposed solution (algorithm).

ASSESSMENT CRITERIA Panel

The panel includes assessment criteria such as *Quality of Information, Amount of Information, Diagrams and Illustrations, Content Organization, etc.* clearly specifying requirements for the students' execution of the Performance Tasks and the assessment.

Conclusions. UbD principles aim to give opportunities for creation of a more effective and engaging learning process. Many educators use this approach to involve students in active knowledge observations. This UbD vision is neither highly original nor very radical, but extends the overall teaching practice in a more real life-oriented context. As a teacher in Computer Sciences in a Secondary School (i.e. "Mihail Arnaudov" Secondary School, Sofia) I am in the stage of deployment of the proposed solution in 12 Grades students as a revision of the topic Algorithms. The chosen target group of learners has the Computer Science as a main profiling subject during their secondary education. Until now, the presented solution is not approbated in a Bulgarian setting, but is shared and approved by UbD lecturers (professors in Teachers College, Columbia University, New York) and practitioners (teachers in USA schools) that assessed it as very good, foreseeing its successful experimental verification in Bulgaria.

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ДА РАЗБЕРЕМ АЛГОРИТМИТЕ КАТО ГИ МОДЕЛИРАМЕ ПО НОВ НАЧИН

Десислава Панева-Маринова

Статията представя ново решение за обучение по темата „Алгоритми“ с цел подобреното ѝ разбиране. Решението е базирано на подхода „Разбиране чрез моделиране“ и предлага учебна практика за стимулиране на творческото мислене и ученето чрез създаване, ангажирайки учениците за по-активно участие в учебния процес.