Visual Programming towards the Development of Early Analytical and Critical Thinking

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Abstract

Analytical thinking is a transversal learning skill that helps an individual excel in wide areas, professional, social, civic, and personal. It facilitates the establishment of objectives, the evaluation of alternatives, and sound decision making. In academics, it offers transversal benefits independently of thematic area such as skilled reading, writing, reasoning, problem solving, and evaluation. Introducing engaging methods for building analytical thinking early in life can help children develop fundamental learning-to-learn skills with wide applicability in subjects ranging from science and technology to humanities and art and become active future citizens. Despite the usefulness of analytical thinking throughout an individual's lifetime, development of the skill in early life in the context of primary school curricula is not representative of its importance. Current teaching avenues mostly deploy math, which provides a general theoretical background. However, they fail to leverage the inherent link between technology education and creativity, which emerges when children are encouraged to find innovative solutions through brainstorming and problem solving sessions. This work deploys programming concepts as a means for developing analytical thinking among primary school children through wider blended learning that combines inquiry-based individual exploration and class collaboration. The advantages of the proposed approach are numerous: the precise, step-wise, and structural nature of programming is inherently analytical; it promotes methodological thinking, problem deconstruction, experimentation with alternative paths, and definition of a precise solution; Open-ended sandbox gaming approaches foster motivation, creativity, and entrepreneurial thinking; finally, activities can be integrated into existing school practices enhancing the learning experience. This work is partly funded by the Life Long Learning Programme of the European Commission. Outcomes will be validated in schools in Greece, the Czech Republic, Romania, and Sweden.

1. Introduction

An analysis of school programs in a number of European countries shows that analytical thinking development lags behind needs in elementary school. Only later in life does analytical thinking begin to come into play in certain subject areas in high school. Among young children, the teaching of subject areas that could contribute to analytical thinking, such as math, mostly focuses on necessary processing skills, e.g. performing arithmetic operations, and much less to developing a critical mind. Similarly, in the rare cases that programming is used in elementary school education, the children are involved with "how to" skills on specific operations.

However, it is crucial to provide students with opportunities to develop as analytical and creative thinkers **Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.**. An analytical thinking process is described in research as a methodical step-by-step approach for breaking down complex problems, facts, or thoughts into their constituents parts, identify causes and effects patterns, analyse problems to arrive to an appropriate solution building the capacity to think in meaningful and thoughtful ways **Errore. L'origine riferimento non è stata trovata.**. Concerning the nature of the approach, Parselle **Errore. L'origine riferimento non è stata trovata.** descibes it as a process that is 'focused, sharp, linear, deals with one thing at a time, contains time, is deconstructive, contains no perspective, is subject to disorientation, is brain centered, and tends to the abstract'.

Programming can act as a tool for developing an analytical mind through its structural and precise nature. According to Paper, programming can offer great learning opportunities and can help students develop their own 'style of thinking' **Errore. L'origine riferimento non è stata trovata.**. Kahn **Errore. L'origine riferimento non è stata trovata.**, taking into consideration Papert's work, refers to programming as 'a fertile ground for learning general thinking skills' such as 'problem decomposition, component composition, explicit representation, abstraction, debugging, and thinking about thinking' **Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.**.

Introducing students in programming is not a straightforward process **Errore. L'origine riferimento non è stata trovata.**. Studies highlight the fact that novice programmers face difficulties in understanding basic programming structures; as a result, educators must address significant misconceptions **Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.**. The process of breaking down the problem, identifying causes and effects, and understanding how programming constructs operate are among the difficulties that students face. Inappropriate activities, mental models, and programming learning environments can be seen to cause students' confusion **Errore. L'origine riferimento non è stata trovata.**.

The cMinds project deploys programming concepts as a means for engaging students in analytical thinking. Programming concepts are deployed as tools that, if meaningfully combined, can lead to the desirable outcome. Students are invited to engage in analytical thinking practices towards solving specific mind games, logic problems, and puzzles. In the next section the cminds didactical framework is further described. The early design of the on-line tools comes next. Our aim is not to present a final approach but rather to demonstrate work in progress.

2. Our Didactical Framework and Innovation

cMinds is innovative in not only bringing to the foreground analytical thinking skills-related learning activities early in life, but in introducing specific, innovative didactical approaches that complement related existing school curricula and increase children's motivation. cMinds deploys programming concepts as a means for developing analytical thinking in elementary school through wider blended learning activities that embody features of inquiry and project-based learning.

In contemporary learning theories the learner is described as 'an active learner of knowledge acquisition' **Errore. L'origine riferimento non è stata trovata.**. Inquiry-based learning is well in line with such a notion; it is an educational strategy where the exploration of knowledge is brought into focus in the learning process. Inquiry is defined as 'a seeking for truth, information, or knowledge -- seeking information by questioning' **Errore. L'origine riferimento non è stata trovata.**. Though researchers have proposed different definitions for inquiry **Errore. L'origine riferimento non è stata trovata.** they generally agree that inquiry-based learning aims **Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.**: a) address an answer to a particular question of a scientific nature, b) enrich learners' cognitive background on scientific concepts c) engage learners in the process of answering scientific questions and d) encourage the development of skills required in using scientific tools, practices, and techniques.

Inquiry enhances students' learning achievement, especially in the aspects of problem solving skills, ability to provide explanations for varying forms of data, critical and analytical thinking, and understanding of concepts from diverse subject areas (**Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.Errore. L'origine riferimento non è stata trovata.**). Project-based learning provides many unique opportunities for teachers to communicate meaningfully and to establish relationships with their students. Teachers are challenged to change their role from coach to facilitator and co-learner. Students' products, drafts, and works set a basis for further discussion **Errore. L'origine riferimento non è stata trovata.**.

cMinds deploys blended learning to enhance the educational experience for students and teachers through: tutorials on basic programming concepts, problem deconstruction and identification of components, identification of objectives, causes, effects, and termini, alternatives' evaluation and visualization, solution modelling, process optimization through iteration, solution synthesis and decision making, and result sharing and reflection on outcomes. Recognizing the importance of supporting the teaching process, cMinds introduces good practice guidelines on the integration of proposed programming-based analytical thinking concepts into existing practices.

3. Design: an On-Going Process

Proof-of-concept tool development on the inquiry-based didactical framework presented above is a process in progress. The cminds demonstrator supports a range of logical problems. Image constructible programming concepts are used towards composing a solution (see figure 1). The demonstrator consists of three district areas/zones: the tutorial area, the practice area where learners can explore solutions in the context of a given problem, and the comparison - solution visualization area. Before moving on to the description of each, this section describes the definition of a 'problem' in the context of this work.

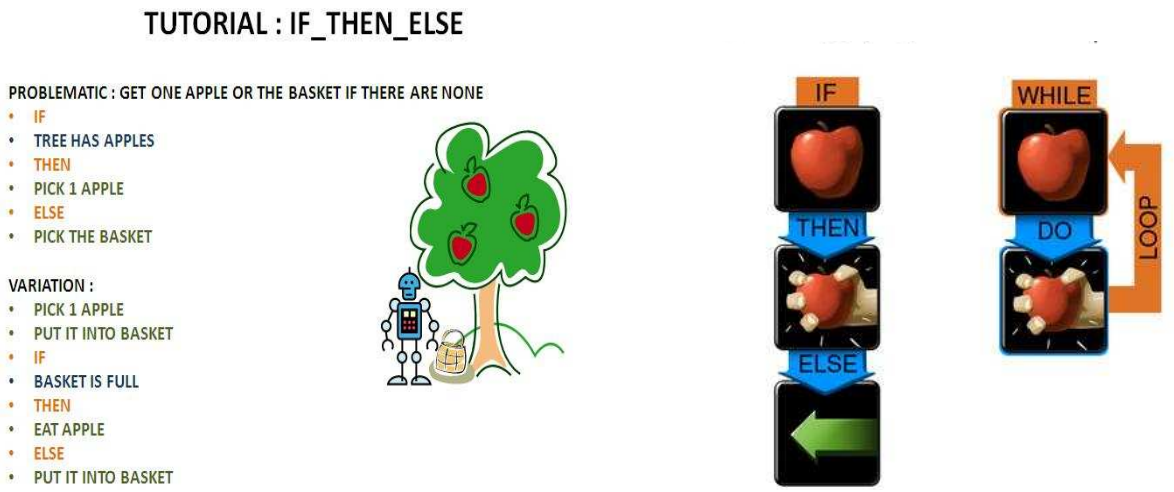

Figure 1. Example: Tutorial for the programming concept of conditional statements and graphical prsentation of a conditional loop

The logic problems considered for integration into the demonstrator can be solved using programming concepts following well accepted algorithmic approaches such as: brute force, divide and conquer, decrease and conquer, and more (for more details see **Errore. L'origine riferimento non è stata trovata.**). They include classical problems such as the tower of Hanoi and the 'river crossing' or 'transport' puzzles. The Tower of Hanoi puzzle was invented by the French mathematician Edouard Lucas in 1883. Students are given a tower consisting of a number of disks whose sizes differ. The disks are placed in a peg while two more pegs exist. The objective is to transfer the entire tower to one of the empty pegs tranfering one disk at a time while never placing a larger one onto a smaller. The number of discs may vary allowing the teacher to calibrate the complexity of the problem. The objective in the 'river crossing' or 'transport' problems is to carry items from one river bank to another taking into account arising restrictions on how many items can be transported at the same time or how many items may be safely left together.

In the **'tutorial area'** students are introduced to basic programming concepts through simple demonstrations. The objective is to familiarize students with the idea of controlling behavior through the application of programming constructs such as conditional statements, loops, and switches.

After the familiarization stage, students can select a logic problem from a basket (n-puzzles, pattern problems, transport problems, mazes, etc). Students are invited to document their thoughts, rationale for the solution they choose, the given data, and the termini through a ‘digital memo’, which facilitates the thinking process.

Students are then called to propose a solution to the selected problem. They are guided through the solution process in two stages: First, they are presented with **an area for hands-on practice and experimentation**. Students are encouraged to experiment through trial and error. Students are given the opportunity to reflect upon a possible solution and to intuitively deconstruct the problem into smaller parts the solution to which leads to the overall outcome. Second, students are invited to address the solution by controlling the behavior of a robot. In this **‘robot phase’** (see figure 2) students are guided to use appropriate image-based constructs (see figure 1) to compose a solution script in a visual-programming **‘code zone’**. The visualization of the results of the script in other words the effect of the series of coding statements, appears in an **‘effect zone’** on the left of the screen. The coexistence of the two stages on the screen, i.e. coding and effects visualization, aims at introducing the concept of ‘control’ through graphical correlation of cause and effect.

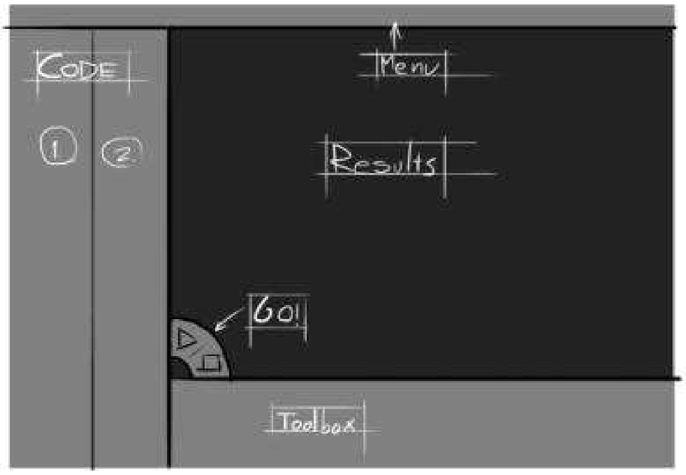

Figure 2. Abstractive demonstration of the Robot Phase

Another core feature of the cminds demonstrator is the **comparison area/ zone**. Once students complete a solution, they are encouraged to compare it with an ‘optimal’ one (based on specific parameters) that is coded in advance into the application. Students are provided with the opportunity to visually observe the execution of the two scripts. They further have the opportunity to skim through and comment on their classmates’ solutions. The comparison zone aims at encouraging students to share their ‘products’. Sharing leads to reflective comments, scrutinizing, and meaningful conversations in a collaborative learning process.

The online applications deploy mostly graphical, age-appropriate interfaces that foster children’s natural curiosity and creativity. ‘Early results’ help build children’s confidence through a sense success that motivates further engagement.

4. Instead of Conclusion

This paper does not aim to present final outcomes, but rather to demonstrate work in progress and ideas concerning the proposed inquiry-based pedagogical framework that deploys programming concepts to build critical thinking among young children. It will be concluded in November 2012. The proposed tools and methodologies will be validated in real-life conditions in schools in Greece, the Czech Republic, Romania, and Sweden aiming to generate feedback on acceptance and effectiveness. Learning requirements of the schools are taken into consideration and integrated into tool design.

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