Chiazzese, G., Fulantelli, G., Pipitone, V., & Taibi, D. (2017). Promoting computational thinking and creativeness in primary school children. In J. M. Dodero, M. S. Ibarra Sáiz, & I. Ruiz Rube (Eds.), Fifth International Conference on Technological Ecosystems for Enhancing Multiculturality (TEEM'17) (Cádiz, Spain, October 18-20, 2017) (Article 6). New York, NY, USA: ACM. doi:10.1145/3144826.3145354

Promoting computational thinking and creativeness in primary school children

Giuseppe Chiazzese
Consiglio Nazionale delle Ricerche - Istituto per le Tecnologie Didattiche
Via Ugo La Malfa, 153, Palermo
Italy
giuseppe.chiazzese@itd.cnr.it

Giovanni Fulantelli
Consiglio Nazionale delle Ricerche - Istituto per le Tecnologie Didattiche
Via Ugo La Malfa, 153, Palermo
Italy
giovanni.fulantelli@itd.cnr.it

Vito Pipitone
Consiglio Nazionale delle Ricerche - Istituto per l'Ambiente Marino Costiero, Mazara del Vallo,
Italy
vito.pipitone@cnr.it

Davide Taibi
Consiglio Nazionale delle Ricerche - Istituto per le Tecnologie Didattiche
Via Ugo La Malfa, 153, Palermo
Italy
davide.taibi@itd.cnr.it

ABSTRACT

This paper presents the preliminary results of the project "Computational Thinking for children education", aimed at promoting computational thinking, creativity and learning amongst primary school children. The didactic activities of the project focus on computer programming and, in particular, the development of video games. The paper introduces also a teaching model based on narrative learning where the screenplay of the game has a key role. A preliminary analysis of the project results highlights how children's perception of computer programming is influenced by practical coding sessions; furthermore, these results suggest that some individual features (e.g. gender; math and language competencies), and the socio-economics familiar context can significantly impact on development of computational thinking skills.

CCS CONCEPTS

• Social and professional topics → Computational thinking • Social and professional topics → Computing education programs • Social and professional topics → K-12 education

KEYWORDS

Computational Thinking, Kodu Game Lab, primary school children education, computational thinking tools

1 INTRODUCTION

Nowadays, children are digital natives, able to interact with digital devices, and to perform actions with them. At the same level of writing, reading and arithmetic skills, programming (a.k.a. coding) is becoming a teaching priority in all educational curricula around the world. Coding can be considered as the communication language that allows the human mind to express a task in a manner to be executable by a digital agent. Starting from the primary school age, the art of programming changes the children perspectives from application users to application creators. The raising role of coding in the pedagogical debate is strictly related to the concept of *computational thinking*, that Wing defines as "a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use" [1]. As García-Peñalvo points out ''computation thinking can be defined as the application of high level of abstraction and an algorithmic approach to solve any kind of problems'' [2][3], thus highlighting the fundamental idea that computational thinking may be applied to various kinds of problems that do not directly involve coding tasks [4]. Several authors have outlined the role of coding as an enabler of computational thinking (an extensive literature is available in [5] [6]). Through coding, children become *computational thinkers* able to analyze problems, identify algorithmic solutions, elaborate ideas, and write programs by composing set of instructions in a specific programming language.

Today coding has become a more accessible and funny activity thanks to the visual and block languages paradigm [7]. It opens up new opportunities for programming without struggling with the text-based coding. Scratch **Error! Reference source not found.**, Code.org [9], Blocky Games, Gameblox, Kodu Game Lab [10] are learning environments where beginners, supported by visual programming, speed up their developing skills to build complex and exciting applications. Visual programming languages allow teachers to organize new educational activities aimed at promoting computational thinking processes and facilitating the learning of programming concepts [11][12]. In particular, Kodu Game Lab includes features that we identify as specifically suitable in primary school context. In fact, it enables children to image 3D virtual worlds and to program characters in a virtual stage by composing instructions through a language based on visual tiles [13]. The visual tile has the affordance of the semantic meaning of the instruction. For example, tiles represent the sensory capabilities (e.g. to see, hear, touch) or actions (e.g. move, take, fire) of the characters. Moreover, Kodu Game Lab provides an easy to use, enjoyable, creative and highly accessible programming environment. From a teaching perspective Kodu Game Lab provides interesting opportunities to design learning activities able to foster computational thinking processes [14].

Repenning [15] identifies three stages of the computational thinking process that a computational thinking tool must elicit:

- Problem formulation (abstraction);
- Solution expression (automation);
- Execution and evaluation (analysis).

With respect to primary school pupils, literature has emphasized the relevance of narrative strategies to stimulate learning processes [16]. For this reason, we propose a computational thinking teaching model that extends the Repenning stages of *Computational Thinking Process* by including a narrative stage as a preliminary level. The narrative stage is the description of a story to be implemented in the virtual stage. The resulting model is shown in Table 1.

Table 1: The stages of the teaching model adopted in the project

Stage	Description
Storyline (Narrative)	The narrative description of characters and events in a story
Problem formulation (Abstraction)	A formulation of the story in terms of actors, protagonists, antagonists, virtual stage elements, game goals, rules and characters' actions
Solution expression (Automation)	*WHEN* happen something *DO* something (Kodu programming paradigm)
Execution and evaluation (Analysis)	The testing phase using the Play action of Kodu tool.

The next section illustrates how the model has been applied in the design of a pilot teaching course for promoting computational thinking processes in primary school children. Section 3 reports the methodology, materials and procedures to run the research project. Finally, preliminary results are presented in section 4.

2 THE PROJECT: COMPUTATIONAL THINKING FOR CHILDREN EDUCATION

The project "*Computational Thinking for children education*" has been funded by the Italian Ministry of Education and carried out through a joint effort of two institutes of the National Research Council of Italy and a primary school. In particular, the school is located in the historic town of Mazara del Vallo, the largest Italian fishing port. This town is situated in the center of the Mediterranean and since the early 1970 it has experienced a huge migratory flow from Tunisia. Nowadays the largest Tunisian community in Italy is settled in Mazara del Vallo. In the last thirty years the school involved in the project has developed several intercultural activities, thus becoming a national pedagogical laboratory for many national projects. The school is attended today by about 750 students, coming from heterogeneous social and economic groups. The percentage of immigrants is about 15% of the total school population, and most of them come from families that have been living in the city for a long time. The presence of Italians is also very varied in terms of economic and social factors. The school is preferred by many families of professionals and employees for its prestige, but also by many disadvantaged families living in the center of the city. All these factors have been taken into account in the design of the pilot course and in the analysis of the project results

The teaching model proposed in this paper has been experimented within a *programming lab* specifically designed for primary school children to stimulate their creativity and coding to foster computational thinking abilities. Students have been guided in the creation of a video game, through the different phases that characterize its development (from design to implementation).

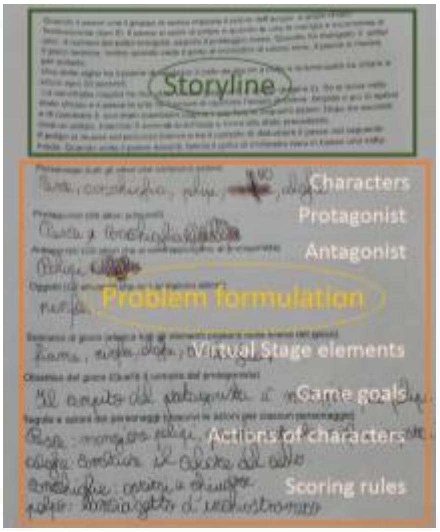

Figure 1: A computational thinking process applied by children.

As introduced in the former section, the teaching model follows the 4 dimensions identified in table 1. Figure 1 shows the result of the first stage of the model (*Narrative*): one child has elaborated the abstract formulation of a story (*problem formulation*) by extracting key information items from the narrative description of the story (*storyline*); specifically, s/he has identified characters, protagonists, antagonists, virtual stage elements, scoring rules, game goals, and characters' actions. Then, children have translated the key information items into programming instructions according to the WHEN-DO paradigm (*solution expression*) of the Kodu language by using tiles (Figure 2). Afterwards, children have transferred the programming instructions to the Kodu programming environment. Finally, the children play with and test (execution and evaluation) their code in order to detect errors.

Figure 2: Two characters with their instructions identified by the child.

As the project structure is concerned, it is possible to identify two main phases. Each phase has been designed to meet a specific sub-objective, but all phases concur to reach the general aim of the project. Next sections will present each phase in details.

2.1 Phase 1: COOL for Game - COding Open Labs

The first phase is an introductory phase. It has the aim of introducing primary school children to computational thinking through open labs that have been activated at the National Research Council of Italy.

The open labs have been focused on the following themes:

A) *Programming as a kind of game*: tools for teaching programming through game play.

B) *Comparing Computer Code and Genetic Code*: code sequencing to determine actions and characteristics of living and artificial organisms.

C) *What if I want to build my video game?*

The activities related to this phase have been organized in three days, one for each open lab.

2.2 Phase 2: Kodu COding Open Lab

This is the core phase of the project. After the introductory meetings in which school children familiarized with coding, they were involved in practical activities.

The Kodu Coding Open Lab has been organized in six sessions, each being a part of the specific learning path, specifically designed to teach programming principles to school children. The learning path involves the child in a collaborative process of creating and developing a video game by using the Kodu Game Lab environment.

The first two sessions introduce children to the visual programming; in the following three sessions children are engaged in the development of a videogame; a final session evaluates the acquired programming skills and their activity perception. All sessions have been held at the computer lab of the school:

- 1 session (2 hours) introduction to visual programming and the Kodu environment. In this session students will learn the basis of visual programming by manipulating physical tiles of Kodu language [17].
- 1 session (2 hours) design of a virtual game scenario, definition of goals, choice of rules, construction of game actions, creation of score system.
- 3 Coding sessions (2 hours) for video game development and testing (Figure 3). Children were guided in the autonomously construction of simple games starting from the narrative description. The three sessions had increasing levels of difficulty.
- 1 evaluation session (2 hours) to assess acquired programming skills (Figure 4).

The narrative dimension is particularly stressed in all sessions.

Figure 3: Primary school children during the Coding session.

The *Storyline* provides children with a short screenplay of the virtual stage describing the game to be implemented.

The story with its characters, environmental elements and actions is introduced. Children are highly motivated to program their characters and make the story come to life in the virtual stage. The activities are not deemed formal school activities but rather they are implemented in a context where students are engaged in a playful learning activity that stimulates the principles of programming [18].

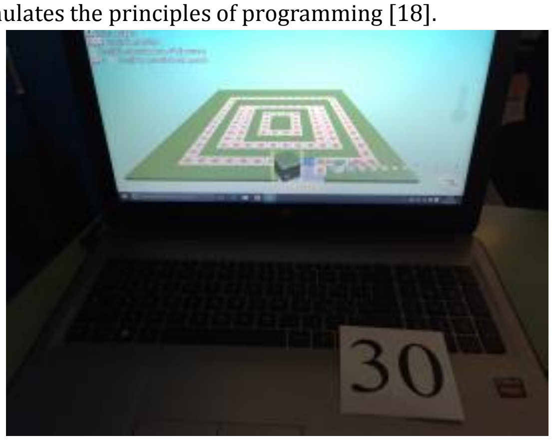

Figure 4: A virtual world created by one of the student participating the experimentation

3. METHODOLOGIES

3.1 Participants

The project involved four primary school classes and a total number of 81 students (N=81). However, for the present paper, we have selected a subsample consisting of the students who attended more than 75% of the total number of sessions, and who completed a questionnaire submitted at the beginning of the project activities (pre-test) and a corresponding questionnaire at the end of the pilot (post-test). The total number students in the sample under investigation is 51 (N=51; 29 male and 22 female).

3.2 Material and procedures

Different tools have been used to collect data. A pre-test and a post-test were posed in order to detect differences in the attitude towards computer programming amongst students. The survey was extracted by the "Kodu Game Lab - Classroom Kit" translated and adapted to the Italian children[1].

In addition, the "Q1 ELEMENTARI." questionnaires have been delivered to the post-test, with the specific aims of measuring the reading, numeracy and reasoning abilities of children [19].

Finally other measures about the performance of students in Italian language and Math and information on the socio-economics familiar context have been provided directly by the school.

The preliminary study presented in this paper focuses on the comparison of the results in pre- and post- tests, on the performance of students in Italian and Math, and on their socio-economics familiar context.

3.3 Pre-test and post-test

The pre-test consists of 10 items. The first two items refer to generic information about the student (age and class). The following items concern the time spent by students to play with video games (item 3); former participation to a programming course (item 4); perceived knowledge about programming (item 5); level of competence in the history subject, a discipline that is not strictly connected with programming but influences the narrative stage of the development process (item 6). In the second part of the questionnaire, students are asked: to indicate how much they agree on considering programming as creative, difficult, easy, fun, interesting, only for computer guru, boring, frustrating, cool, something in which they are good at (item 7); the interest in attending a programming course (item 8); the future interest in working in the IT field (item 9); the steps needed to make a video game (item 10). The post-test includes most of the items in the pre-test, and add some further questions. A first set of questions investigates the experience of using the Kodu environment: what school subject reminds the environment (item 1), how much time did they spend to develop the Kodu game and how much to play with it (item 2), how much fun or easy was to develop and play with the game (item 3,4,5,6). Items from 7 to 12 coincide with pre-test items from 5 to 10. Finally, items 13 and 14 investigate what students liked most in the Kodu environment, and what could be improved.

4. RESULTS

[1] https://www.microsoft.com/en-us/download/details.aspx?id=18229

Preliminary data analysis shows that male students spend more time playing with the video game than females (55.2 % of boys spend between 1 and 2 hours versus 18.2% of girls; 17.2 % of males spend between 3 and 4 hours versus 4.5% of females). It is interesting that 36.4% of females do not play videogames, and 9.1% of them does not own a digital device. Mobile devices (phones, game mobile consoles, tablets) are used as the gaming platform by 59.1% of females and 58.6% of males, while males prefer specific game consoles (41.4% of males Vs. 13.6% of females). The 27,3% of females does not play with game console.

The item 1 of the post-test shows that Math (25%), Science (21%), Art (17%) and Informatics (16%) are the top disciplines reminding the Kodu environment. English (5%) and Logic (5%) are also mentioned.

A Wilcoxon signed-rank test has been applied to measure if the learning activities has modified the students' perception of computer programming. The test has highlighted a significant difference ($p<.05$) in the *funny, cool, exciting, creative and Something I'd be good at* dimensions between pre and post tests (Z=-3.666, p= .000; Z=--2.041, p= .041; Z=-2.060, p= .01; Z=-3.267, p= .001).

In order to assess the item in which the students had to describe the building process of their preferred game, two external experts have been involved. They individually assigned a score to the answer provided by the students in the pre-test and post-test questionnaires, according to a specific scale that takes into account: the general description of the tasks; the specific steps to create a video game; the completeness of the description in terms of video games characteristics such as environment, character, actions.

The evaluation of experts shows a very modest awareness of students about the steps needed to make a video game in the pre-test. In general, students were unable to go beyond mentioning their favourite video game, without any further description related to design. This limited awareness appears to be quite transversal among students, given the reduced average variance. This result changes in a significant way in the post-test, with a substantial increase in mean scores, ranging from 0.9 to 2.1, and a parallel increase in average variance, from 0.6 to 1.8.

Moreover, none of the students reached the highest score assigned by the experts in the pre-test, while 6 students (3 girls and 3 boys) achieved this result in the post-test. These students share some individual and family features: in fact, they received high marks in Italian and in Math, and all of them come from families with both parents born in Italy and having high-school diploma or university master degree as education levels.

However, the absolute values of the scores attributed by the independent evaluators give a static picture of the results achieved by the project. To overcome this measurement constraint, the score increase between pre- and post-tests has been calculated. This provides a more dynamic view of the project results and, consequently, it provides data to identify multiple relationships.

Figure 5 shows the score gains obtained by the students, in relation to the marks (from 6 to 10) obtained in Italian (blue) and Math (red).

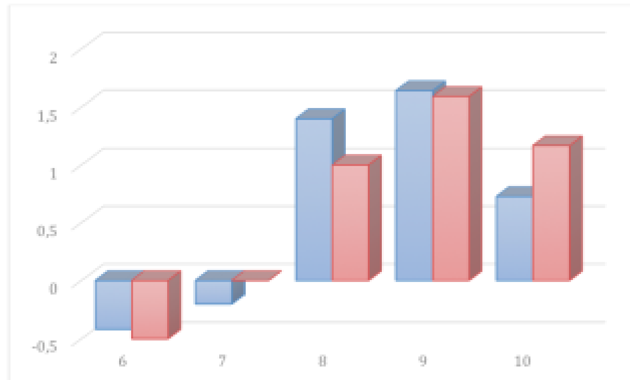

Figure 5: Project results in relation to the school performance

Educational achievements are related to the individual abilities of the students. For this reason, the performance of students in Italian and Math has been used as a proxy for individual skills. While Italian achievements provide cues on reading, text comprehension, and reporting skills, performance in Math can be used as an indicator for students' logical and problem solving skills. All these skills are closely related to the creation, design and implementation of a video game.

As shown in Figure 5, the student score bias is not uniform either linear compared to the marks obtained in Italian and Mathematics. For students with scarce individual abilities, the score bias is negative, maybe due to student's difficulties in attention capacity as well as in engaging in the didactic and formative activities. As individual skills grow, score biases increase. In particular, students who get 9 marks in Italian and Mathematics have the highest increases (increments on average are over 1.5). In the case of students at the top of school achievements (with 10 marks in Italian and Mathematics), the high scores obtained before the pilot reduce the potential increments, which stand between 0.5 and 1. These last students, as we have pointed out before, form the group of students who reaches the highest score possible at the end of the pilot.

Interestingly, girls are the group that gets the most positive outcomes from the project activities (boys get a mean score increase of 0.8, girls get an increase of 1.1).

Data analyzed so far highlight a correlation between results achieved by students and the socio-economic and cultural context of the family of origin, thus confirming the fact that the family context influences students' performance in education, at all level of studies [20].

In the case of students coming from families where at least one parent is not Italian, the differences between pre and post-test are about half a point increase, while the place of birth of the student is not particularly relevant. The family dimension and the cultural context of reference is certainly much more pervasive than the simple geographical reference of the student's place of birth.

By taking into account the socio-economic features of Mazara del Vallo town, we have also distinguished between students whose mothers are dedicated to domestic activities and students having a working mother. The difference in test scores after and before the pilot increases significantly. While the first group get an increment of 0.7, the second group get an increase of 1.9. This is something that, contextualized in the territory of experimentation, can be associated with the relationship between performance and economic conditions. The better the economic conditions of the family are, the higher the training opportunities and the facilities (books, computers, internet access, etc.) available to students are [21][22]. These elements result in better final results. Table 2 shows how the increments of the score vary depending on parents' level of education.

Table 2: Increments of score related to parents' educational level

Father		Mother	
primary or middle school degree	secondary school or university degree	primary or middle school degree	secondary school or university degree
0.3	1.1	1	1.7

These data highlight the fundamental role of the cultural context, which is related to two different reasons: the family income and the socio-cultural level of the family [23][24].

A further element influencing the differences in the score variations can be attributed to the intensity with which students play video games. Such intensity could, in fact, involve greater individual predisposition to these tools and a higher motivation in understanding their working mechanisms. For this reason, in Table 3 we have represented incremental scores with respect to two conditions: the genre and the use of video games.

Table 3: Increments of score, related to gender and time spent in playing with video game (item 3)

	Do not play with video games	Play with video games
Male	1.9	0.9
Female	0.9	0.3

In a way against intuitive, playing video games does not make any major increases in the scores reported by the questionnaires. In fact, girls who do not play video games have gained the greatest benefits from the project. This data highlight the transversality of benefits in terms of improving skills, but above all the existence of persistent and widespread commonplaces on programming activities that are not reflected by our preliminary results.

5 CONCLUSIONS

Results presented in this paper provide preliminary insights on how primary school students' computer programming - considered as an important enabler for computational thinking skills - can be improved through practical coding sessions. In particular, the use of a visual programming tool and the adoption of a narrative approach have stimulated a positive perception about computer programming in children; specifically, as emphasized by the pre- and post-test comparison, children perceive computer programming as *funny, cool, exciting, creative and "Something I'd be good at"*.

These results tend to highlight that programming is not a prerogative of a specific group of students. However, as for any learning activity, educational achievements are influenced by individual abilities and the family context. In particular, students with higher marks in Math and Italian language have achieved higher educational outcomes than their peers with lower marks; furthermore, the socio-economics familiar context significantly impacts on the improvement of computational thinking skills.

Further investigation is necessary in order to better correlate the results of the project with students' reading skill. In particular, the teaching model adopted in the project is based on narrative learning, a solution which has been largely appreciated by the children, but that could have penalized pupils with scarce linguistic competencies (e.g. children with one or both parents born abroad). Moreover, data revealing that playing video games does not make any major increase in the coding skills achievements should be contextualized in the specific socio-economic features of the school, thus identifying other factors that could have neutralized the effect of this variable.

During this pilot study other questionnaires have been submitted to measure reading and the reasoning skills. The evaluation of these questionnaires is an ongoing work that authors are carrying on. In addition, the games developed by children during the experimentation will be also analysed through automatic procedures in order to extract features such as: characters, game elements and programming rules. The extracted data will be used to correlate these features with children problem solving, reading comprehension and programming abilities. The results are under evaluation and will be presented in a future work.

ACKNOWLEDGMENTS

All primary school children participating to this learning experience, their teachers and the principal of the school to have facilitated the implementation of the activities.

REFERENCES

[1] J. M. Wing. 2006. Computational thinking. *Commun. ACM* 49, 3 (March 2006), 33-35. DOI: https://doi.org/10.1145/1118178.1118215

[2] F. J. García-Peñalvo. 2016. What computational thinking is. *Journal of Information Technology Research* , 9(3), v-viii.

[3] A. M. Pinto-Llorente, S. Casillas-Martín, M. Cabezas-González, F. J. García-Peñalvo. 2017. Building, coding and programming 3D models via a visual programming environment. *Quality & Quantity*, 1-14.

[4] J. M. Wing. 2008. Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences*, 366(1881), 3717-3725

[5] S. Yee Lye and J Hwee Ling Koh. 2014. Review on teaching and learning of computational thinking through programming. *Comput. Hum. Behav.* 41, C (December 2014), 51-61.

[6] F. J. García-Peñalvo, S. Reimann, M. Tuul, A. Rees, I. Jormanainen. 2016. An overview of the most relevant literature on coding and computational thinking with emphasis on the relevant issues for teachers. Belgium: TACCLE3.

[7] D. Bau, J. Gray, C. Kelleher, J. Sheldon, F. Turbak, F. 2017. Learnable programming: blocks and beyond. *Communications of the ACM*, 60(6), 72-80.

[8] M. Resnick, J. Maloney, A. Monroy-Hernández, N. Rusk, E. Eastmond, K. Brennan, A. Millner, E. Rosenbaum, J. Silver, B. Silverman, and Y. Kafai. 2009. Scratch: programming for all. *Commun. ACM* 52, 11 (November 2009), 60-67. DOI=http://dx.doi.org/10.1145/1592761.1592779

[9] Code. 2017. Hour of Code website**.** Retrieved from http://code.org/learn

[10] A. Fowler, T. Fristce, M. MacLauren. 2012. Kodu game lab: A programming environment. *The computer Games Journal* 1, 1 (May 2012), 17-28.

[11] K. J. Harms, E. Balzuweit, J. Chen, C. Kelleher. 2016. Learning programming from tutorials and code puzzles: Children's perceptions of value. *Visual Languages and Human-Centric Computing (VL/HCC), 2016 IEEE Symposium on*. DOI=http://doi.org/10.1109/VLHCC.2016.7739665

[12] O. S. Akinola, B. O. Akinkunmi, T. S. Alo. 2012. A Data Mining Model for Predicting Computer Programming Proficiency of Computer Science Undergraduate Students. African Journal of Computing & ICT 5, 1 (January 2012), 43-52.

[13] G. Chiazzese, M. R. Laganà. 2011. Online learning with virtual puppetry. *Journal of e-Learning and Knowledge Society* 7, 3 (September 2011), 121-129 DOI=https://doi.org/10.20368/1971-8829/557

[14] D. S. Touretzky, D. Marghitu, S. Ludi, D. Bernstein, L. Ni. 2013. Accelerating K-12 computational thinking using scaffolding, staging, and abstraction. In *Proceeding of the 44th ACM technical symposium on Computer science education* (SIGCSE '13). ACM, New York, NY, USA, 609-614. DOI: http://dx.doi.org/10.1145/2445196.2445374

[15] A. Repenning, A. R. Basawapatna, and N. A. Escherle. "Principles of Computational Thinking Tools." In: P. Rich P., C. Hodges (eds) *Emerging Research, Practice, and Policy on Computational Thinking*. Springer International Publishing, 2017. 291-305.

[16] J. Szurmak, T. Mindy. 2013. Tell me a story: The use of narrative as a tool for instruction. *Indianapolis, IN* (2013): 546-552.

[17] D. S. Touretzky. 2014. Teaching Kodu with physical manipulatives. *ACM Inroads* 5, 4 (December 2014), 44-51. DOI=http://dx.doi.org/10.1145/2684721.2684732

[18] G. Chiazzese, A. M. Cafari, D. Taibi, G. Fulantelli. 2015. EduCodeGame - Risolvere problemi di matematica con Kodu: uno studio Pilota. *Teach Different! EMEMITALIA conference*.

[19] R. De Beni, Gruppo MT. 1995. "Q1 ELEMENTARI" - Prove per la compilazione del profilo iniziale del nuovo documento di valutazione. Organizzazioni Speciali.

[20] S. V. Schnepf. 2007. Immigrants' educational disadvantage: an examination across ten countries and three surveys. *Journal of Population Economics* 20, 3, 527-545. DOI=http://dx.doi.org/10.1007/s00148-006-0102-y

[21] R. Haveman, B. Wolfe. 1995. The determinants of children's attainments: a review of methods and findings. *Journal of Economic Literature* 33, 4 (December 1995), 1829–1878.

[22] S. Sirin. 2005. Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research 75*, 3 (Fall 2005), 417-453.

[23] N. Xia. 2010. *Family factors and student outcomes*. Ph.D. Dissertation. Pardee RAND Graduate School, Santa Monica, CA. Retrieved from https://www.rand.org/pubs/rgs_dissertations/RGSD256.html

[24] G. Becker, N. Tomes. 1986. Human capital and the rise and fall of families. *Journal of Labor economics* 4, 3 (July 1986), S1-S39.