On the relationship between Engagement, Learning, and Creativity in Computer Science: Toward better understanding and improved methods

Sofia Papavlasopoulou
Norwegian University of Science and Technology (NTNU), Trondheim, Norway
(spapav@idi.ntnu.no)

ABSTRACT
Interactive ways of learning and creative activities in teaching methods of Computer Science (CS) have drawn great interest in the last years. The goal of this PhD project is to focus on the main research question: *How could practices for computer science education become more attractive and effective for students and especially female students?* Initially the project will define the theoretical and the existing teaching practices of CS at schools. Next, empirical tests will evaluate the effectiveness of proposed learning practices based on learning activities of different types, e.g. collaborative games, supervised or unsupervised project work. The methodology used is both qualitative and quantitative, using questionnaires, observations and interviews.

Keywords: CS education; programming; learning; female students; teaching methods

INTRODUCTION

Despite the economic crisis, demand for Computer Science (CS) and Information Technology (IT) professionals persist. Currently, there are multiple efforts to broaden participation in CS and introduce computational literacy to young students [32]. Education in schools should also be raising young students' interest in CS and IT subjects. Many projects of learning activities have moved their attention to students' creative participation.

Despite the fact that students use computers for many tasks in their everyday life, the majority of them do not understand what computer science is and how it relates to algorithmic thinking and problem solving. The lack of exposure to CS in schools leads to few students choosing computer science as a career. Another crucial aspect is the low number of female students in CS subjects. Females more often than males choose disciplines like linguistics, cultural studies, and arts. In school, girls typically show less interest in CS topics; something that later prevents them from studying and pursuing a CS career [31].

To increase the interest, engagement, and participation in CS (both generally and particularly targeting female students), numerous approaches and projects have been initiated, including: the CS Unplugged [CS Unplugged, 2012], Alice [4], Scratch [27] and Greenfoot [20]. In their study Denner et al. 2012 [9] targeted at middle school girls providing evidence that coding games can support learning and enhance their engagement with computer science concepts. Although, many projects focusing on female students, do not have the expected success, probably due to the fact that they don't evaluate their strategies [8]. Building upon previous research on motivating and engaging students with CS in terms of creativity [1, 13], this research work will investigate and ultimately introduce a program based on creative development activities as a means to facilitate a particular process by which youths can engage with CS.

The purpose of this PhD project aims to contribute in exploring ways to provide the opportunity for an interactive way of learning. In particular, investigate and flourish the existing teaching methods of CS and computer programming in order to become more effective and attractive for students in the high school and first year CS students. Additionally, enhance student's computational, problem solving skills and creativity. As female students show less interest in CS, main emphasis will be given exploring the reasons of that phenomenon and explore how different methods and tools could give the ability to excite young women's interest in CS.

BACKGROUND AND MOTIVATION

The last decades have seen various attempts to introduce creativity to CS teaching. Niguidula and van Dam [28] were some of the pioneers of this movement. To date,

IDC'16, June 21-24, 2016 Manchester, UK

several successful efforts have been initiated [18, 7, 2]. Most of these approaches have been applied to CS high school courses with documented success. The "Gr8 Designs for Gr8 Girls" project at the University of Toronto offers one-day programs in which girls rotate through four different activities focusing on design and creativity [8]. Another notable initiative is the Computational Thinking course at Colby College taught by Bruce Maxwell, which uses Python and Turtle Graphics for 2D graphics as a medium of creativity, expression, communication, and experimentation. The work of Buechley et al., [3] made particular impact in the area of textiles, incorporating microcontrollers designed for wearable computing. Revell, 2003 [29] introduced the Sesame Workshops philosophy identifying some of the challenges and solutions in designing interactive educational activities that can be used by children. Moreover, there is a need to make children programming a far more informal, approachable, and natural activity [10]. Roque et al., 2012 [30] investigate ways to support the collaboration on creative activities. The aforementioned projects represent an exciting direction for bringing computing to a much larger community of students and practitioners. The reported projects and developments inspire and guide us during the lifetime of the proposed project.

Our experience indicates that combining physical artifacts, programming languages and sensors is a promising approach to increase interest in CS. According to Woods, during creative learning activities one of the main benefits is that "pupils have control over their own learning processes, and ownership of the knowledge produced, which is relevant to their concerns" (p.3). Similarly, regarding collaboration during creative learning activities, Jeffrey and Craft, indicated that "findings have shown that young students use their imagination and experience to develop their learning; they strategically collaborate over tasks; contribute to the classroom curriculum and pedagogy; and evaluate critically their own practices. Hence, when creating interactive programming and IT experiences, in general the following three conditions should be strived for: 1) active engagement in the learning process; 2) personal connection and 3) creating projects that are of value to a larger community.

The project builds on the experience gained with implementation and dissemination of creative activities for children based on makers' event based on open source hardware/software (like Arduino, 3D printers) and recycled materials.

RESEARCH GOAL AND METHODS

Research questions

The problem foundation of this PhD project may be expressed by the following research question

RQ: How could practices for computer science education become more attractive and effective for students and especially female students?

In order to investigate this overall question and its parameters the following sub questions (SQ) have been set as a part of this research.

SQ1. What is the role of creativity in teaching methods of computer science?

SQ2. Does programming environments like Scratch, Arduino and 3d printers have positive impact on students' attitudes and effectiveness on learning programming?

SQ3. How teaching methods enriched with digital tools could aid students improve their performance in coding, computational skills and problem solving?

Research method, data collection and analysis

In order to develop a theoretical understanding of issues of teaching practices of computer science and programming in and outside of schools, I will follow iterative cycles, starting by surveying existing methods and their limitations in explaining the impact of novel characteristics that would support learning. The project will seek to have scenarios for schools focused on high school and first year CS students, and learning activities of different types, e.g. collaborative games, supervised or unsupervised project work, constructionist approach.

Initially, the goal is to examine which are the current methods that include programming environments used to introduce and teach programming concepts to students (SQ1). I have already executed an in-depth literature review which was mainly focused on the making approach to teaching and learning STEM and CS concepts. The review included a variety of making activities using digital tools that promote learning, creativity and engagement to students. The findings helped me identify which are the tools and methods used, in which subject areas and how the making types of instructions were designed. Despite the fact that the most popular and effective tools are Scratch and Arduino, there are also other relevant programming environments that have promising results and need further investigation. Overall results showed that students can achieve a satisfying level of learning CS, engineering and STEM, as well as gain a positive attitude towards programming.

Up to date, I have completed a preliminary field study, in Kodeloypa workshop which is part of NTNU University in Trondheim, Norway. The program, dedicated to computer science education is based on constructionism and the hypothesis that the interactions between the young students and artifacts in a creative activity are vital [12, 13]. In this program students (15 years-old that have none or very little experience with programming) introduced to programming by playfully interacting with digital artifacts that also exhibit physical and aesthetical characteristics. Such artifacts allow students to learn by collaborating and iteratively testing and rebuilding their designs [4] using Scratch and Arduino. There are 105 students in total that attend the one-day workshop during Autumn 2015.

Data from this project were collected through a post questionnaire that measures students' attitudes to programming. Also students answered open ended questions by writing their thoughts and impressions towards their workshop experience. Observations used to record students verbal and physical acts during programming activities. In addition, the final code of their projects was kept for further analysis.

The research will follow to find answers to the sub questions of my research (SQ2, SQ3). As there are different approaches of teaching, I will design a computer science curriculum in line with constructionism using a combination of tools that permit also physical computing. My decision was influenced by a field work (Kodeloypa workshop). To examine the new teaching methods applied we will focus on schools, University and workshops that take place in Norway.

Data collection and analysis

Instruments to collect the data will be Pre/post questionnaires which will contain test items both for quantitative and qualitative data such as open-ended questions. Also observations, interviews and students' final projects will also give the perception of Computer Science concepts and their attitudes towards programming. Main focus will be also on measuring Learning outcome as well as their engagement [21]

The revised Bloom Taxonomy and the framework of meaningful learning [19, 26] are planed to be used as tools to analyze the students' learning of CS concepts, computational skills and disciplines in general during the activities. A triangulation among different types of evaluation will be used to ensure accuracy of the reported results. As well, findings from our studies and repetitive literature research will help us extend our research by setting a new starting point.

CONCLUSION

Large amount of different software and hardware is available and already used to support learning and teaching. This aspect brings in front many opportunities for improving the learning process and lower the distance from a more creative and innovative way of learning. Application and evaluation of enriched methodologies and tools are critical steps toward helping researchers and educators understand different aspects of what students learn through these pedagogical approaches. Teachers struggle to efficiently interleave problem-solving activities with creative activities in ways to promote learning while maintaining student interest, while providing 21rst century skills.

ACKNOWLEDGMENTS

I would like to thank my supervisors, Letizia Jaccheri and Michail Giannakos (Department of Computer & Information Science, Norwegian University of Science and Technology (NTNU), letizia.jaccheri@idi.ntnu.no, michail.giannakos@idi.ntnu.no), for their support.

REFERENCES

[1] B Adams, J. 2007. Alice, Middle-Schoolers, and The Imaginary Worlds Camps. *In Proceedings of ACM technical symposium on Computer Science Education* (SIGCSE'07), 307–311

[2] Balter, O., Bailey, D. 2010. Enjoying Python, processing, and Java in CS1. *ACM Inroads* 1, 4: 28-32

[3] Buechley, L., Eisenberg, M., Catchen, J., and Crockett, A. 2008. The LilyPad Arduino: Using Computational Textiles to Investigate Engagement, Aesthetics, and Diversity in Computer Science Education. *In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '08), 423-432

[4] Cassell, J. (2004). Towards a Model of Technology and Literacy Development: Story Listening Systems, *Journal of Applied Developmental Psychology* 25, 75-105.

[5] Cooper, S., Dann, W., Pausch, R. 2000 Alice a 3-D tool for introductory programming concepts. *Journal of Computing Sciences in Colleges* 15, 5: 107-116

[6] Cooper, S., et al. 2003 Teaching Objects-first in Introductory Computer Science. *In Proceedings of ACM technical symposium on Computer Science Education* (SIGCSE'03), 191-195

[7] Cooper, S., Dann, W., and Pausch, R. 2003. Teaching objects-first in introductory computer science. *In ACM SIGCSE Bulletin* 35, 1: 191-195

[8] Craig, A., Fisher, J., Forgasz, H. 2011. Evaluation framework underpinning the digital divas programme. In: *Proceedings of ITiCSE 2011*, 313-317

[9] Denner, Jill, Linda Werner, and Eloy Ortiz. 2012 Computer games created by middle school girls: Can they be used to measure understanding of computer science concepts? *Computers & Education* 58, 1: 240-249.

[10] Eisenberg, M., Elumeze, N., MacFerrin, M., and Buechley. L. 2009. Children's programming, reconsidered: settings, stuff, and surfaces. *In Proceedings of the 8th International Conference on Interaction Design and Children* (IDC '09*)*, 1-8

[11] Jaccheri, Letizia, and Guttorm Sindre. 2007. Software engineering students meet interdisciplinary project work and art. *Information Visualization, 11th International Conference* (IV'07), 925-934)

[12] Jaccheri, L., and Giannakos, M. N. 2012. Open source software for entertainment. *In Proceedings of Entertainment Computing* (ICEC '12), Springer LNCS, 604-607

[13] Giannakos, M. N., and Jaccheri, L. 2013. Designing creative activities for children: the importance of

collaboration and the threat of losing control. *In Proceedings of the 12th International Conference on Interaction Design and Children* (IDC ’13) 336-339

[14] Giannakos, M. N., and Jaccheri, L. 2013. What motivates children to become creators of digital enriched artifacts?. *In Proceedings of the 9th ACM Conference on Creativity & Cognition* (C&C ’13) 104-113

[15] Giannakos, M. N., and Jaccheri, L. 2014. Code Your Own Game: The Case of Children with Hearing Impairments. *In Entertainment Computing* (ICEC ’14) Springer Berlin Heidelberg, 108-116

[16] Giannakos, M. N., Jaccheri, L., and Leftheriotis, I. 2014. Happy Girls Engaging with Technology: Assessing Emotions and Engagement Related to Programming Activities. In Learning and Collaboration Technologies. Designing and Developing Novel Learning Experiences, 398-409

[17] Giannakos,M., Jaccheri, L. Proto. R. 2013. Teaching Computer Science to Young Children through Creativity: Lessons learned from the case of Norway. *In Proceedings of Computer Science Education Research Conference* (CSERC '13), 103-111

[18] Guzdial, M. 2009. Teaching Computing to Everyone. Communications of the ACM (CACM) 52, 5: 31-33

[19] Howland, J., Jonassen, D., and Marra, R. 2011. Meaningful Learning with Technology. (4th Ed.) Pearson Education, Inc.

[20] Henriksen, P., Kölling, M. 2004. Greenfoot: combining object visualisation with interaction. *In: Conf. on Object Oriented Prog. Systems Languages and Applications*, 73-82

[21] Henrie, C. R., Halverson, L. R., & Graham, C. R. (2015). Measuring student engagement in technology-mediated learning: A review. *Computers & Education*, *90*, 36-53.

[22] Høiseth, M. Giannakos and L. Jaccheri L. 2013. Research-Derived Guidelines for Designing Toddlers' Healthcare Games. *In Extended Abstracts on Human Factors in Computing Systems* (CHI EA '13), 451-456.

[23] Høiseth, M. Giannakos, M. Alsos, O. and Jaccheri. L. and Asheim, J. 2013. Designing Healthcare Games and Applications for Toddlers, *In Proceedings of the 12th International Conference on Interaction Design and Children* (IDC '13), 137-146

[24] Jeffrey, B and Craft, A. 2004. Teaching creatively and teaching for creativity: distinctions and relationships. *Educational Studies* 30,1: 77-87

[25] Kafai, Yasmin B. 2006. Playing and making games for learning instructionist and constructionist perspectives for game studies. *Games and culture* 1.1: 36-40

[26] Lorin W. Anderson, David R. Krathwohl, Peter W. Airasian, Kathleen A., Eds. 2001. A Taxonomy for Learning, Teaching and Assessing. A Revision of Bloom's Taxonomy of Educational Objectives. Addison-Wesley Longman.

[27] Maloney, J., Resnick, M., Rusk, N., Silverman, B. and Eastmond, E. 2010. The scratch programming language and environment. *Trans. Comput. Educ.* 10, 16: 1-15

[28] Niguidula, D., and Van Dam, A., 1986. Pascal on the Macintosh: A Graphical Approach. Addison-Wesley Longman Publishing Co.

[29] Revelle. G. L. 2003. Educating via entertainment media: The Sesame Workshop approach. *Comput. Entertain.* (CIE), 1, 1, 7

[30] Roque, R., Kafai, Y., and Fields. D. 2012. From tools to communities: designs to support online creative collaboration in scratch. *In Proceedings of the 11th International Conference on Interaction Design and Children* (IDC ’12), 220-223

[31] Tai, R. et al. Planning early for careers in science. Science 312, 1143–1144, (2006) Tai, R. H., Liu, C. Q., Maltese, A. V., and Fan, X. 2006. Planning early for careers in science. *Life sci,* 1, 0-2,

[32] Webb, D.C., Repenning, and A., Koh, K.H 2012. Toward an emergent theory of broadening participation in computer science education. *In Proceedings of the 43rd ACM technical symposium on Computer Science Education* (SIGCSE ’12) 173-178

[33] Woods, P. 1995. Creative Teachers in Primary Schools. Buckingham: Open University Press.