Teaching Tip: Flipping the Class to Engage Students in Learning Programming Algorithms

Cristina Hava Muntean
School of Computing, National College of Ireland, Mayor Street, IFSC, Dublin 1, Ireland
Cristina.Muntean@ncirl.ie

Abstract: Flipped Classroom as pedagogical model is a new trend in teaching and learning that is applied when teaching STEM subjects at undergraduate level. This pedagogy involves, studying at home the theory and practicing in the classroom. Therefore, increased in-class practical hours can be achieved. This paper introduces the proposed Flipped Classroom based course design methodology for programming courses and presents a pilot study that made use of the methodology when teaching advanced programming concepts such as sorting and search algorithms as part of a programming module at National College of Ireland. Students perception towards Flipped Classroom pedagogy was instigated in terms of engagement and satisfaction. Majority of students confirmed that they found that Flipped Classroom is more engaging than traditional classroom teaching and improved their learning on the studied topics. The results also show that Flipped Classroom is effective in teaching programming concepts and provides an enjoyable learning experience.

Introduction

With the latest technology advancements, the vast majority of the students have a computer or a mobile device that can connect to the internet. They do also love to watch videos and access information on a daily basis. Therefore, Flipped Classroom as pedagogical model is new trend in teaching and learning that is applied when teaching STEM subjects at undergraduate level. FC is defined as "a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (Flipped Learning Network, 2014). Flipped classroom teaching method involves, studying at home the theory and practicing in the classroom. Students are required to watch video lectures, to view teaching slides, to listen to screencast and to read materials before coming to the class. Then, the class session is devoted to effective learning tasks, practicing the basic knowledge acquired at home through group and individual problem solving exercise, discussion, and experiments.

This new teaching approach supports student-centered learning, students become more actively engaged in their learning process, can improve students' self-learner skills (Mason, 2013), and develops problem solving critical thinking, creativity, communication and collaboration skills. One of the key benefits of preparing at home is that students can save their valuable class time for reinforcing content learned and clarifying any struggle they have (Enfield, 2013). Although this new teaching approach has many advantages there are also many challenges to be addressed such as developing materials for both online and in-class activities, preparing lecturer own videos and there is no guarantee that students will do the assign homework.

Various research studies have investigated the benefits of applying flipped classroom, in different modules such as computer networking (Chen, Wang, Kinshuk, & Chen, 2014), mathematics (Bradford, Muntean, & Pathak, 2014), statistics (Touchton, 2015), biology (Jensen, Kummer, & Godoy, 2015), or pharmaceutics (McLaughlin et al., 2014). In the Computer Science domain, computer programming courses are considered to be very difficult. Programming is a very useful skill and it is fundamental in computer science education. Various research (Alhazbi, 2016; Horton, 2015; Chis et al., 2018) has reported their experiences of using Flipped Classroom when teaching programming skills. The results showed increased student attendance and higher engagement. However, there are no clear guidelines and standards on how to implement this instructional model in teaching programming.

Karaca and Ocak (Karaca, 2017) have applied the Flipped Classroom approach to a computer science course on algorithms and programming, in order to evaluate its impact on students' cognitive load. The results showed that the students from the flipped group had lower cognitive load than the students from traditional face-to-face classroom. The main limitation of this study was that it was a bit narrow in scope by only looking to student's cognitive load and did not present other factors that may impact on their cognitive load.

The research work presented in this paper is part of the European Union Horizon 2020 NEWTON project that focuses on design, development and deployment of TEL innovative educational solutions for all levels of

education, starting from primary to third degree institutions hosted on its learning management system, NEWTON TEL Platform (NEWTELP). NEWTON Project's innovative technologies include Augmented Reality and Virtual Reality (AR/VR) (Bogusevschi et al., 2018), Virtual Teaching and Learning Laboratory (Ghergulescu et al. 2018; Bogusevschi et al., 2019), adaptive and personalised multimedia and multiple sensorial media (mulsemedia) (Bi, et al., 2018; Moldovan & Muntean, 2017; Moldovan et al. 2016), personalisation and gamification (El Mawas et al., 2018a), interactive educational computer-based video games (El Mawas et al., 2018b). Different innovative pedagogical approaches are also deployed as part of the teaching and learning process such as flipped classroom, game-based and problem-based learning (Muntean et al., 2018; Muntean et al., 2017; Zhao et al., 2018; El Mawas et al., 2018c; Muntean et al., 2017, Zhao et al., 2019). A multitude of Small and Large-Scale educational TEL pilots have and are currently being carried out in different European schools and universities, assessing knowledge acquisition benefits, learner experience, learners interest in STEM subjects, platform usability and teachers' feedback following the use NEWTON's innovative solutions.

This paper introduces the proposed Flipped Classroom based course design methodology for programming courses and presents results of a case study that made use of the proposed four stages based methodology when teaching advanced programming concepts such as sorting and search algorithms as part of a programming module at National College of Ireland. The purpose of this study was to investigate the perception of students towards Flipped Classroom methodology applied in a programming module. The suitability of the proposed Flipped Classroom based course design methodology to teach computer programming topics is also discussed.

Flipped Classroom based Course Design Methodology

This section provides a description of the research methodology and proposed course design methodology that involved the use of Flipped Classroom pedagogy in the teaching process. Table 1 presents in detail the proposed four stages based methodology to be followed when Flipped Classroom pedagogy is applied on a programming course. The proposed methodology was applied in the teaching process of the Advanced Programming module delivered to 3rd year undergraduate students.

Stage 1: Learning Management System Set-up • A course management system (e.g. Moodle) must be used to provide access to videos, PowerPoint slides, in-class activities, quizzes and other materials. • Access restrictions are set-up on the provided materials to ensure sequential access (e.g. first, watch the videos, then complete a mini- quiz and after that access to slides, samples of code and in-class activities is provided)
Stage 2: Educational Material Development • Short video lectures up to 5 minutes in length are created introducing the principles of a particular topic • Other materials such as PowerPoint slides, samples of programming code, in-class activities, mini-quizzes are also created. •
Stage 3: In-class Activities • An online mini quiz is given to the students at the beginning of the class to assess students' out-of-class preparation and to provide feedback to the students on their learning • Brief review of out-of-class concepts studied is provided by the lecturer • In-depth concepts are taught by the lecturer and extra materials (e.g. slides, samples of code or pseudocode) are provided to the students though the course management system • In-class practical based activities are given to the students. Students may work in a group of 2-3 people or individually on the given tasks • The lecturer interacts with the students, provides instant feedback and assesses students' progress. • Materials (e.g. videos) to be studied out-of-class for the next week teaching session are enabled in the course management system before finishing the class. Students are reminded about out-of-class preparation
Stage 4: Students Feedback • An online survey that collects feedback from the students regarding their learning experience is provided in the class at the end of a full cycle of flipped classroom pedagogy based teaching process • Survey results are used to adapt the materials and the in-class activities for the next cohort of students.

Table 1. Stages for Flipped Classroom pedagogy deployment on a programming course

The Flipped Classroom pedagogy was used to teach the following sorting and search algorithms: bubble sort, insertion sort, linear search and binary search over a 5-week period. A set of two short videos, up to 5 minutes as duration, was created for each of the four algorithms. Each set of videos explained the principle of an algorithm and an exemplification on how the algorithm is applied in a real life scenario was provided.

Students were asked to watch the videos in advance of the class session that covered a particular algorithm. They were allowed to watch the videos as many times they wanted. In return, classroom time was utilized by the lecturer to explain the pseudo-code of the algorithm and to provide support to the students on the practical element of the module using PowerPoint slides and samples of Java code lines. The students were given in the class the activity to practice the implementation and testing of the algorithm and to raise and answer questions. The lecturer and two teaching assistants provided constant support and feedback to the students during the class session.

Case Study Results

51 undergraduate students, 20% females and 80% males enrolled into Advanced Programming module part of the BS(Hons) in Computing course, year 3 degree, provided by National College of Ireland, took part in study. The module was delivered during Semester 1 of the academic year 2017/2018. Figure 1 and Figure 2 show the students age distribution and what type of students are. 72% of the students were young, up to 24 years old.

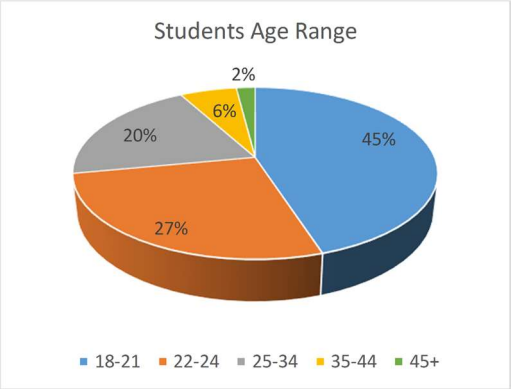

Figure 1 Distribution of Students Age

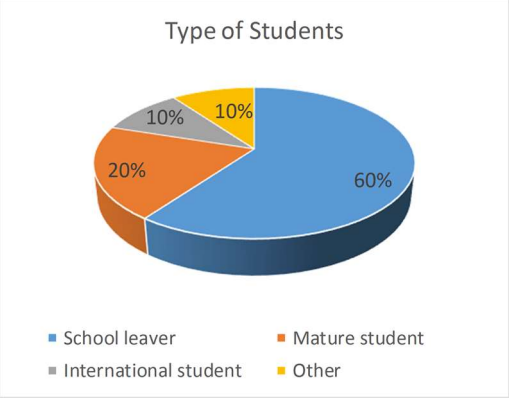

Figure 2 Distribution of Type of Students

The perception of students towards Flipped Classroom methodology applied in a programming module was investigated through a questionnaire, provided at the end of the case study as part of stage 4 presented in Table 1. The questionnaire consisted of 14 quantitative questions that assessed students' opinion on problem solving skills, self-directed learning, flipped classroom based learning environment, satisfaction, and engagement. Each question was answered on a 1 to 5 Likert scale (1 – never, 2- rarely, 3-sometimes, 4- often and 5 – always). Questions that assess learner engagement and satisfaction with the Flipped Classroom pedagogy are analysed and discussed now. The final version of the paper will present an analysis of the other questions from the questionnaire.

Learner Engagement

Error! Reference source not found. Table 2 shows the distribution of the answers given by the students to the 3 questions that have assessed student's engagement when Flipped Classroom pedagogy was applied. The aggregated result shows that the students rated their engagement, on average, at 3.83. The students rated the second question that compares Flipped Classroom versus traditional teaching, on average, at 3.93 that is very close to option 4 - often. These results clearly show that the Flipped Classroom teaching approach applied in a programming course does aid in engaging the students in learning.

Questions	Responses				
	5- Always	4 - Often	3 - Sometimes	2 - Rarely	1 – Never
I regularly watch/ will watch again the videos	22%	37%	24%	14%	4%
The Flipped Classroom is more engaging than traditional classroom teaching.	35%	39%	10%	16%	0%
I felt more motivated to learn about sorting and searching algorithms	33%	41%	14%	10%	2%

Table 2. Students answers to questions on engagement

Learner Satisfaction

Table 3 shows the distribution of the answers given by the students to the four questions that have assessed students' satisfaction when Flipped Classroom methodology was applied. The aggregated result shows that the students rated their satisfaction, on average, at 3.92. The answers given to the first question shows that 74% considered that flipped classroom has improved their learning on sorting and searching algorithms and the average rate is 3.95.

Overall, the results of the study show that Flipped Classroom pedagogy is suitable for teaching programming concepts, engage the students in learning and is well appreciated by the students.

Questions	Responses				
	5- Always	4 - Often	3 - Sometimes	2 - Rarely	1 – Never
The Flipped Classroom has not improved my learning of sorting and searching algorithms.	4%	10%	12%	35%	39%
Short flipped learning videos are more effective than traditional face-to-face lectures.	31%	33%	24%	6%	6%
I like watching the lessons on video.	45%	27%	16%	10%	2%

Table 3. Students answers to questions on their satisfaction with the Flipped Classroom methodology

Conclusions

This research paper presented a Flipped Classroom based course design methodology for programming courses and investigated the use benefits of proposed design methodology when teaching programming concepts at undergraduate students. A case study was run over a five week teaching period and made use of this methodology applied on Advanced Programming. Students perception on Flipped Classroom based methodology applied in the class was investigated through a questionnaire, provided at the end of the case study. Students feedback in terms of enjoyment and satisfaction with the proposed teaching methodology was collected. Majority of students (84%) confirmed that they found that Flipped Classroom technique is more engaging than traditional classroom teaching and improved their learning on the studied topics. The results also show that Flipped Classroom is effective in teaching programming concepts (88% of students confirmed this) and provides an enjoyable learning experience. This methodology also supports the paradigm "create once, use many use anywhere" (Muntean et al., 2007), in terms of educational content development. Therefore, we recommend lecturers to explore the possibility of utilizing this teaching method.

As users (e.g. students) of educational and training services expect not only high-quality videos and efficient educational material but also a perfect integration of the educational material with the day-to-day operational environment (Muntean, it its word to be explored as future work user Quality of experience when accessing the video clips from their own mobile devices (e.g. laptop, smartphone).

Acknowledgments

This research is supported by the NEWTON project (http://www.newtonproject.eu/) funded under the European Union's Horizon 2020 Research and Innovation programme, Grant Agreement no. 688503

References

Alhazbi, S. E. (2016). Using flipped classroom approach to teach computer programming. In Proceedings of IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE), Bangkok, Thailand. pp. 441-444

Bi, T., Pichon, A., Zou, L., Chen, S., Ghinea, G., & Muntean, G.-M. (2018). A DASH-based Mulsemedia Adaptive Delivery Solution . *ACM Multimedia Systems Conference (MMSys), International Workshop on Immersive Mixed and Virtual Environment Systems (MMVE).* Amsterdam, The Netherlands, pp. 1-6

Bogusevschi, D., Tal, I., Bratu, M., Gornea, B., Caraman, D., Ghergulescu, I., Muntean, H. C. & Muntean, G.M. (2018). Water Cycle in Nature: Small-Scale STEM Education Pilot. Proceedings of AACE EDMEDIA+ Innovative Learning: World Conference on Educational Media and Technology, Amsterdam, Netherlands, pp. 1496-1505

Bogusevschi, D., Muntean, H. C. & Muntean, G.M. (2019). Teaching and Learning Physics using 3D Virtual Learning Environment: A Case Study of Combined Virtual Reality and Virtual Laboratory in Secondary School. AACE 30th Annual conference of the Society for Information Technology and Teacher Education (SITE 2019), Las Vegas, USA

Bradford, M., Muntean, H. C., & Pathak, P. (2014). An analysis of flip-classroom pedagogy in first year undergraduate mathematics for computing. Proceedings of the IEEE Frontiers in Education Conference (FIE), Spain, pp.1-5.

Chen, Y., Wang, Y., Kinshuk, & Chen, N.-S. (2014). Is FLIP enough? Or should we use the FLIPPED model instead? *Computers & Education*, *79,* 16–27.

Chis, A.E., Moldovan, A.N., Murphy, L., Pathak, P. & Muntean, C.H. (2018). Investigating Flipped Classroom and Problem-based Learning in a Programming Module for Computing Conversion Course. *Educational Technology & Society, 21(4)*, pp. 232-247

El Mawas, N., Ghergulescu, I., Moldovan, A.-N. & Muntean, C.H. (2018a). Pedagogical based Learner Model Characteristics. Ireland International Conference on Education (IICE), Dublin, Ireland, April, 2018

El Mawas, N., Tal, I., Moldovan, A. N., Bogusevschi, D., Andrews, J., Muntean, G.-M., & Muntean, C. H. (2018b). Final Frontier Game: A Case Study on Learner Experience. Proceedings of the 10th International Conference on Computer Supported Education (CSEDU). Madeira, Portugal, pp. 122-129

El Mawas, N., Bradford, M., Andrews, J., Pathak, P. & Muntean, C.H. (2018c). A Case Study on 21st Century Skills Development Through a Computer Based Maths Game. Proceedings of AACE EDMEDIA+ Innovative Learning: World Conference on Educational Media and Technology, Amsterdam, Netherlands, pp. 1160-1169.

Enfield, J. (2013). Looking at the Impact of the Flipped Classroom Model of Instruction on Undergraduate Multimedia Students at CSUN. *Technology Trends*. Vol. 57, No. 6, pp. 14-27

Flipped Learning Network. (2014). The Four Pillars of FLIPTM. Retrieved from http://www.flippedlearning.org/cms/lib07/VA01923112/Centricity/Domain/46/FLIP_handout_FNL_Web.pdf (Access date: 12 February, 2019)

Ghergulescu I., Lynch, T., Bratu, M., Moldovan, A.N., Muntean, C.H. & Muntean, G.M. (2018). STEM Education with Atomic Structure Virtual Lab for Learners with Special Educational Needs. Proceedings of 10th annual International Conference on Education and New Learning Technologies (EDULEARN), Palma de Mallorca, Spain, pp. 8747-8752

Horton, D. & Craig, M. (2015). Drop Fail Pass Continue: Persistence in CS1 and Beyond in Traditional and Inverted Delivery. Proceedings of the 46th ACM Technical Symposium on Computer Science Education, pp. 235-240

Jensen, J. L., Kummer, T. A., & Godoy, P. D. d M. (2015). Improvements from a flipped classroom may simply be the fruits of active learning. CBE-Life Sciences Education, 14(1).

Karaca, C., & Ocak, M. A. (2017). Effect of Flipped Learning on Cognitive Load: A Higher Education Research. *Journal of Learning and Teaching in Digital Age* (JOLTIDA), 2(1), 20–27

Mason, G., Shuman, T., & Cook, K. (2013). Comparing the Effectiveness of an Inverted Classroom to a Traditional Classroom in an Upper Division Engineering Course. *IEEE Transaction in Education*. Vol. 56, No. 4, pp. 430-435

McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M. & Mumper, R. J. (2014). The flipped classroom: A course redesign to foster learning and engagement in a health professions school. Academic Medicine, 89(2), 236–243.

Moldovan, A. N., & Muntean, C. H. (2017). QoE-aware Video Resolution Thresholds Computation for Adaptive Multimedia. *IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (MBSB).* Cagliari, Italy, pp. 1-6

Moldovan, A.-N., Ghergulescu, I., & Muntean, C. H. (2016). VQAMap: A novel mechanism for mapping objective video quality metrics to subjective MOS scale. *IEEE Transactions on Broadcasting, Vol. 62(3),* 610-627

Muntean, C.H., El Mawas, N., Bradford, M., & Pathak, P. (2018). Investigating the impact of an immersive computer-based math game on the learning process of undergraduate students. Proceedings of the 48th IEEE Annual Frontiers in Education Conference (FIE), San Jose, CA, pp. 1-7

Muntean, C. H., Andrews, J., & Muntean, G.-M. (2017). Final Frontier: An Educational Game on Solar System Concepts Acquisition for Primary Schools. *17th IEEE International Conference on Advanced Learning Technologies (ICALT).* Timisoara, Romania, pp. 335-337

Muntean, C.H., Muntean, GM., McManis, J., & Cristea A.I. (2007). Quality of Experience-LAOS: create once, use many, use anywhere. *International Journal of Learning Technology 3 (3),* 209-229

Muntean, C.H., & McManis, J. (2006). End-user Quality of Experience oriented adaptive e-learning system. Journal of Digital Information, 7(1).

Touchton, M. (2015). Flipping the classroom and student performance in advanced statistics: evidence from a quasi-experiment. Journal of Political Science Education, 11(1), 28–44.

Zhao, D., Chis, A. E., Muntean, G.-M., & Muntean, C. H. (2018). A large-scale Pilot Study on Game-based Learning and Blended Learning Methodologies in Programming Courses. *10th annual International Conference on Education and New Learning Technologies (EDULEARN).* Palma de Mallorca, Spain, pp. 3716-3724

Zhao, D., Muntean, C. H. & Muntean, G.-M. (2019). The Restaurant GAME: A NEWTON Project Serious Game for C Programming Course, AACE 30th Annual conference of the Society for Information Technology and Teacher Education (SITE 2019), Las Vegas, USA.