Improving Learning Satisfaction in a Programming Course by Using Course-Level Personalisation with NEWTELP

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***Abstract*—On one side, there is an increasing amount of learning material available on the Internet and an increasing use of technology in learners' daily activities. On the other side, we see high level of disengagement in STEM area and a need for effective technology-based teaching and learning that can improve learning effectiveness, efficiency and learner satisfaction. This paper investigates the impact of employing personalisation in a programming module delivered at undergraduate level through the NEWTELP platform. Preliminary results have shown that students perceived that personalisation has improved their learning experience and their learning outcomes.**

Keywords—personalization, learning experience, programming, technology-enhanced learning, pilot

I. INTRODUCTION

Many developed countries worldwide and especially in Europe are experiencing a crisis amongst their young generations in respect of scientific education. The number of students specialising in science, mathematics and computing disciplines is declining, raising issues regarding the capabilities of countries to innovate [1], [2]. If this tendency is not changed, Europe and the whole world will be facing a risk of severe shortage of scientists. Related to this shortage, there is strong evidence that many young people's disengagement from the STEM area starts during the secondary education level [3]. In many countries, students start choosing which subjects they wish to study at an early age. There are several factors for disengagement, but there are two that outstand: the secondary school students' perception that scientific subjects are difficult, and ii) science careers are seen less 'profitable' than other options in terms of job quality and pay levels.

Several initiatives have addressed these aspects by focusing on formal teaching and learning at different levels, trying to attract students towards STEM subjects. However, there is a need also for non-formal science education to encourage students to pursue STEM careers and to disseminate the benefits of science using the latest technological and pedagogical advancements.

Among these initiatives, NEWTON project (http://www.newtonproject.eu) a large EU Horizon 2020 Innovation Action project designs, develops and deploys innovative solutions for technology-enhanced learning (TEL) involving delivery of state-of-the-art STEM content to diverse learner audiences. The NEWTON innovative technologies include solutions for adaptive and personalised multimedia and multiple sensorial media (mulsemedia) delivery, augmented and virtual reality (AR/VR) enhanced learning, virtual teaching and learning labs, remote fabrication labs and gamification. These technologies are used in conjunction with different pedagogical approaches including self-directed, game-based learning and problem-based learning methods.

This paper focuses on studying how employing course level personalisation as part of the approaches proposed by the NEWTON project will positively influence learner satisfaction and perceived learning outcome.

II. LITERATURE REVIEW

A. Personalisation in TEL

Extensive research work has focused on user modelling and personalisation over the past few decades. Some of the main areas of research include: learner modelling for delivering adaptive and personalised e-learning solutions [4], modelling and monitoring of users' emotional states based on usage patterns [5], [6], human usage and mobility usage patterns in telecommunication networks [7], users' attitudes and behaviour with regard to mobile devices energy consumption [8], [9], users' interaction with media technologies and services [10], users' perceived quality of experience [11], [12], user modelling on social networks for personalised media recommendations[13], and learning recommendations [14].

Research and standardisation effort was also put towards user model interoperability in multi-application scenarios, which refers to enabling applications and services to exchange user model elements and use the exchanged information to enrich the overall user experience [15].

While user modelling and personalisation opens new challenges and privacy concerns [16], the EU also recognizes the importance of user modelling and personalisation for today's digital age. In such a context EU has funded or is presently funding a number of projects among which it is worth mentioning the VUMS (virtual user modelling and simulation

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standardization)[1] cluster that represents a cooperation between the VERITAS[2], VICON[3], MyUI[4], GUIDE[5] and VAALID[6] projects, on their common issues regarding user modelling.

B. Case Studies in Programming Courses

Current research work indicates personalised gamification as a new teaching approach applied in programming modules. For example, Antonaci et al. [17] developed an algorithm based on student behaviour and their profile types, where different game elements and gamification tasks are provided to students while they interact with the educational content. However, no case study evaluation results of the proposed personalised gamification algorithm were provided in the paper. A theoretical framework of personalisation in gamification was proposed by Knuttas et al. [18]. Relationships between game genres, learning techniques and learning styles are considered in the personalisation process, and game genres recommendations for certain learning styles are proposed. Zaric et al. [19] have proposed a model for personalisation of gamification in programming e-learning environments based on students learning style. The relationship between different students' profiles and game elements were investigated. Preliminary results showed statistically significant interconnections between learning styles, game elements and their mutual influence.

Apart of gamification, the learning analytics field has also been recently researched as a new avenue for providing personalised learning. Various events (e.g., key strokes, program edits, compilations, executions and submissions [20] that occur during the learning, teaching and assessment process have been considered in the process of providing a personalised learning environment. PredictCS [21] automatically detects lower performing or "at-risk" students in programming courses and adaptively sends them feedback thus providing a personalised learning. Student characteristics, prior academic history, logged interactions between students and online resources, and students' progress in programming laboratory work are used to build predictive models.

Augmentation of the IDE programming environment is another approach that is being researched and enables personalised learning in programming courses. BlueFix [22] and HelpMeOut [23] systems recommend to the students error corrections that peers have applied before for the same type of code programming errors.

III. Course-Level Personalisation in NEWTELP

A. NEWTELP

The NEWTON Technology enhanced Learning Platform (NEWTELP) developed as part of the NEWTON project integrates and deploys a multitude of novel and emerging mechanisms and TEL methodologies. NEWTELP integrates several components on top of a Learning Management System including adaptive multimedia and multi-sensorial media distribution [24], gamification [25] and personalisation [26].

Adaptive multimedia delivery component [24], adapts the video delivery by changing parameters such as bitrate or resolution during the streaming process using an MPEG-DASH-based mechanism. The mechanism aims to maintain high user Quality of Experience (QoE) by performing content delivery adjustment according to the delivery network conditions. Mulsemedia is considered a new type that unlike classic multimedia that usually involves two senses (auditory, visual), involves three or more human senses (olfactory, haptic, etc.).

The Gamification component [25], [27] with its Gamification Portal allows the dynamic configuration of elements and rules in logically separated gamification containers to support a multi-tenant application through an easy-to-use UI. A large set of gaming parameters and conditions can be configured to assign typical rewards such as points, badges and levels. Leaderboards and players status are also managed by the Gamification Portal and provided as SaaS. Teachers can define their engagement strategy by configuring gamification elements rules based on the main events managed by NEWTELP and its content.

NEWTELP supports both instructional and assessment content through quizzes. Furthermore, NEWTELP supports integration of external content such as: augmented and virtual reality [28], educational games [29], [30], virtual labs [31]–[33] and fabrication labs [34].

B. NEWTELP Learner Model

NEWTELP Learner Model includes learner pedagogical characteristics, disability, affective state, and multisensorial preferences [26].

The *pedagogical characteristics* include demographic data (e.g., student name, gender, age, etc.), grouping data (e.g., college/school name the learner is enrolled, education level such as primary school, secondary school or university), learning preferences (e.g., preferred language, media presentation type, learning style that can be retrieved using questionnaires such as Index of Learning Styles (ILS), etc.), and course or learning activity-based information (e.g., knowledge level, completed tasks, assessments, accessed material, etc.). The learner disability information includes the disability type, the specific disability name, the disability level and any other relevant details.

The *learner affective based characteristics* include the learner motivation, described as student interest and self-efficacy when conducting the learning activity and his/her emotions that include both learning emotions and a subset from DEQ (Discrete Emotion Questionnaire). The *multisensorial characteristics* are related to what multisensorial devices are

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[1] VUMS, http://wiki.iao.fraunhofer.de/index.php/VUMS_-_Virtual_User_Modelling_and_Simulation_Standardisation

[2] VERITAS - Virtual and Augmented Environments and Realistic User Interactions to achieve Embedded Accessibility Designs, http://veritas-project.eu/

[3] VICON - Virtual User Concept for Inclusive Design of Consumer Products and User Interfaces, http://vicon-project.eu/

[4] MyUI - Mainstreaming Accessibility through Synergistic User Modelling and Adaptability, http://www.myui.eu/

[5] GUIDE - Guidelines for Teachers Working with Students with Medium-light Cognitive Impairment, http://www.guideproject.eu/

[6] VAALID - Accessibility and Usability Validation Framework for AAL Interaction Design process, http://www.vaalid-project.org/

available to the learner, as well as learner preferences regarding multi-sensorial aspects such as visual, olfactive, haptic and air flow. The media presentation characteristics are related to their media presentation choice.

The information stored in the NEWTON Learner Model is collected explicit from the user (e.g., through forms embedded into the platform), or it is provided by the learning system administrator when a user account is created. Some information is also collected implicit through logging and monitoring of learner's interaction with the learning platform.

C. Course Level Personalisation in NEWTELP

The personalisation focuses on recommending learning content/resources based on learner characteristics described in the Learner Model. The role of personalisation is to provide the most suitable version of content that best matches the learner profile specified in the Learner Model. The most suitable content version is determined based on the description of the content item, the user profile and best-matching algorithm. The best-matching algorithm implemented combines content pedagogical suitability rules, content type and information from the Learner Model. The content description and content pedagogical suitability are specified through metadata that is attached to each content item. The following type of metadata can be added to each content item disability, learning style, multimedia and multisensorial preferences.

Furthermore, mandatory content and learning activities are tagged at the content level. Content items or learning activities tagged as mandatory are provided to everyone and no personalisation is performed by the system. This is mainly useful when the teacher wants to perform a test in the class, to give a survey to the students or just to ensure that everyone receives a specific learning material. Content items can also be grouped in a sequence order. This allows the teacher to specify how the personalisation to be performed and to recommend learning activities in a specific sequence. For example, pre-tests could have a sequence group number of 1, learning materials could have a sequence group number of 2, and post-tests could have a sequence group number of 3. Quiz-based learning activities, that are tagged as scoring helpers, are used to update the learner knowledge level for each topic of the course. This enables personalisation through additional remedial content. Low performers will get access to remedial content. For example, if the student has a knowledge level lower than 40% (out of 100), he/she will receive additional remedial content.

The personalisation mechanism will determine first the next most suitable learning activity (i.e., given the sequence number) and the second most suitable content version given the information from the user model and the available content and its metadata. The workflow is presented in Fig. 1.

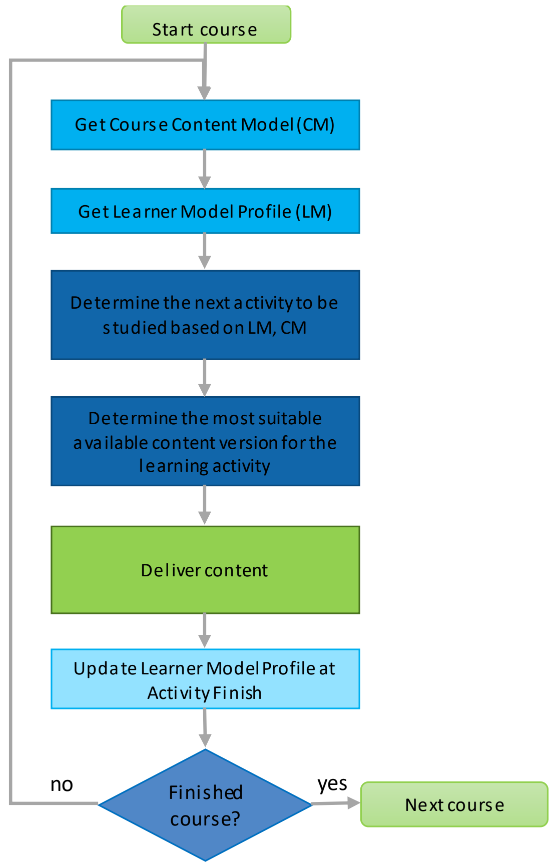

Fig. 1 Course level personalisation workflow in NEWTELP.

IV. Programming Pilot

A. The Programming Pilot and the Personalisation course on the Variables Topic

The personalisation mechanism was applied on the Variables topic part of a C++ programming module. The NEWTON Project Programming Large-Scale pilot was carried out on EM108 Software Development for Engineers module in Spring 2019 over a 12-week period. This module is offered to first year undergraduate students from School of Electronic Engineering, Dublin City University. 166 students participated in the pilot and they used the NEWTELP platform as their main Learning Management System to access the educational material and the learning activities provided by the lecturer.

Following a layered evaluation approach as suggested by Paramythis et al. [35], this paper evaluates the personalisation process that provides media presentation and remedial content. The other features of the personalisation mechanism will be evaluated in a different pilot study. The course-level personalisation applied on the Variables topic through media presentation and remedial content contained the following stages. Before starting the course, the students were informed of the mapping between different media presentation choices and the format of learning material they will receive, as shown in Table I. Then, the students were asked to select their media presentation preference under their profile stored by the NEWTELP platform, as illustrated in Fig. 2.

Students then were able to access the course on the NEWTELP platform, as illustrated in Fig. 3. The four materials circled in red are media presentation personalisation materials. Each student had access to the ones that correspond to their media presentation choices. It is worth noting that, though presented in different styles, all these four materials covered the same knowledge concepts. After they viewed/interacted with these materials, they were presented with a quiz, which, along with the remedial material, formed the personalisation through

TABLE I. MAPPING BETWEEN MEDIA PRESENTATION CHOICE AND FORMAT OF MATERIALS PRESENTED

Media Presentation Choice	Format of material presented
Image and text	Pdf
Interactive application	Serious game
Audio	Mp3
Multimedia	Mp4

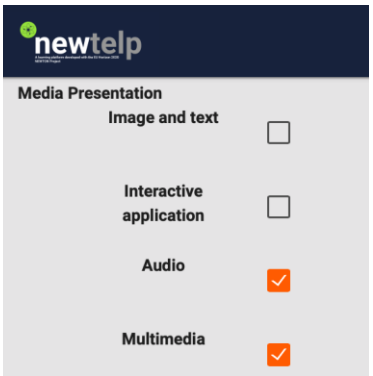

Fig. 2. Media presentation preferences under learner's profile

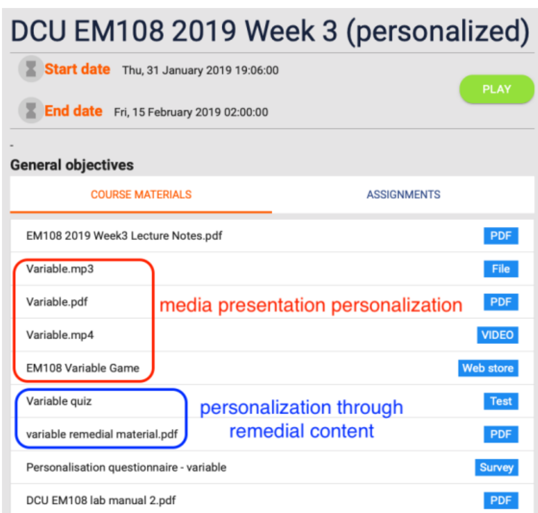

Fig. 3. Personalized course on Variable on the NEWTELP platform.

remedial content. If the student fails the quiz (i.e., got less than 40 out of 100 in the quiz), immediately following the quiz, he/she is presented with the remedial material. After studying the remedial material, the student is presented the same quiz again. The process repeats until the student passes the quiz.

B. *Methodology*

Knowledge tests and pre-questionnaires were given to the students at the beginning of the module. A post-test and post questionnaire were given to the students at the end of the module. Once the personalised course was completed, the students were asked to answer a questionnaire, which contains 10 questions, as listed in Table II. The questionnaire covered the following aspects:

TABLE II. QUESTIONS IN THE POST-PERSONALISATION COURSE QUESTIONNAIRE

#	Question
Q1	I'm satisfied with the materials given to me based on my media presentation preferences
Q2	I'm happy to read the remedial material given to me after the test
Q3	The remedial material helped me to fill my knowledge gap
Q4	Personalisation through media presentation improved my learning experience
Q5	Personalisation through remedial content improved my learning experience
Q6	Personalisation through media presentation improved my learning outcomes
Q7	Personalisation through remedial content improved my learning outcomes
Q8	I prefer to learn without media presentation personalization
Q9	I prefer to learn without remedial material
Q10	I would like to have more personalized learning experience in the future

1. Students' opinion on the quality of the personalised learning materials provided in the course (Q1, Q2 and Q3).
2. Students' opinion on whether the personalised course improved their learning experience (Q4 and Q5).
3. Students' opinions on whether the personalised course improved their learning outcomes (Q6 and Q7).
4. Whether the students prefer to learn without personalisation (Q8 and Q9) and if they were willing to have more personalised learning experience in the future (Q10).

Each question is answered on a 5-level Likert scale (i.e., strongly disagree, disagree, neutral, agree and strongly agree). Questions 2, 3, 5, 7, and 9, include one extra option "Not applicable, I passed the test in the first try, so no remedial material was given". Questions 4, 6, and 8, include the extra option "Not applicable, I didn't choose any media presentation preference in my profile, so I was not given any type of materials".

V. RESULTS

Valid answers in the post questionnaire were received from 117 students. The following type of answers were considered as invalid and excluded from our analysis: (i) incomplete questionnaire that had missed answers for one or more questions; and (ii) inconsistent answers, e.g., from students who indicated they passed the quiz in the first attempt and/or did not choose any media presentation preference in their profiles in some questions but answered otherwise in some other questions.

The results are summarised in Fig. 4. As can been seen from the results of Q1, Q2 and Q3, the materials provided by the NEWTELP platform to students during the personalised course achieved high satisfaction among students: 64% students agreed or strongly agreed that they were satisfied with the materials given to them based on their media presentation preferences; while only 6% disagreed or strongly disagreed; 63% students were happy to read the remedial content after the test while only 3% disagreed (note that 13% students passed the test on first

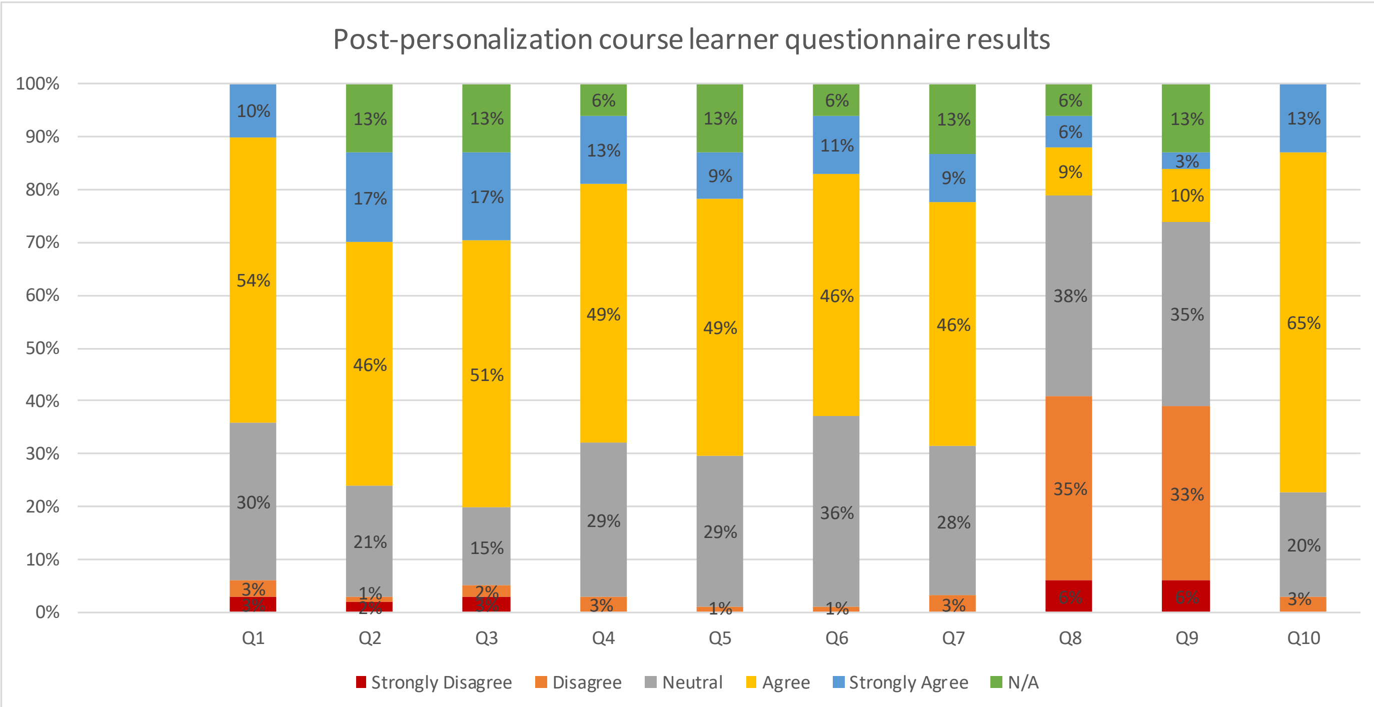

Fig. 4 Post-personalisation learner questionnaire results.

trial, so no remedial content was given to them); 68% students agreed or strongly agreed that the remedial content targeted their knowledge gap, while only 5% gave negative answers (again, 13% selected the "N/A" option because they passed the test on their first trial).

Q4 and Q5 investigated whether students thought the personalised course improved their learning experience. The results revealed that the majority of students believed their learning experience was improved. In particular, 62% of all students either agreed or strongly agreed that personalisation through media presentation improved their learning experience while only 3% disagreed (note that 6% selected "N/A" because they did not select their preferences, so no materials were presented to them). Regarding personalisation through remedial content, 58% of all students agreed or strongly agreed it improved their learning experience, while only 1% disagreed (note that 13% passed the quiz on first trial so no remedial content was given).

Students' opinion on whether the personalised course improved their learning outcomes was gathered through Q6 and Q7. Again, the majority of students gave positive feedback. For media presentation-based personalisation, 57% of all students agreed or strongly agreed, while only 1% gave negative feedback (6% selected "N/A"). For personalisation through remedial content, 55% of all students agreed or strongly agreed that it improved their learning outcomes while only 3% disagreed (13% selected "N/A").

Q8 and Q9 focused on students' attitude towards personalisation after their first personalised learning experience. As the results show, only 15% students agreed or strongly agreed they would prefer to learn without media presentation in the future and only 13% students indicated they would prefer to learn without remedial content. Moreover, Q10 results show that 78% of students would like to have more personalised learning experiences in the future while only 3% answered otherwise.

In summary, the personalisation mechanism applied on Variables topic achieved very positive feedback in the following aspects: 1) overall quality of materials in both media presentation-based personalisation and remedial content-based personalisation; 2) improved students' learning experience; 3) students' opinion on their learning outcomes. Furthermore, after this case study, personalisation was well accepted by most students and is welcomed in the future as well.

VI. Conclusions

Personalisation is one solution towards addressing issues such as learner's disengagement with STEM subjects and improving their learning experience. However, there is still a need to identify what personalisation layers and approaches will make a difference and what is their impact on learning outcomes and learning experience.

This paper introduced the NEWTELP personalisation component and the NEWTON Project Programming Large-Scale pilot that was deployed in DCU during 2019 Spring semester. The preliminary results have shown that students perceived that the personalisation at a course level improved their learning experience and improved their learning outcomes. Future work will focus on cross analysis of student's perception on personalisation as per all course sessions and analysis of the impact of personalisation on students' motivation aspects given the results from pre and post surveys. Moreover, future work will also use a within-subjects evaluation to assess the impact of personalisation on the learning outcomes by comparing topics that were personalised with topics that were not personalised.

REFERENCES

[1] OECD, "How is the global talent pool changing (2013, 2030)?," *Education Indicators in Focus*, vol. 5, Apr. 2015.

[2] I. Ghergulescu, C. Flynn, and C. O'Sullivan, "Adaptemy Science: Adaptive Learning for Science for Next Generation Classroom," presented at the E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education, 2015, pp. 1477–1482.

[3] C. van Tuijl and J. H. W. van der Molen, "Study choice and career development in STEM fields: an overview and integration of the research," *Int J Technol Des Educ*, vol. 26, no. 2, pp. 159–183, May 2016.

[4] P. Brusilovsky and E. Millán, "User Models for Adaptive Hypermedia and Adaptive Educational Systems," in *The Adaptive Web: Methods and Strategies of Web Personalization*, P. Brusilovsky, A. Kobsa, and W. Nejdl, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2007, pp. 3–53.

[5] I. Ghergulescu and C. H. Muntean, "ToTCompute: A Novel EEG-Based TimeOnTask Threshold Computation Mechanism for Engagement Modelling and Monitoring," *Int J Artif Intell Educ*, vol. 26, no. 3, pp. 821–854, Sep. 2016.

[6] I. Ghergulescu and C. H. Muntean, "Motivation Monitoring and Assessment Extension for Input-Process-Outcome Game Model:," *International Journal of Game-Based Learning*, vol. 4, no. 2, pp. 15–35, 32 2014.

[7] R. Trestian, F. Zaman, and G.-M. Muntean, "Spotted: Connecting People, Locations, and Real-World Events in a Cellular Network," *Handbook of Research on Innovations in Information Retrieval, Analysis, and Management*, pp. 1–40, 2016.

[8] M. V. J. Heikkinen, J. K. Nurminen, T. Smura, and H. Hämmäinen, "Energy efficiency of mobile handsets: Measuring user attitudes and behavior," *Telematics and Informatics*, vol. 29, no. 4, pp. 387–399, Nov. 2012.

[9] I. Ghergulescu, A.-N. Moldovan, and C. H. Muntean, "Energy-aware Adaptive Multimedia for Game-based E-learning," in *9th IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB 2014)*, Beijing, China, 2014, pp. 1–6.

[10] P. B. Brandtzæg, "Towards a unified Media-User Typology (MUT): A meta-analysis and review of the research literature on media-user typologies," *Computers in Human Behavior*, vol. 26, no. 5, pp. 940–956, Sep. 2010.

[11] A.-N. Moldovan, I. Ghergulescu, and C. H. Muntean, "A Novel Methodology for Mapping Objective Video Quality Metrics to the Subjective MOS Scale," in *9th IEEE International Symposium on Broadband Multimedia Systems and Broadcasting (BMSB 2014)*, Beijing, China, 2014, pp. 1–7.

[12] A.-N. Moldovan, I. Ghergulescu, and C. Muntean, "Learning Assessment for Different Categories of Educational Multimedia Clips in a Mobile Learning Environment," presented at the Society for Information Technology & Teacher Education International Conference, 2014, pp. 1687–1692.

[13] F. Abel, Q. Gao, G.-J. Houben, and K. Tao, "Analyzing User Modeling on Twitter for Personalized News Recommendations," in *User Modeling, Adaption and Personalization*, 2011, pp. 1–12.

[14] X. Dang and I. Ghergulescu, "Effective Learning Recommendations Powered by AI Engine," in *Proceeding International Workshop on Personalization Approaches in Learning Environments (PALE)*, 2018, p. 6.

[15] F. Carmagnola, F. Cena, and C. Gena, "User Model Interoperability: A Survey," *User Modeling and User-Adapted Interaction*, vol. 21, no. 3, pp. 285–331, Aug. 2011.

[16] E. Toch, Y. Wang, and L. F. Cranor, "Personalization and privacy: a survey of privacy risks and remedies in personalization-based systems," *User Model User-Adap Inter*, vol. 22, no. 1, pp. 203–220, Apr. 2012.

[17] A. Antonaci, R. Klemke, C. M. Stracke, and M. Specht, "Identifying game elements suitable for MOOCs," Springer, 2017.

[18] A. Knutas, R. van Roy, T. Hynninen, M. Granato, J. Kasurinen, and J. Ikonen, "Profile-Based Algorithm for Personalized Gamification in Computer-Supported Collaborative Learning Environments.," in *GHITALY@ CHItaly*, 2017.

[19] N. Zaric, S. Scepanović, T. Vujicic, J. Ljucovic, and D. Davcev, "The Model for Gamification of E-learning in Higher Education Based on Learning Styles," in *International Conference on ICT Innovations*, 2017, pp. 265–273.

[20] P. Ihantola *et al.*, "Educational Data Mining and Learning Analytics in Programming: Literature Review and Case Studies," in *Proceedings of the 2015 ITiCSE on Working Group Reports*, New York, NY, USA, 2015, pp. 41–63.

[21] D. Azcona, I.-H. Hsiao, and A. F. Smeaton, "Personalizing computer science education by leveraging multimodal learning analytics," 2018.

[22] C. Watson, F. W. Li, and J. L. Godwin, "BlueFix: using crowd-sourced feedback to support programming students in error diagnosis and repair," in *International Conference on Web-Based Learning*, 2012, pp. 228–239.

[23] B. Hartmann, D. MacDougall, J. Brandt, and S. R. Klemmer, "What would other programmers do: suggesting solutions to error messages," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2010, pp. 1019–1028.

[24] T. Bi, A. Pichon, L. Zou, S. Chen, G. Ghinea, and G.-M. Muntean, "A DASH-based Mulsemedia Adaptive Delivery Solution," in *Proceedings of the 10th International Workshop on Immersive Mixed and Virtual Environment Systems*, New York, NY, USA, 2018, pp. 1–6.

[25] J. Playfoot, C. De Nicola, and F. Di Salvadore, "A New Experiental Model to Innovate the STEM Learning Process," presented at the International Technology, Education and Development Conference, Valencia, Spain, 2017, pp. 4145–4153.

[26] N. E. Mawas, I. Ghergulescu, A.-N. Moldovan, and C. Hava, "Pedagogical based Learner Model Characteristics," presented at the Ireland International Conference in Education, 2018, p. 5.

[27] T. Lynch, J. Playfoot, C. D. Nicola, G. Guarino, F. D. Salvadore, and I. Ghergulescu, "Gamification Elements in STEM Subjects Lessons Learned from NEWTON Project," in *Ireland International Conference on Education*, 2018, p. 4.

[28] D. Bogusevschi, C. H. Muntean, N. E. Gorji, and G.-M. Muntean, "Earth Course: A Primary School Large-Scale Pilot on STEM Education," presented at the 10th International Conference on Education and New Learning Technologies, Palma, Spain, 2018, pp. 3769–3777.

[29] N. E. Mawas *et al.*, "Final Frontier Game: A Case Study on Learner Experience," in *Proceedings of the 10th International Conference on Computer Supported Education - Volume 2: CSEDU*, Funchal, Madeira, Portugal, 2018, pp. 122–129.

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

[31] T. Lynch and I. Ghergulescu, "NEWTON Virtual Labs: Introduction and Teacher Perspective," in *2017 IEEE 17th International Conference on Advanced Learning Technologies (ICALT)*, Timisoara, Romania, 2017, pp. 343–345.

[32] D. Bogusevschi *et al.*, "Water Cycle in Nature: Small-Scale STEM Education Pilot," in *Proceedings of EdMedia: World Conference on Educational Media and Technology*, 2018, pp. 1496–1505.

[33] I. Ghergulescu, T. Lynch, M. Bratu, A.-N. Moldovan, C. H. Muntean, and G. M. Muntean, "STEM Education with Atomic Structure Virtual Lab for Learners with Special Education Needs," in *EDULEARN18 Proceedings*, Palma, Mallorca, Spain, 2018, pp. 8747–8752.

[34] M. A. Togou, C. Lorenzo, E. Lorenzo, G. Cornetta, and G.-M. Muntean, "Raising Students' Interest In STEM Education via Remote Digital Fabrication: An Irish Primary School Case Study," presented at the 10th International Conference on Education and New Learning Technologies, Palma, Spain, 2018, pp. 2835–2840.

[35] A. Paramythis, S. Weibelzahl, and J. Masthoff, "Layered evaluation of interactive adaptive systems: framework and formative methods," *User Modeling and User-Adapted Interaction*, vol. 20, no. 5, pp. 383–453, Dec. 2010.