Adaptemy Science: Adaptive Learning for Science for Next Generation Classroom

Ioana Ghergulescu, Conor Flynn, Conor O'Sullivan
Adaptemy, Ireland
{ioana.ghergulescu, conor.flynn, conor.osullivan}@adaptemy.com

Abstract: This paper proposes Adaptemy Science, an adaptive learning environment for science for next generation classroom. Adaptemy Science is built on existing research on adaptive learning and technologies for classroom and integrates the latest pedagogical advances and innovation in learning and teaching science. Adaptemy Science aims to provide adaptive, personalized, fun and engaging science learning experiences, to improve the science learning outcomes, and empower teachers. The feasibility of Adaptemy Science was investigated with teachers within a focus group. The teachers acknowledged the suitability and the benefits of the proposed solution.

Introduction

One of the main challenges that Europe and the United Sates will face is the lack of scientists. There is a decreasing trend in the proportion of STEM (Science, Technology, Engineering and Mathematics) graduates. Since 2000, the proportion of graduates specialising in science, mathematics and computing in Europe has been reduced from 12% to 9% (Henriksen, Dillon, & Ryder, 2015). There is a concrete risk of shortage of scientists as it is estimated that by 2030, in Europe and US the proportion of STEM graduates will be between 4% and 8% (OECD, 2015). Mathematics and science are the most difficult-to-staff fields, resulting in decreasing staffing in schools with higher turnover and decrease in school performance (Goldhaber, Krieg, Theobald, & Brown, 2014; Ingersoll & Perda, 2009).

Furthermore, there is strong evidence of young people disengagement from the STEM area and that disengagement from STEM starts during secondary education level as in many countries, students start choosing which subjects they wish to study at this early age (Bøe, Henriksen, Lyons, & Schreiner, 2011; Henriksen et al., 2015).

Therefore, there is a need for products and innovation that will engage students with science in particular and STEM subjects in general and will empower teachers. Furthermore, there is an increasing need for smart learning environments and classrooms that support personalized learning and engage students. In addition, there is a need for empowering teachers with the help of effective tools and dashboards and make them effective coordinators of adaptive and personalized learning (Ghergulescu et al., 2015).

This paper proposes Adaptemy Science, an innovative, effective, adaptive and personalized Science environment. Adaptemy Science is built on an adaptive and personalised system and takes into consideration the latest research in pedagogy and innovation in learning and teaching science subjects, as well as teacher's needs.

Pedagogy and Innovation in Learning and Teaching Science Subjects

Special attention should be given to pedagogy in general and to specific transformation of subject matter while creating innovative products for science. Different researchers have directed their attention to the research, creation and support of Pedagogical Content Knowledge (PCK) (Beyer & Davis, 2012; Jüttner, Boone, Park, & Neuhaus, 2013; Koehler, Mishra, Kereluik, Shin, & Graham, 2014; Loughran, Berry, & Mulhall, 2012; Loughran, Mulhall, & Berry, 2004; Nilsson & Loughran, 2012; Van Driel, Jong, & Verloop, 2002; Williams & Lockley, 2012; Wischow, Bryan, & Bodner, 2013; Yeh, Hsu, Wu, Hwang, & Lin, 2014).

PCK is an academic construct defined as "the knowledge that teachers develop over time, and through experience, about how to teach particular content in particular ways in order to lead to enhanced student understanding" (Loughran et al., 2012). PCK is "the combination of the rich knowledge of pedagogy and content together, each shaping and interacting with the other so that what is taught, and how it is constructed, is purposefully created to ensure that particular content is better understood by students in a given context" (Loughran et al., 2012). PCK is made of two elements (Loughran et al., 2012): CoRe (Content Representation:

pronounced 'core'), which offers an overview of the particular content taught when teaching a topic and PaP-eRs (Pedagogical and Professional–experience Repertoires; pronounced 'papers'), which are succinct, but specific, accounts of practice that are intended to offer windows into aspects of the CoRe. When developing CoRe the teacher should have in mind questions such as: What you intend the students to learn about this idea?, Why it is important for students to know this?, What else you know about this idea?, What are the difficulties/limitations connected with teaching this idea/ knowledge about students' thinking which influences your teaching, teaching procedures?, What are the specific ways of ascertaining students understanding around this idea?

An effective and successful science teacher has the role of a mediator of learning, as opposed to being a transmitter of knowledge. The successful teacher would monitor students' understanding, respond to their needs and make sure the students would grasp the required concepts (Loughran et al., 2012).

In order to lead to enhanced and engaged student understanding, special attention should be given to the following teaching orientations (according to Smith and Neale as cited in Wischow et al., 2013): discovery, processes, content mastery and conceptual change. Discovery relates to providing materials and interesting activities, encouraging students to try new things, posing questions, and managing activities. Processes, as a teaching orientation, relates to demonstrating and teaching steps in scientific method, providing opportunities to practice, maintaining students correct use of method, managing activities. Content mastery is achieved by demonstrating, asking factual questions, correcting students' errors, giving clues and hints, providing practice, and giving tests. Conceptual change is achieved by eliciting children's ideas, providing discrepant events, challenging children to predict and explain, contrasting alternatives, presenting scientific conceptions, providing ways to apply new concepts, encouraging debate (according to Smith and Neale as cited in Wischow et al., 2013). In an educational digital product in general and in a science product in particular, special attentions should be given to motivation monitoring and adaptation (Ghergulescu & Muntean, 2011, 2012, 2014).

Furthermore, when designing a science lesson, important consideration should be given to the following: lesson planning, teaching procedures, practices activities, inquiry-based learning, experiments and gaming elements (Loughran et al., 2012; Beyer & Davis, 2012; Rivet & Krajcik, 2004; Honey & Kanter, 2013). While teaching science, the use of Venn diagrams, concept maps (Loughran et al., 2012) as teaching procedures could be included in daily lessons. The importance of teachers' stories have illustrated that sharing experience through narrative is one way of accessing teachers' knowledge about practice. (Loughran et al., 2012). As opposed to telling, it is crucial that teachers create meaningful and engaging activities, practices and discussion between students and/or between teacher and student(s) about science ideas and the ways these differ from everyday understandings. In Science, the teacher could introduce inquiry-based approach, experiments, and project-based curriculum materials that contextualize the learning of science in meaningful real-world problems, engage students in science inquiry, and use learning technologies (Beyer & Davis, 2012; Rivet & Krajcik, 2004). Games and gaming elements could be used in order to increase student engagement (Honey & Kanter, 2013).

Adaptemy Science

Overview

Adaptemy Science builds on the Adaptemy platform, a smart, personalized and adaptive learning environment for classroom (Ghergulescu et al., 2015) and, incorporates the latest research on pedagogy and innovation in teaching science.

Adaptemy system makes appropriate adjustments and recommendations based on the student profile and knowledge of the subject, and provides an adaptive and personalized learning experience. Adaptemy creates a fun and engaging learning experience, provides feedback, shows relevance, and develops confidence and satisfaction. Additionally, it empowers the teacher by providing a number of tools for class monitoring, management and reporting and assists schools in the transitions to the digital classroom (Ghergulescu et al., 2015). The main components of the system are: domain model (with a separation between content and curriculum organization), user model, and adaptation and personalization engine. Through adaptive and personalized learning experiences, students can revise, learn, practice and do assignments. The system includes various tools to empower the teachers: Live class, Class Managements, Reports and Assignments. The Adaptemy System was used in order to deliver learning experience on Mathematics in a pilot study in over 60 schools in Ireland.

Adaptemy Science incorporates the latest research on pedagogy and innovation in teaching science both in the domain model (in content and curriculum organization), and the adaptation and personalization engine that will adapt and personalize both the learning experience and the feedback. The main difference between Adaptemy Maths and Adaptemy Science are at curriculum and content organization, and personalization of each learning session. A new adaptation layer for learning session personalization that incorporates science pedagogy was designed and incorporated in the existing adaptation and personalization engine. The main similarities between Adaptemy Maths and Adaptemy Science are student navigation, teacher tools and learner modeling.

Adaptemy Science goals are: (i) to create a fun, motivating and engaging learning experience in Science, (ii) to provide an adaptive and personalized learning experience by making appropriate adjustments and recommendations based on student profile (e.g., ability, level, knowledge, etc.) on Science materials, (iii) to empower the teachers. Adaptemy Science could be used as a standalone educational technology for learning, practice, revision or e-assessment as well as to complement existing programs and textbooks and teaching practices in Science.

Content, Curriculum Organisation and Learning Session Personalization Layer

Adaptemy follows the Framework for the Delivery of Personalized Adaptive Content (DPAC) (Howlin & Lynch, 2014) used also by the RealizeIT platform and used in the Adaptemy system. The curriculum is defined by specifying knowledge items, and the hierarchy, prerequisites and relationships between knowledge items. The curriculum is represented by a hierarchy structure and a curriculum prerequisite network. The curriculum prerequisite network contains all the prerequisite relationships between the knowledge items. Adaptemy Science follows the National Curriculum and Assessments guidelines for Science Curriculum.

The content is defined for each knowledge item, supports various content formats (ranging from text to audio, video and animations). The questions are defined using generic data structures which are used to represent question forms. The question form is used to generate a question at runtime, enable more practice and minimise the possibility of students gaming the system.

The curriculum map for Adaptemy Science contains three disjoint curriculum prerequisite networks Curriculum Prerequisite Biology Map, Curriculum Prerequisite Chemistry Map and Curriculum Prerequisite Physics Map. Figure 1 presents a slice from the Curriculum Prerequisite Biology Map and Figure 2 presents a slice from the Curriculum Prerequisite Physics Map. As compared with the Curriculum Prerequisite Mathematics Map, the maps for Science are wider, especially because of the multitude of concepts and individual branches.

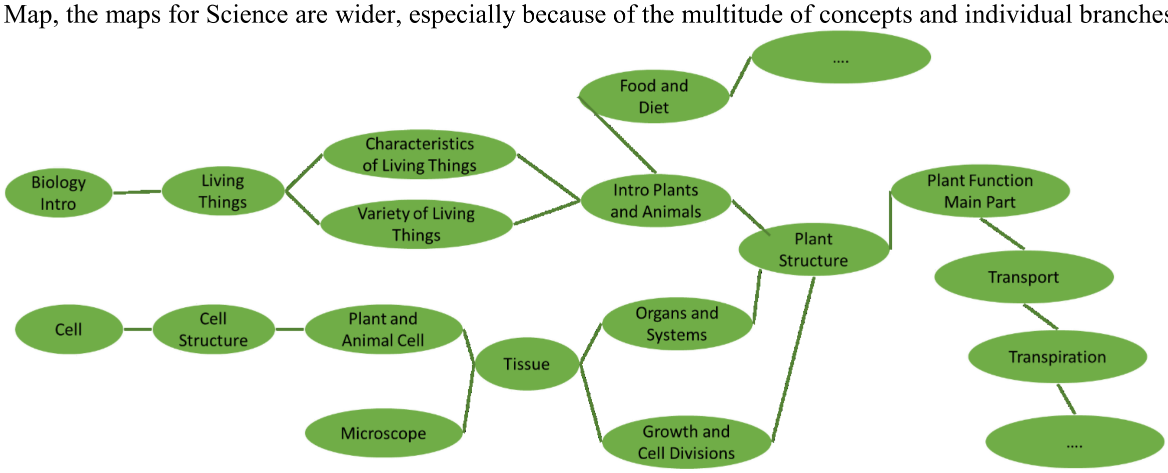

Figure 1: Curriculum Prerequisite Biology Map Slice

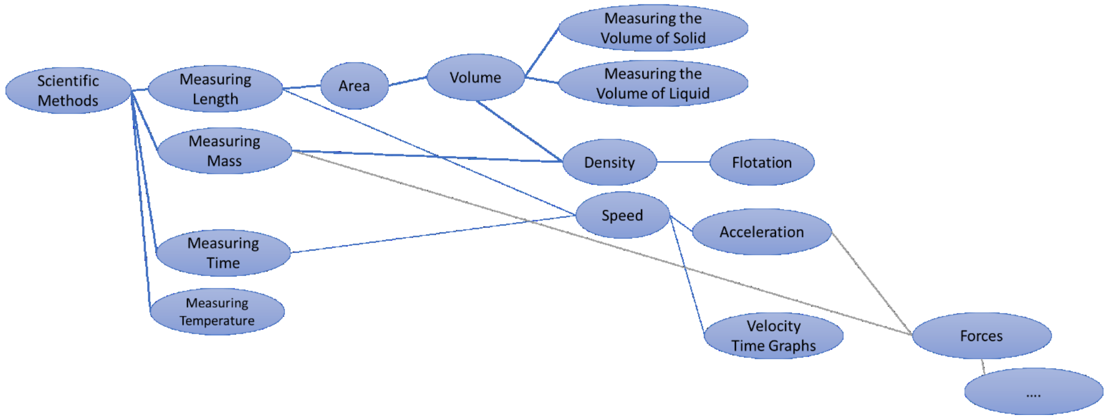

Figure 2: Curriculum Prerequisite Physics Map Slice

As diagrams are important elements in learning and teaching in Science, Adaptemy Science will use them in question description and solutions. Various types of questions will be used, including enter answer, multiple choice, true or false, matching. Each question will be tagged on 2 dimensions: difficulty level (easy, medium and hard), and comprehension (essential knowledge, procedures and problem solving). Figure 3 and Figure 4 illustrate two essential knowledge questions when the difficulty level differs. Figure 5, Figure 6 and Figure 7 illustrate three easy questions on different comprehension levels (essential knowledge, procedures and problem solving).

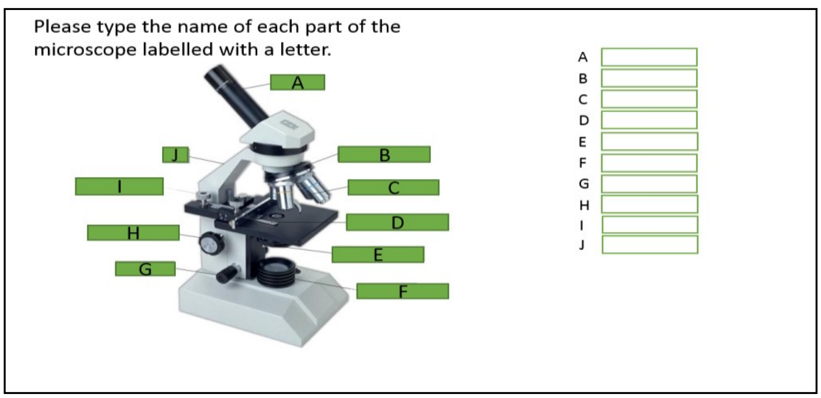

Figure 3: Microscope parts - Question Example 1 – essential knowledge - hard

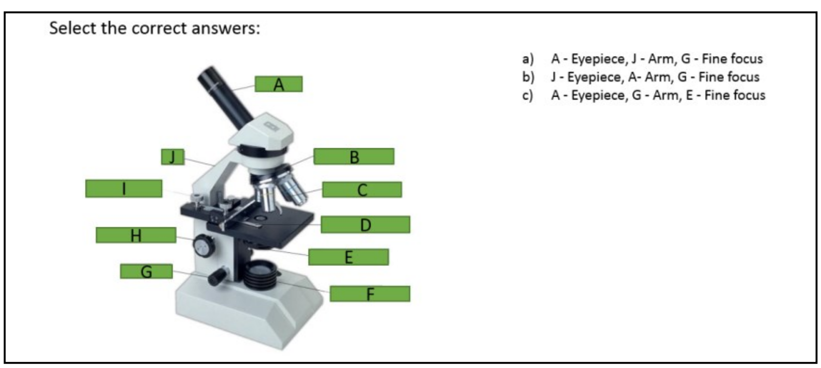

Figure 4: Microscope parts - Question Example 2 – essential knowledge - medium

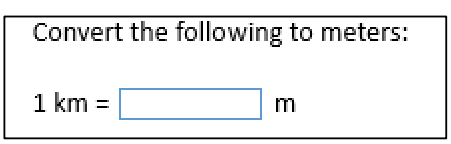

Figure 5: Distance Measurement - Question Example 1 – essential knowledge - easy

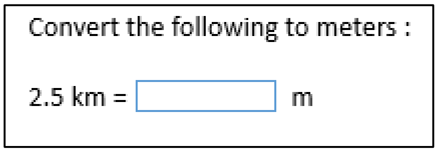

Figure 6: Distance Measurement - Question Example 2 – procedures – easy

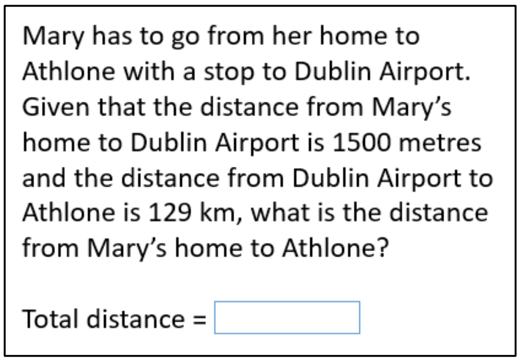

Figure 7: Distance Measurement - Question Example 3 – problem solving – easy

The learning session personalization layer integrates the pedagogical aspects of teaching science.
Each learning session is personalized and learning concepts will start first with questions to ensure understanding in general and in particular essential knowledge. Second the questions will empower science practices, both procedural and problem solving questions.

Adaptemy Science Focus Group

A focus group with teachers was conducted in order to investigate the feasibility of the proposed solution for science. The focus group investigated the feasibility of the proposed Adaptemy Science and its benefits in general, as well as the assumption that there is a difference in pedagogy between science and maths, the content and curriculum representation and organization in general. The teachers acknowledged:

- the difference in pedagogy between science and maths
- the suitability of the curriculum prerequisite approach (where there are more parallel branches that a single, complex, ramified branch as in maths)
- the suitability of the proposed content type
- the suitability of Adaptemy Science
- the benefits of Adaptemy Science

Conclusions

This paper presented Adaptemy Science – an adaptive learning environment for science for next generation classroom. Adaptemy Science builds on previous research and development on adaptive learning and incorporates the latest research on pedagogy and innovation in teaching science. The Adaptemy Science benefits include: personalised questions (i.e., everyone gets different questions, with hints and specific feedback on responses), appropriate questions (i.e., questions difficulty adjust to each learner, improving engagement, but the "score" is still comparable), learner profiling (i.e., a network of estimates of ability across each concept is built in order to identify misconceptions), learning recommendations (next step recommendation for each individual is provided, not just where to focus, but exactly what to do), learner self-guidance (visualisations and hints to enhance self-awareness of progress, with step-by-step coaching and rewards), teacher monitoring & control (i.e., live classroom tools, dashboards and reports, with assignments and detailed student reports), and programme-level insights (i.e., for educators and publishers in order to discover key patterns of learning to improve each part of the education system). The Adaptemy Science limitations include: lack of integrated virtual laboratories for science, little inquire-based practice. Future work will address further evaluation of Adaptemy Science with students and teachers.

References

Beyer, C. J., & Davis, E. A. (2012). Learning to critique and adapt science curriculum materials: Examining the development of preservice elementary teachers' pedagogical content knowledge. *Science Education*, *96*(1), 130–157. http://doi.org/10.1002/sce.20466

Bøe, M. V., Henriksen, E. K., Lyons, T., & Schreiner, C. (2011). Participation in science and technology: young people's achievement-related choices in late-modern societies. *Studies in Science Education*, *47*(1), 37–72. http://doi.org/10.1080/03057267.2011.549621

Ghergulescu, I., Flynn, C., & O'Sullivan, C. (2015). Adaptemy – Building the Next Generation Classroom (Vol. 2015, pp. 79–88). Presented at the EdMedia: World Conference on Educational Media and Technology.

Ghergulescu, I., & Muntean, C. H. (2011). Learner Motivation Assessment with <e-Adventure> Game Platform (Vol. 2011, pp. 1212–1221). Presented at the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education. Retrieved from http://www.editlib.org/p/38880/

Ghergulescu, I., & Muntean, C. H. (2012). Measurement and Analysis of Learner's Motivation in Game-Based E-Learning. In *Assessment in game-based learning* (pp. 355–378). Springer. Retrieved from http://link.springer.com/chapter/10.1007/978-1-4614-3546-4_18

Ghergulescu, I., & Muntean, C. H. (2014). A Novel Sensor-Based Methodology for Learner's Motivation Analysis in Game-Based Learning. *Interacting with Computers*, *26*(4), 305–320.

Goldhaber, D., Krieg, J., Theobald, R., & Brown, N. (2014). The STEM and Special Education Teacher Pipelines: Why Don't We See Better Alignment Between Supply and Demand? *Phi Delta Kappan (in Press, Available as CEDR Working Paper 2014-3)*. Retrieved from http://t.cedr.us/papers/working/CEDR%20WP%202014-3.pdf

Henriksen, E. K., Dillon, J., & Ryder, J. (2015). *Understanding student participation and choice in science and technology education*. Springer. Retrieved from http://link.springer.com/content/pdf/10.1007/978-94-007-7793-4.pdf

Honey, M., & Kanter, D. E. (2013). *Design, Make, Play: Growing the Next Generation of STEM Innovators*. Routledge.

Ingersoll, R. M., & Perda, D. (2009). The mathematics and science teacher shortage: Fact and myth. *Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania*. Retrieved from https://www.csun.edu/science/courses/710/bibliography/math%20science%20shortage%20paper%20march%202009%20final.pdf

Jüttner, M., Boone, W., Park, S., & Neuhaus, B. J. (2013). Development and use of a test instrument to measure biology teachers' content knowledge (CK) and pedagogical content knowledge (PCK). *Educational Assessment, Evaluation and Accountability*, *25*(1), 45–67. http://doi.org/10.1007/s11092-013-9157-y

Koehler, M. J., Mishra, P., Kereluik, K., Shin, T. S., & Graham, C. R. (2014). The Technological Pedagogical Content Knowledge Framework. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), *Handbook of Research on Educational Communications and Technology* (pp. 101–111). New York, NY: Springer New York. Retrieved from http://link.springer.com/10.1007/978-1-4614-3185-5_9

Loughran, J., Berry, A., & Mulhall, P. (2012). *Understanding and developing science teachers' pedagogical content knowledge*. Rotterdam; Boston: SensePublishers. Retrieved from http://dx.doi.org/10.1007/978-94-6091-821-6

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, *41*(4), 370–391. http://doi.org/10.1002/tea.20007

Nilsson, P., & Loughran, J. (2012). Exploring the Development of Pre-Service Science Elementary Teachers' Pedagogical Content Knowledge. *Journal of Science Teacher Education*, *23*(7), 699–721. http://doi.org/10.1007/s10972-011-9239-y

OECD. (2015). *Education Indicators in Focus - How is the global talend pool changing (2013, 2030)?* Retrieved from http://www.oecd.org/education/skills-beyond-school/EDIF%2031%20%282015%29--ENG--Final.pdf

Rivet, A. E., & Krajcik, J. S. (2004). Achieving standards in urban systemic reform: An example of a sixth grade project-based science curriculum. *Journal of Research in Science Teaching*, *41*(7), 669–692. http://doi.org/10.1002/tea.20021

Van Driel, J. H., Jong, O. D., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Education*, *86*(4), 572–590. http://doi.org/10.1002/sce.10010

Williams, J., & Lockley, J. (2012). Using CoRes to Develop the Pedagogical Content Knowledge (PCK) of Early Career Science and Technology Teachers. Retrieved from http://scholar.lib.vt.edu/ejournals/JTE/v24n1/williams.html

Wischow, E. D., Bryan, L., & Bodner, G. M. (2013). SECONDARY SCIENCE TEACHERS' DEVELOPMENT OF PEDAGOGICAL CONTENT KNOWLEDGE AS RESULT OF INTEGRATING NANOSCIENCE CONTENT IN THEIR CURRICULUM. *COSMOS*, *08*(02), 187–209. http://doi.org/10.1142/S0219607712500073

Yeh, Y.-F., Hsu, Y.-S., Wu, H.-K., Hwang, F.-K., & Lin, T.-C. (2014). Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the Delphi survey technique: Development and validation of TPACK-practical. *British Journal of Educational Technology*, *45*(4), 707–722. http://doi.org/10.1111/bjet.12078