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Towards a Pedagogical Model for Science Education: Bridging Educational Contexts Through a Blended Learning Approach

José Bidarra & Ellen Rusman

This paper proposes a design framework to support science education through blended learning, based on a participatory and interactive approach supported by ICT-based tools, called *Science Learning Activities Model* (SLAM). The development of this design framework started as a response to complex changes in society and education (e.g. high turnover rate of knowledge, changing labour market), which require a more creative response of learners to the world problems that surround them. Many of these challenges are related to science and it would be expected that students are attracted to science, however the contrary is the case. One of the origins of this disinterest can be found in the way science is taught. Therefore, after reviewing the relevant literature we propose the SLAM framework as a tool to aid the design of science courses with high motivational impact on students. The framework is concerned with the assumption that science learning activities should be applicable and relevant to contemporary life and transferable to 'real-world' situations. The design framework proposes three design dimensions: context, technology and pedagogy, and aims at integrating learning in formal and informal contexts through blended learning scenarios by using today's flexible, interactive and immersive technologies (e.g. mobile, AR, VR).

Keywords: pedagogical model, blended learning, mobile learning, gamification, digital storytelling, formal and informal learning

Introduction

Increasingly, cognitive scientists are finding themselves developing models, frameworks, tools and pedagogies consistent with emerging contexts and new circumstances. In these new environments, the research moves beyond simply observing and actually involves systematically engineering learning contexts in ways that allow us to improve and generate evidence-based assertions about learning.

Coherent and integrated tools, content-based curriculum, and pedagogical models that help teachers systematically understand, predict and design how learning occurs in new learning scenarios are needed to cope with and benefit from the changing circumstances. As we look toward the future of education in the 21st century, the prominence of a robust STEM (Science, Technology, Engineering, and Mathematics) curriculum is unquestioned. In the following, we begin the process of describing a framework aimed at improving science programmes (defined here as STEM) using a participatory and interactive approach supported by ICT-based tools, and adding the Arts (as in "STEAM") to broaden the theoretical perspectives followed. Art education is recently receiving a lot of attention for teaching students' creative skills and a flexible mind-set that works across border lines (Kim, 2012). It's important to show students how technical notions relate to everyday situations and provide activities that help them apply known concepts in new contexts, thus promoting transfer of learning. In a study by *The National Foundation for Educational Research* (Wellcome Trust, 2011), exploring young people's views on science education, UK youngsters indicated that they would be more engaged with science if it were more applicable and relevant to contemporary life and transferable to 'real-world' situations. Furthermore, they expressed a preference for more practical, hands-on activities, when seen to be relevant to and integrated into the theoretical element of lessons, which they believed made learning science more interesting and subsequently easier to understand. This is achievable by fostering students' curiosity, supporting them during their personal and social meaning making processes and assisting them in developing creativity, problem solving and critical thinking skills. These are processes that are fostered by educational approaches that place the learner in an active role. The core elements of active learning are student activity and engagement in the learning process (Prince, 2004). Examples, although not exhaustive, of such educational approaches are inquiry-based learning, problem-based learning and collaborative learning.

In this regard, we also find the “21st Century Competences” relevant, as put forward by Voogt & Pareja Roblin (2012), covering major skills for success in our digital and networked world:

- *Creativity*– the ability to develop from scratch new solutions to emerging problems (communication, digital literacy);
- *Critical thinking*- the capacity to read, interpret, and evaluate new information (citizenship, communication, digital literacy);
- *Problem solving* - the ability to make decisions and implement the best solutions (communication, collaboration, digital literacy);
- *Productivity* - the ability to be more productive and apply higher-level skills (ICT competences are important here).

However, according to Anastopoulou et al. (2012), evidence shows that young learners are not easily attracted to science as a school subject (Lyons, 2006a; 2006b). Also, learners need to acquire the mental models that science investigation requires, but it is now widely acknowledged that the barrier to engagement goes further than a struggle with cognitive demands and constructs, such as ‘control of variables’ (Kuhn, Iordanou, Pease & Wirkala, 2008). In the U.S. the *National Research Council* (2011) has identified the issue of disengaged students in STEM classes across the country, namely in algebra, geometry, trigonometry, biology, chemistry, physics—which are among the toughest to teach well. Across Europe the same problem exists and the *Scientix* 2015 report (Kearney, 2016) shows that “in both mathematics and science, underachievement of 15-year-olds remains above the ET 2020 benchmark of 15%, and most countries across Europe continue to face a low number of students interested in studying or pursuing a career in the STEM field." (p.5) Concurrently, the European Commission (2015) has launched a campaign to encourage girls aged 13-18 to study science, with the slogan "Science, it's a girl thing!". This campaign tried to reverse the situation whereby girls tend to gravitate away from science and technology studies. Moreover, according to a recent study on the changing pedagogical landscape (European Commission, 2015) the importance of lectures in higher education usually precludes other teaching and learning techniques, such as projects, laboratories, seminars and tutorials. But there are signs that this situation is changing to varying degrees, with the introduction of new pedagogies harvesting the affordances offered by new technologies. Another EU study by the *High Level Group on the Modernisation of Higher Education* (2014), indicates that MOOCs and other recent innovations are only one part of a wave of change in higher education, recognizing that blended learning or other forms of on- and off-campus learning are now widespread. Recent research also reports on the success of e-learning and b-learning experiences in the environmental science area (Azeiteiro, Leal Filho & Caeiro, 2014; Azeiteiro, Bacelar-Nicolau, Caetano, & Caeiro, 2015; Coelho, Teixeira, Bacelar-Nicolau, Caeiro & Rocio, 2015). However, the lack of clear direction as to how the higher education system would need to change in order to accommodate students' needs, results in most universities being unwilling to follow high risk strategies, either alone or together. With this in mind, we set out to define a conceptual framework with innovative tools, new pedagogies and formative assessment methods for teaching science, integrating formal and non-formal learning contexts in blended learning scenarios, aimed at **upper secondary school level and new university students**. Our goal is to upturn the tendency to avoid science degrees or dropping out of science courses at a more advanced level. The framework proposed may be adapted and used in other areas of knowledge but the main emphasis is on science learning.

Virtual learning scenarios

Online interaction has become a way of life for “Generation Y” students (Tapscott, 2008; Black, 2010) wherever they are: at home, on the move, or at school. We cannot ignore that these students are no longer the same target population for which our education systems were designed a few decades ago. For the institutions there are good news, as for the first time in history we have a large supply of educational technologies that are chosen by students and not imposed by governments and schools: smart mobile phones (most students have one), networking software (freely available, e.g. Hangouts, WhatsApp, Skype), learning applications (widely available, e.g. Apple Store, Google Play) and open educational resources (in growing supply, e.g. MOOCs, iTunes U, Khan Academy). There are other tools available for learning organizations, such as collaborative tools (e.g., blogs, wikis, knowledge-building software), immersive environments (e.g. virtual worlds), media production and distribution tools, and many more.

Furthermore, teachers and educators have always emphasized the importance and need for "authentic learning activities", where students can work with real world problems (Brown, Colins & Duguid, 1989). Therefore, the development of educational activities for students that combine learning resources from the real world with those from the digital world has become an important and challenging research topic for science educators. Blended learning activities may be accomplished, for example, through the use of mobile communication and wireless technologies, allowing for experimentation, augmented reality, image collection, map sharing, and communication with other students, anytime and anywhere. An interesting approach is to use STEAM learning strategies that use art and design methods to approach STEM subjects creatively, and make them connected to the real world, and thereby relevant to all students, not just for those already interested (Pomeroy, 2012).

Globally, these developments lead to a re-conception of education as a mobile and flexible exchange of ideas in specific contexts. It goes beyond the traditional view of “classroom instruction”, and that of education as the “transmission of knowledge” within the constraints set by a curriculum. Instead, education is viewed as an on-going process of learning through continued exploration, participation and negotiation in various circumstances, roles and environments an individual plays a part in (e.g. school, work, leisure, family/private contexts), integrating learning and meaning making processes in formal and informal contexts. Learning in this way is in fact pervasive or ubiquitous, meaning that it is on-going 24 hours a day, seven days a week, anywhere. Pervasive learning is also a social process that connects learners to communities consisting of devices, people, and culture, so that students can construct relevant and meaningful learning experiences, authoring specific content (text, images, audio, video), in locations and at times that they find meaningful and relevant; also contributing themselves to the needs identified within these different communities. This allows learners to experience a continuous learning process, across contexts, integrating these various learning experiences by means of the affordances reachable via technology.

In a recent study with school students (ages 11–14), the effective use of a toolkit (nQuire), a system to support scripted personal inquiry learning (Sharples et al., 2015) was reported. These researchers found that the toolkit was successfully adopted by teachers and pupils in contexts that included teacher-directed lessons, an after-school club, field trips, and learner-managed homework. The toolkit effectively sustained the transition between individual, group, and whole-class activities, while supporting learning across formal and informal settings. A comparable study, in which a scripted inquiry-based learning approach is sustained by means of integrated technological artefacts able to support learning science and complex skills across contexts, is weSPOT (Mikroyannidis et al., 2013).

According to the EU Commission initiative *Opening Up Education* (2013), between 50% and 80% of students in EU countries never use digital textbooks, exercise software, podcasts, simulations or learning games. Most teachers at primary and secondary level do not consider themselves as 'digitally confident' or able to teach digital skills effectively, and 70% would like more training in using ICTs. But this is also a digital challenge higher education faces: with the number of EU students rising significantly, universities need to adapt traditional teaching methods and offer a mix of face-to-face and online learning possibilities. However, even if the majority of today´s generation of learners uses digital devices, Internet applications and social media on daily basis, mostly for communication and entertainment, there is little knowledge of how to use such tools and media to make science education more meaningful, effective and attractive. It is important to promote science as a backdrop for learning about the real world in which we live, especially by attracting low achievers and helping them develop some of the key competences that are basic-life skills.

Gradually, the rupture of traditional assumptions and educational models has propelled cognitive scientists into the exploration of emergent learning formats that might meet the needs of a “participative learner” by incorporating new kinds of inputs, media consumption and production practices, global resources, and accommodate the move into a more learner-centred environment. Nevertheless, at this stage, the majority of universities and schools still need to change and narrow the impact of these on-going transformations by harnessing the power of the options available in an ever-changing digital media landscape. Moreover, teaching and learning opportunities for youth are now available in expanding learning environments (Guetl & Chang, 2008), next to the traditional institutions (schools and universities), for example, encompassing science discovery centres, community spaces and non-profit organisations.

These students grew up in a new technological environment, with its own techno-culture, and they will live in a demanding, competitive, complex and increasingly connected world. The technological revolution has produced a generation of students who grew up with multidimensional and interactive media sources, a “Generation Y” whose expectations and perspectives are different from those that preceded it (Tapscott, 2008; Black, 2010). Furthermore, this is a generation that lives in a complex world where science has an important role to play. This suggests the need for convincing learning scenarios and designs that will engage learners, whatever the gender, with emphasis on science topics and curricula.

Emerging scenarios: digital storytelling and gamification

Despite storytelling’s recent renaissance, storytelling is not a fad or an innovation *per se*; it has been used throughout history for teaching and learning, but also for business, psychology or health care. Stories help us make meaning out of our or others’ experience (and perception) of the world. Stories also help build connections with prior knowledge and improve memory, and as a result good stories are remembered longer by students than regular lessons (Bidarra, 2014). In this day and age we are referring to digital artefacts that include: a compelling narration of a story; elements that provide a meaningful context for understanding the story being told; titles, images and graphics that capture and/or expand upon emotions found in the narrative; voice, music and sound effects that reinforce ideas; and mechanisms that invite thoughtful reflection from the audience (Bidarra, Figueiredo & Natálio, 2015).

Given storytelling's central role in living and learning, and the technological explosion during the past decades, it is not surprising to find digital storytelling entering the academic mainstream, so long after being essential for theatre, movies, and games. We think that our framework could also benefit from the interrelated concepts of storytelling, digital narratives and gamification, connecting technology and pedagogy in activities designed for science learning, aimed at both male and female students.

Eventually, stories may also be part of games, and, in the field of education, the application of games supporting learning processes has developed into an increasing body of research (Bidarra, Rothschild, Squire & Figueiredo, 2013). A common implementation is called "gamification"; it identifies the notion of using elements of video games, such as points, levels, badges, and achievements, and their application in professional or educational contexts. The concept also has been around for some time through loyalty systems like frequent flyer miles, green stamps, and library summer reading programs.

Research in gamification has acquired considerable momentum over the years (Deterding, O'Hara, Sicart, Dixon & Nacke, 2011; Lee & Hammer, 2011; Kapp, 2012; Kelle, 2012). Essentially, to these authors the core of the concept is that it integrates the mechanics of gaming in non-game activities to make these more effective and enjoyable. More specifically, gamification in educational settings seeks to integrate game dynamics and game mechanics into learning activities, for example, using tests, quizzes, exercises, badges, etc., in order to drive the intrinsic motivation and foster participation of students.

In this context, we can define game mechanics as the set of rules and rewards that make up game play, a satisfying and highly motivational activity, in other words, making it more challenging and engaging. In a way, educational processes have always used “gamification” in learning activities by applying scores (points) on marked assignments. However, this “game-based” system doesn’t seem very engaging for school and university students (Lee & Hammer, 2011); so, perhaps education processes could be improved by adding other play factors, such as digital narratives, additional gamification principles, and immersive technologies, that are able to involve students in a way that is more physical so learning becomes more experiential, memorable, and intense.

The increased availability of smartphones and tablets with Internet connectivity and high computing power makes the use of Augmented Reality (AR) applications a promising development for education. This breaks down the walls of the classroom, connecting schools and communities (Squire, 2013). In the near future, eventually everyone with a smartphone or a tablet will be capable of viewing augmented information. This makes it possible for a teacher to develop engaging educational activities, with games and resources that can take advantage of the augmented reality technologies, therefore improving learning outcomes. We believe that the use of AR will change significantly many current teaching activities by enabling the addition of supplementary information that may be viewed on a mobile device (Squire & Dikkers, 2012), guiding learning activities in context and helping students to improve their individual as well as their collective understanding of educational content.

Establishing a *Science Learning Activities Model* (SLAM)

Within the realm of blended learning there are frameworks to address various situations encompassing both school and university contexts, mostly departing from a traditional e-learning perspective to incorporate new technology. A very comprehensive study of the relevant literature is presented by Wong & Looi (2011), including their own framework called Mobile Seamless Learning (MLS) sustained by the view that "learners need to be engaged in an enculturation process to transform their existing epistemological beliefs, attitudes, and methods of learning. Therefore, at the early stage of learners' engagement in mobile devices, teachers need to model the seamless learning process by gradually and systematically incorporating mobile learning activities into the formal curriculum" (p.5). We argue that, to profit from the opportunities that the seamless learning spaces of today offer, we need an innovative perspective for the instructional design of science education supported by an operational model of activities.

Another study by Park (2011) compares mobile learning (m-learning) with electronic learning (e-learning) and ubiquitous learning (u-learning), and describes the technological attributes and pedagogical affordances of mobile learning presented in various studies. We find relevant for science learning that the mediation of mobile devices may serve as a catalyst for face-to-face interactions in the field, inside labs, or for solving problems in groups, both in schools and universities. In a previous work (Pereira et al., 2008) we presented Universidade Aberta's (Portuguese Open University) pedagogical model for distance education in detail – the essential framework is still guiding the institution today – with the emphasis almost exclusively on the deployment of e-learning. At the time we did not consider other emerging concepts such as b-learning (blended learning), and the above mentioned m-learning or u-learning.

However, it was acknowledged that a number of face-to-face sessions were relevant in online post-graduate programmes at the university. Basically, we found that a great deal depends on the educational context and pedagogical strategy followed, so there is no point in restricting the options for either the faculty or the institution.

Essentially, based on the scientific literature reviewed, there are three consensual "umbrella" denominations in these attempts to build operational frameworks for learning environments in the 21st Century: context, technology and pedagogy. According to Guetl & Chang (2008), the main reference models, architectures and e-frameworks for learning deal essentially with these three dimensions, namely, the Learning Technology Systems Architecture (LTSA), Personal Learning Environments, e-Learning Framework Reference Model for Assessment, ePortfolio for Lifelong Learning, and the Reference Model for e-Learning Governance (Baruque & Melo, 2004; Chang & Uden, 2008; JISC, 2012; Hadiputra & Widyani, 2013). Although these frameworks for an e-learning architecture tend to use a variety of approaches, there is too much emphasis on technology and not much on pedagogy or educational context.

In this study towards a SLAM design framework, that we consider a work in progress to form a more contemporary and sustainable model for science learning, a meta-analysis of other established models was undertaken. The triumvirate "context, technology and pedagogy" was chosen for this purpose, leaving aside other aspects such as societal, organizational and governance matters. Our review did not put away the "classic" models and moved to newer ones, quite the opposite. From the start there was an interest in seeking the convergence of the established models with emerging ones.

Context

Context usually refers to broad concepts such as society and organizations, knowledge domains, experts and peers, tools and techniques, time and location, among other aspects. But for educational purposes we might as well consider other factors ranging from scale to crossover experiences, for instance, patent in MOOCs and flipped classroom experiences. If one believes that context matters in terms of science learning and cognition, then learning processes must be examined not as isolated variables within controlled settings but as components to be understood in more realistic situations. So, in order to make our model operational, we have to consider the possible contexts of education, formal and non-formal settings, degree and non-degree programmes, and embrace upper secondary school to early higher education contexts. According to the PISA 2012 report, the latter are the educational levels with the highest dropout rate and where lower achievement in science occurs (OECD, 2012). Clearly, to reach specific objectives in these levels each educational case would have to be identified, the main variables reviewed, and the right instructional design applied in order to help educators plan and design adequate blended learning environments (Park, 2011). Gender patterns are also important, for instance, the context of a degree in Engineering is different from that of a degree in Mathematics, and that reflects the way male or female students are attracted to a specific science subject (European Commission, 2012).

Bearing in mind the teaching perspective, one common feature of organizations incorporating online learning methods in their mode of operation is the fact that there is no necessary spatial contiguity, at all times, between student, teacher, and the learning environment. The same kind of discontinuity may exist in temporal terms, namely the reciprocal contacts between students, teachers and the teaching or training system (Trindade, Carmo & Bidarra, 2000). However, the face-to-face mode and the online learning mode have been converging, not only due to the success of blended learning experiences but also due to the progress in ICT and their permeating all learning environments in most developed countries. Using mobile devices and accessing the Web in schools and universities, but also at home and on the move, taking advantage of quality open learning products (iTunes U, MOOCs, Khan Academy, etc.), all create favourable conditions for increasing students' autonomy and for stimulating independent learning in various settings.

Another perspective to consider in blended environments may be to foster group learning and develop solutions for awareness, as the up-to-the-moment understanding of another person's interaction with a shared workspace (Gutwin & Greenberg, 2001). Thus contextual information is important to establish where group members frequently shift between individual and shared activities within a programme, in order to help instructional designers create awareness support within group activities.

Technology

In this day and age, educational technology is concerned with connectivity, ubiquitous learning, web interface systems, and learning platforms. Many of these permit access to remote labs and equipment, available for many topics including astronomy, biology, chemistry, computer networking, earth science, engineering, hydraulics, microelectronics, physics and robotics (Open University, 2015). Researchers concerned with technologies for supporting effective learning have labelled the multiple literacies that are aligned with technology as "Twenty-First Century Literacy" (Brown et al., 2005), and these may be described as the combination of:

- *Digital Literacy* – the ability to communicate with an ever-expanding community to discuss issues, gather information, and seek help;

- *Global Literacy* - the capacity to read, interpret, respond, and contextualize messages from a global perspective;
- *Technology Literacy* - the ability to use computers and other technology to improve learning, productivity, and performance;
- *Visual Literacy* - the ability to understand, produce and communicate through visual images;
- *Information Literacy* - the ability to find, evaluate and synthesize information.

Students who create portfolios and digital stories improve their skills by using software that combines a variety of multimedia tools enabling operations with text, still images, audio, video and Web publishing. In this regard, digital storytelling can provide a meaningful reason for students to learn science and produce visual media content with the help of scanners, digital still cameras, and video cameras. Riesland (2005) calls for a new definition of visual literacy education, one that will allow students to successfully navigate and communicate through new forms of multimedia, while taking on the role of information producers rather than just being information consumers.

In the case of mobile learning technology, usability constraints are relevant according to Kukulska-Hulme (2007), for instance, (1) physical attributes of mobile devices, such as small screen size, heavy weight, inadequate memory, and short battery life; (2) content and software application limitations, including a lack of built-in functions, the difficulty of adding applications, challenges in learning how to work with a mobile device, and differences between applications and circumstances of use; (3) network speed and reliability; and (4) physical environment issues such as problems with using the device outdoors, excessive sun brightness affecting screen reading, concerns about personal security, possible radiation exposure from devices using radio frequencies, the need for rain covers in rainy or humid conditions, amongst others. But these tend to be resolved overtime with the rapid advances in digital technology.

From another viewpoint, technology-centric models have influenced and continue to influence how we think about mobile learning and blended learning. A typical example is Johansen's (1988) “classic” Time-Space Matrix, a very useful way to consider the particular circumstances a groupware system has to address to be effective in cooperative work. Today, this conceptual matrix is still an established model to design and support synchronous and asynchronous learning activities in a blended learning situation (Table 1). Following this model, specific academic content may be delivered with the help of multimodal activities, determined by space and time factors.

A current and more developed model for co-operative work, which may also be used for collaborative learning purposes, is the conceptual framework proposed by Lee & Paine (2015), designated by Model of Coordinated Action (MoCA). This is a descriptive model that highlights “Action”, as translated in specific “Activities”, consisting of seven dimensions of co-ordinated action. This is of interest to the SLAM framework because, while the time-space matrix implies a mere binary division between local vs. distributed, and synchronous vs. asynchronous, in this model each of these “dimensions” falls on a continuum. According to Lee & Paine (2015), coordinated action can be conceived of as people working together toward a shared goal. This also applies to communities of learners situated in a seamless real-virtual environment where specific educational strategies are supported by appropriate learning activities.

Pedagogy

New pedagogies are emerging every year and the account of the last few years has been very prolific. According to the Open University’s last report (2015), many innovative pedagogies can be identified within very specific themes: scale, connectivity, reflection, extension, embodiment and personalisation. But perhaps what is of utmost importance today is a teaching approach that is flexible enough, and an instructional design that can be changed by the learner according to his/her personal needs and learning context. To this end, the Personal Learning Environment (PLE) concept emerged within the UK and other countries a decade ago as a strategy associated with the application of Web 2.0 technologies to education (Johnson & Liber, 2008). It gained momentum from 2005 onwards with research disseminated by authors like S. Wilson, M. van Harmelen, G. Atwell, S. Downes, G. Siemens and T. Anderson (Mota, 2009). This extends to a learning network concept in which a learner can find his/her own pathway, based on the paths previous learners chose through activities, tasks and resources, and following personal learning objectives in order to become competent (Koper, Rusman & Sloep, 2005). PLEs essentially highlight the learning environment as a collection of tools and services that a learner may choose to access resources, and a network of people; sometimes there is an interface to integrate the different components. These so-called Personal Learning Environments, or PLEs, are today a privileged field of research in ODL, encompassing several technological perspectives that may include social networks, free virtual environments and open software, connecting various learning resources that may be suitable for inclusion in current educational frameworks (van Harmelen, 2008).

However, PLEs are not just pieces of software, they comprise environments where people, tools, communities, and resources combine in a very loose kind of way (Wilson, 2008), clearly supporting formal and informal learning. Making a case for PLEs Attwell, Bimrose & Brown (2008) stated that "a PLE should be based on a set of tools to allow personal access to resources from multiple sources and to support knowledge creation and communication" (p. 82), and suggest an inventory of the possible pedagogical functions of a PLE:

- Access/search for information and knowledge;
- Aggregate and scaffold by combining information and knowledge;
- Manipulate, rearrange and repurpose knowledge artefacts;
- Analyse information to develop knowledge;
- Reflect, question, challenge, seek clarification, form and defend opinions;
- Present ideas, learning and knowledge in different ways and for different purposes;
- Represent the underpinning knowledge structures of different artefacts and support the dynamic re-rendering of such structures;
- Share by supporting individuals in their learning and knowledge;
- Networking by creating a collaborative learning environment.

Following up on this, taking a learner-centred approach to connect the three umbrella concepts discussed above – context, technology, pedagogy – we engaged in a structured approach to make the SLAM model operational. Thus we propose **ten seamless dualities that may co-exist in multimodal activities**, explicitly indicating the extremes of a continuum (Table 2).). These may originate learning scenarios that contain multiple learning activities set within the boundaries of the seamless dualities. For instance, a learning scenario may consist of a learning activity where learners explore the various types of architecture, and the structural principles that underlie those buildings. More informally, learners are asked to bring in their experiences with the construction of structures (e.g. building a tree house facilitates learning of the structural principles of a real building).

The SLAM model we propose may be the right tool to help design and explore science learning activities and ensure the attainment of specific learning objectives. It points to new forms of teaching, learning and assessment that are perfectly in line with the recent report published by the UK Open University (2015). Many of the new pedagogies put forward in the report are relevant to our aims, for instance:

- *Crossover learning* - connecting formal and informal learning
- *Learning through argumentation* - developing skills of scientific argumentation
- *Incidental learning* - harnessing unplanned or unintentional learning
- *Context-based learning* - how context shapes and is shaped by the process of learning
- *Computational thinking* - solving problems using techniques from computing
- *Learning by doing science with remote labs* - guided experiments on authentic scientific equipment
- *Adaptive teaching* - adapting computer-based teaching to the learner’s knowledge and action
- *Stealth assessment* - unobtrusive assessment of learning processes

On a more critical note, we are aware that there is today an enormous pressure on learners in social networks, as these can provide easy access to entertaining conspiracy theories and pseudo-scientific news, so there is more need than ever to enable young people to engage in rational scientific discourse and practice. Also it’s important to teach them to judge and validate the quality of information. Concurrently, as the STEAM curriculum has become increasingly prominent, some have argued that the general addition of an “arts” component diverts from a focus on the hard sciences

(STEM). We think differently, considering the 21st century literacy requisites discussed above, it’s important to develop students’ imagination and help them innovate through hands-on STEAM projects (Kim, 2012).

An interesting solution is to bring about the orchestration of scripted personal inquiry in science learning as put forward by Sharples et al. (2015), building on a combination of technology and pedagogy supporting the teacher. It is not really important to prescribe a flipped classroom or a reduced class-time strategy, whatever that is. We argue that the seamless integration of new technology in blended learning is mandatory in domain specific areas if backed by an appropriate pedagogy enabling authentic learning experiences, and these should include arts and design features that promote the attractiveness of science learning processes across contexts.

Conclusions

We found that a more current framework in which to explore innovative activities in the context of science learning has been lacking, in particular bridging formal and informal learning processes. So, in this paper we discuss and propose a new framework to support science education through blended learning, using a participatory and interactive approach supported by ICT-based tools, which we called *Science Learning Activities Model* (SLAM). The literature reviewed in this study spans references from “classic” models to the current research on mobile, seamless and immersive learning. Considering the current learner-centred approach and the emergent techno-culture, there is a need to provide a model with which institutions and instructors can design science courses that have high motivational impact on students, and are related to authentic settings. By using today’s flexible, interactive and immersive technologies with the appropriate pedagogies, following a design process based on the ten seamless dualities in SLAM, it is possible to have school and university students more motivated in science areas, and expect a more creative response to the world problems that surround them. We also believe that the foundations and basic structure of the framework can be improved, and for that more work has to be done in the field. One particular aspect of future research is to find ways to resolve gender issues in some science areas – engineering is a case in point - exploring how to improve the quality of blended learning designs, for instance, through the active participation of women scientists acting as role models in real and virtual settings.

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