

# A Pedagogical Model for Science Education through Blended Learning

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## Abstract:

This paper proposes a 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 study constitutes a work in progress and started as a response to complex societal developments such as a changing labour market, high turnover rate of knowledge, and use of technology as a natural part of daily life activities. Another concern was the emergence of new challenges in education, like learning in various authentic contexts and in collaboration with others, in ways that influence the circumstances learners live in. Many of these challenges are related to science and it would be expected that students were interested in science, however the contrary is the case. So, after reviewing the relevant literature and the current trend towards a learner-centred approach, we contend that there is a need to provide a model with which teachers can design science courses with high motivational impact on students. By using today's flexible, interactive and immersive technologies (mobile, AR, VR) combined with the appropriate pedagogies, we believe it is possible to have students more motivated in science areas (STEM), and expect a more creative response to the world problems that surround them.

**Keywords:** pedagogical model, blended learning, mobile learning, gamification, digital storytelling, augmented reality, serious games

## Introduction

Increasingly, cognitive scientists are finding themselves developing models, frameworks, tools and pedagogics 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. In the following, we begin the process of describing a framework aimed at improving science programmes (STEM) using a participatory and interactive approach supported by ICT-based tools. It departs from a context of learning increasingly mediated by mobile devices where a balance between learner's "presence" in both the physical and virtual worlds is constantly maintained. In this context the right learning tools and the right activity models are important to address specific science learning objectives.

The model we propose aims to contribute to the solution of a specific problem: few students pursue a career in sciences because the educational system does not motivate them, and because science studies (STEM) seem to be more "difficult" than other fields. 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 such as 'control of variables' (Kuhn et al., 2008). With this in mind, we set out to define a conceptual framework with innovative tools, robust pedagogics and formative assessment methods for teaching science through blended learning, aimed at upper secondary level and new university students, with a view to upturn the tendency to avoid these studies or dropout of science courses at a more advanced level. We argue that, to deal with the seamless learning spaces of today (Wong & Looi, 2011), we need an innovative perspective for the instructional design of science education supported by an operational model of activities. So, since last year, we have been digging deep around various models with the aim of forming an operational framework to help in the instructional design for science learning. We noticed that almost every model has its activities based on a specific context, on a set of technologies, and on clear pedagogical concepts. However, in most cases the affordances of current technologies (e.g. mobile, AR, VR) is not taken into account to create motivating activities, in authentic settings, and adapted to science learning requirements.

### **Blended learning and science activities**

For the most part, online learning has become a way of life for students wherever they are, at home, on the move, or in schools. For the institutions this is good news, as for the first time in history we have educational technologies that cost nothing to governments and schools: smart mobile phones (most students have one), networking software (freely available, e.g. Hangouts, Messenger, Skype), learning applications (freely and increasingly available, e.g. Apple Store, Google Play) and open educational resources (in growing supply, e.g. MOOCs, iTunes U, Khan Academy). There are other free 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, Collins & 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. This may be accomplished, for example, through the use of mobile communication and wireless technologies, which can be moved to any place, allowing for experimentation, augmented reality, image collection, map sharing, and communication with other students.

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 of education as the "transmission of knowledge" within the constraints set by a curriculum. Instead, education is viewed upon as an on-going process of learning through continued exploration and negotiation in various circumstances, roles and environments an individual plays part in (e.g. school, work, leisure, family/private contexts). As Don Tapscott (2008) put it some time ago: "Educators should take note. The current model of pedagogy is teacher focused, one-way, one size fits all. It isolates the student in the learning process. Many *Net Generations* learn more by collaborating—both with their teacher and with each other. They'll respond to the new model of education that's beginning to surface—student-focused and multiway, which is customized and collaborative." (p. 108). Learning in this way is in fact pervasive or ubiquitous, meaning that it is on-going 24 hours a day, 7 days a week, anywhere, anytime. 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. For example, students can watch scientists in action with short video clips, find out what questions are being asked, and explore some of the key ideas. In a recent study with school students ages 11–14, it was reported the effective use of a design toolkit (nQuire), a system to support scripted personal inquiry learning (Sharples et al., 2015). 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. It 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* (25 September 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 challenge for universities as higher education faces a digital challenge: with the number of EU students set to rise significantly in the next decade, 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 help 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 "new 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 an expanding learning ecosystem, next to the traditional educational institutions, for example, encompassing science discovery centres, community spaces and non-profit organisations.

We cannot ignore that students are no longer the same target population for which our education systems were designed a few decades ago. These students grew in a new technological environment, with its own techno-culture, and they will live in a more demanding, competitive and complex world. The technological revolution has produced a generation of students who grew up with multidimensional and interactive media sources, a generation whose expectations and perspectives are different from those that preceded it. Furthermore, this is a generation that lives in a complex world where science has an important role to play. Unfortunately, the majority of schools do not support a guided exploration of the real world, with authentic tasks, that allow for the development of skills to face this societal complexity; currently it looks like most curricula are just dispersed pieces of a puzzle. This suggests the need for convincing narratives and stories that will engage learners with science topics.

## Storytelling, narrative and gamification

Education is susceptible to fads like games and iPads. Despite storytelling's recent renaissance, storytelling is not a fad; 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; as a result good stories are remembered longer by students than regular lessons. 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, narrative and gamification, connecting technology and pedagogy in activities designed for science learning.

So, what is today a good definition of digital storytelling? Essentially 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).

Storytelling is based on a set of four elements that are still valid in the digital age, namely:

- A narrator
- A plot
- A setting
- Characters

Narratives relate a series of events that happened (in the past, as a memory), are happening (in the present), or will happen (in the future). A story must have movement and direction.

There is usually a conflict of some kind. Some common types of conflict may include:

- Conflict between one person and another or between groups;
- Conflict between a person and the natural environment;
- Conflict between an individual and the society.

Narratives are set in a specific time and place. These setting details are usually identified at the beginning of the story in the exposition. Sometimes the setting is kept vague or poorly defined for a reason. Sometimes it is very specific with dates and real city names. The settings, along with characters, are a writer's best opportunity to use rich descriptive language in her/his writing.

For instance, in science education we can consider that an educational "story core" may break down in four parts, from the perspective of the learner:

- First, a dominant challenge that must be evident— a question, a problem, an obstacle, an opportunity, or a goal. This creates tension that gives the story its forward momentum.
- Second, characters change as they wrestle with the problem. Either life or 'the old you' pushes back as new circumstances or 'a new you' struggles to emerge.
- Third, the problem receives closure: solving a mystery, reaching a goal, applying new academic knowledge, and overcoming an obstacle.
- Fourth, a window into the future is open and knowledge gained may be applied to new situations.

Eventually, stories may also be part of games, and, in the field of education, the application of games has had an increasing body of research (Bidarra et al., 2013). A common implementation is called *gamification*, the notion of using elements of video games, such as points, levels, and achievements, and apply them to a work or educational context. 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 (Lee & Hammer, 2011; Deterding, et al., 2011; Kapp, 2012). It's a concept that integrates the mechanics of gaming in non-game activities to make these more effective and enjoyable. When used in the educational field, gamification 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. The most common game mechanics include (Bidarra, Figueiredo & Natálio, 2015):

- *Points*: points are fantastic motivators and can be used to reward users/students across multiple levels or dimensions of a gamified activity. In general people love to be rewarded and, when interacting with a point system, they feel like they have gained something.
- *Levels*: these are often defined as point thresholds, so the students (or users) can use them to indicate a higher status and have access to bonus content.
- *Challenges, badges, achievements, and trophies*: the introduction of goals in an activity makes students (users) feel like they are working toward a goal. Normally, challenges should be configured based on specific actions and should include user/student rewards when they accomplish certain milestones with badges, achievements or trophies.
- *Leader boards or "high-score table"*: in the context of gamification, high-score tables are used to track and display desired actions, using completion to drive valued behavior. In intrinsic motivation terms, they are one of the most important features of a game, bringing the aspiration factor to the process.

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 the students; so, perhaps education processes could be improved by adding other play factors such as digital narratives and immersive technologies that are able to involve students in a way that is more physical (e.g. AR, VR), so learning becomes more memorable and intense.

The increased availability of smartphones and tablets with Internet connectivity and high computing power makes the use of augmented reality applications with these mobile devices possible 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 educational activities, games and resources that can take advantage of the augmented reality technologies for improving learning activities. We believe that the use of AR will change significantly many teaching activities by enabling the addition of supplementary information that may be viewed on a mobile device (Squire & Dikkers, 2012), helping students to improve understanding of educational content.

It is possible to go even further and use, for example, the Augment eco-system to add a layer and show a 3D model that can be used by the teacher in helping students improve learning of orthographic views. Wu and Chiang (2013) found that applying layered 3D animations provided more enthusiasm in the learning activity, better performance in understanding the appearances and

features of objects, and improvements in the spatial visualization capabilities. New interaction metaphors for augmented reality on mobile phones are emerging, for example, applications where users look at the live image of the device's video camera and 3D virtual objects enrich the scene that they see (Hürst & van Wezel, 2012). The development of augmented reality games for education also has some distinctive cases: *Mystery at the Museum*<sup>1</sup> and *Environmental Detectives*<sup>2</sup> are excellent examples of AR games created by the MIT Teacher Education Program.

### **Towards a *Science Learning Activities Model (SLAM)***

Games, storytelling and digital narratives are becoming a relevant part of the seamless learning spaces of today, merging physical and virtual environments, and are backed by widely known technology-based solutions that may be gathered under the vague term of "e-learning". Also mobile learning and immersive learning have emerged as serious contenders to help support the blended learning needs of individuals in this day and age. According to Klopfer (2008), "e-learning itself can mean many things to many people and at its core simply means electronically supported learning, which can be online, on desktop PCs, or even on mobile devices (though the latter is sometimes referred to as m-learning). In practice e-learning often means delivery of information and content to learners through online hypertext, accompanied by images, audio, and video. But e-learning can mean much more, as evidenced by the recent surge of interest in using videogames to teach everything from basic math skills for young learners to advanced communication skills for adults." (p. 8). Some researchers of mobile learning try to define and conceptualize it in terms of devices and technologies while others prefer an educational framework to situate the mobility of learners and the potential of learning. The role of theory seems to be a contested topic in a community that encompasses philosophical affiliations from empiricists to post-structuralists, each with different prospects about the extent and authority of theory in their work. The mobile learning field could nevertheless use the authority and credibility of some conceptual base (Traxler, 2007), and be better integrated in common online learning platforms.

Within the realm of blended learning there are frameworks to address various situations, 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). 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. In these studies the emphasis in activities is important and consensual, especially for science learning, where the mediation of mobile devices may serve as a catalyst for face-to-face interactions in the field, inside labs or solving problems in groups. Furthermore, because education is an applied field, and researchers bring agendas to their work, many seek to produce specific results such as engaging students in the making of science.

Essentially, there are three consensual "large dimensions" in these attempts to build operational frameworks for blended learning: *context*, *technology* and *pedagogy*. In this study for a SLAM framework, that we consider a work in progress towards forming a more sustainable model for science learning, a meta-analysis of other established models was undertaken, departing from those large umbrella concepts. However, our review did not put aside the "classic" models and moved to

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<sup>1</sup> [education.mit.edu/ar/matm.html](http://education.mit.edu/ar/matm.html)

<sup>2</sup> [education.mit.edu/ar/ed.html](http://education.mit.edu/ar/ed.html)

newer ones, quite the opposite, there was from the start an interest in seeking the convergence of the established models with the emerging ones.

### *Context*

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 had to consider all the possible contexts of education and training, formal and non-formal, considering degree and non-degree programmes, and embracing the upper secondary school to early higher education contexts. These are the educational levels with the highest dropout rate and where lower achievement in science occurs. 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 blended/mobile learning environments (Park, 2011).

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 (be it a classroom, a training centre or a science discovery centre). The same kind of discontinuity may exist in temporal terms, namely the reciprocal contacts between students, teachers and the teaching or training system. In this regard, the face-to-face mode and the online learning mode have been found to be converging, not only due to the success of blended learning experiences (flipped classroom, SMOCs) 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 learning products (iTunes U, OCW, Khan Academy, etc.), create favourable conditions for increasing students' autonomy and to stimulate independent learning.

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 it becomes important to consider 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. Also the potential of PLEs has to be recognized and many tools and resources help students fit into the right educational context.

### *Technology*

Researchers concerned with current technologies for supporting effective learning in a seamless way (Brown et al., 2005) have labelled the multiple skills that are aligned with technology as "Twenty-first Century Literacy," 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.

For instance, in the area of “pure” technology literacy, students who create portfolios and digital stories improve their skills by using software that combines a variety of multimedia tools including working 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 by using 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 affects screen reading, concerns about personal security, possible radiation exposure from devices using radio frequencies, the need for rain covers in rainy or humid conditions, among other. 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* that was a very useful way to consider the particular circumstances a groupware system had to address to be effective in cooperative work. Even today, this conceptual matrix is an established model to design and support synchronous and asynchronous learning activities in a blended learning situation (table 1). Following this model, the same academic content may be delivered in four modalities that address the preferences of different student learning profiles.

Table 1. *Time-Space matrix* applied to blended learning activities.

	<b>Same Time</b>	<b>Different Time</b>
<b>Same Space</b>	1. Location aware games, events, and augmented reality enhancements.	2. Completion of activities in a school, university, science centre (in a fixed location).
<b>Different Space</b>	3. Online events, games, synchronous activities, and master classes.	4. Online interaction, asynchronous activities, events, and serious games.

A current and more developed model for cooperative work, which may be also 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 coordinated 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:

1. Synchronicity (the time factor as in the time-space matrix)

2. Physical distribution (the space factor as in the time-space matrix)
3. Scale (total number of participants)
4. Communities of practice (number of communities represented)
5. Nascence (un-established (e.g. new) versus established (e.g. old))
6. Planned permanence (short-term vs. long-term)
7. Turnover (low vs. high)

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*

A “classic” and established framework to integrate technology and pedagogy is Richard Felder’s prominent work called the “Felder-Silverman learning and teaching styles model” (1988). As it addresses the various learners’ profiles the model remains relevant to the seamless learning processes used today by mobile learning and blended learning. The “dimensions” included in this model (sensing or intuitive, visual or verbal, active or reflective, sequential or global) have parallels in other learning style models. However, the operational combinations are unique to Felder’s model. The first dimension (sensing/intuition) is one of four psychological types in Jung’s model, and the third dimension (active/reflective) is a component of Kolb’s learning styles model. The second dimension (visual/verbal) is analogous to the visual-auditory-kinaesthetic formulation used by the modality theory and related to cognitive studies in information processing. The fourth dimension (sequential/global) has abundant references in the literature. These learning style dimensions are based on a continuum and not on opposite categories, thus creating a flexible and effective framework. Therefore, a student’s preference on a given scale (e.g. for sequential or global tendencies) may be strong, moderate, or almost non-existent, may change with time, and may vary from one subject or learning environment to another. Anyone who wants to check his/her learning style may submit an online test via the *Index of Learning Styles Questionnaire* available at the North Carolina State University (and receive immediate feedback):

<http://www.engr.ncsu.edu/learningstyles/ilsweb.html>

Building on the previous model, and emphasizing how variable learning profiles may be across time, perhaps what is needed today is an approach that is flexible and can be designed by the learner according to his/her learning style, personal needs and learning context. To this end, the *Personal Learning Environment* (PLE) concept has emerged within the UK and other countries around the beginning of this century 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). They 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 (such as Elgg) to integrate the different units. 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). They contrast with the current crop of learning platforms that is very much focused on meeting the goals of the central institution in providing a standard technology for teaching and learning. Making a case for PLEs authors Attwell, Bimrose & Brown (2008) stated "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.

So, taking a learner-centred approach to connect the three umbrella concepts discussed above – *context, technology, pedagogy* – in this study we considered a more detailed approach to make the SLAM model operational; thus we propose ten seamless dualities that may co-exist (table 2).

Table 2. The *Science Learning Activities Model (SLAM)* proposal.

<b>Dimensions</b>	<b>Indicators</b>	<b>Descriptors</b>
Context	1. Formal and informal learning	Specification of topics and activities and how they fit together in a set curriculum.
	2. Individual and collaborative learning	Specification of study modes and related resources (allowing for learners' PLEs).
	3. Open and closed learning environment	Structure of free and restricted access to learning environment and resources (e.g. MOOC and SPOC).
Technology	4. Synchronous and asynchronous learning	Technology supporting learning modes (time dimension in Johansen's matrix).
	5. Virtual and physical interaction	Technology for blended learning interaction (space dimension in Johansen's matrix).
	6. Single platform and multi platform	Online learning platforms (e.g. Moodle, Elgg, Blackboard, Edmodo).
Pedagogy	7. Theoretical and practical pedagogy	Approach to a learner-centred pedagogy (e.g. Felder-Silverman Learning Model as a reference for activities but allowing for student PLEs).

	8. Exclusive and open learning design	Design of structured activities for specific outcomes (e.g. games and simulations, master classes, multiple-choice tests). Bloom's taxonomy may be used to design open and mixed activities (e.g. transmedia storytelling, creation of digital narratives, portfolios).
	9. Centralized and peer assessment	Modes of learner assessment components and activities in a formative process.
	10. Pre-structured and open guidance	Modes of scaffolding the learning process across activities.

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, but we recognize this is just a preliminary stage of a study that we hope to continue through a financed EU project. 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 practices. A way to deal with this is finding novel approaches to engage students in personal inquiry learning (Anastopoulou *et al.*, 2012), namely, investigate how technologies can be effectively used to enable inquiry learning and, more specifically, how mobile technology may support evidence-based inquiry learning across formal (classroom) and informal (home and outdoors) settings (Sharples *et al.*, 2015).

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. We argue that the seamless integration of mobile learning in these processes is mandatory as more and more students and teachers make use of portable devices such as tablets and smartphones, as it enables authentic learning experience and guided support of the learning process across contexts.

## Conclusions

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, called *Science Learning Activities Model (SLAM)*. We found that a more current framework in which to place diverse blended learning activities in the context of science learning has been lacking. The literature reviewed in this study spans references from "classic" models to the current research on mobile and immersive learning, however we did not put aside the "classic" models and simply moved to newer ones, we recognize there is still an interest in the established models as they seem to be effective in many situations. However, considering the current learner-centred approach, there is a need to provide a model with which teachers can design science courses with high motivational impact and related to authentic settings. By using today's flexible, interactive and immersive technologies (mobile, AR, VR) with the appropriate pedagogies, we believe it is possible to have students more motivated in science areas (STEM), 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, but to achieve this more work has to be done in the field to strengthen the basic model and help improve the quality of the blended learning designs that are developed.

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