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PERSONAL LEARNING ENVIRONMENT AND THE LEARNING OF MATHEMATICS. POSSIBILITY OR REALITY?

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Abstract:
This paper is about one of those complex and disputed concepts that live in the educational ecosystem: 'Personal Learning Environment' (PLE) and its application and manifestations in Mathematics Education. Although PLE is an expansive concept, that is, it is under construction and generates an on-going discussion; there are some things we can say more definitely about it. I am going to explore different approaches to concept formation as evident in mathematics education. I will therefore describe significant features a PLE should have as being creative and experiential; open and reflective and; connective and social some important ones. I will also survey the existing PLEs in online mathematics education and expose how I intend to design a mathematics course that will use history of mathematics as a cultural context and how this will promote the use of personal learning environments as a means to learn mathematics for young students. The questions my talk will expose arise as part of my own struggle looking for theoretical anchors to define this complex and unstable construct –PLE, and its role in Mathematics Education.

Key words:
Personalisation,
Mathematics Education,
Concept formation,
Digital Tools,
personal learning environment.

INTRODUCTION

It is widely accepted that concepts are the building blocks of human cognition and an important component of our innate capacity of reasoning. In some cases new concepts both shape and lead to social innovation [1]. In educational research where –in some areas— we strive for social innovation, the elaboration of new concepts is at the center of the activity.

But what does the word concept means? It has its origins in the Latin word *concipere,* which is in turn associated with the term *conceive* that means envisaging, imagining; "making up a possible future state of affairs"[1]. He [1], points out at a revealing use of the word concept in the field of product development or design. In this context 'concept car' for example, means a future oriented model of a dream car. "They are like preliminary versions of the essential contours of an emerging product"[1].

How does a concept form? In mathematics for example, concept formation is the process of identifying new classes of objects with interesting and/or new or desirable properties [2]. But if we want to look at how such a concept is formed in student's mind we must ask the question to Mathematics Education. Concept formation in its simplified version, following Vygostky's ideas is a negotiation of meaning mediated by social interactions. It consists in introducing a meeting point, a creative middle [1], where accepted concepts –mathematical in this case— that are being learned interact with experiential, or every day concepts in the child's mind. As a consequence the meaning of that concept (encapsulated in a word sometimes) evolves for the child until it is fully learned and ready to use in different contexts [3]. If they are adopted unthinkingly, they will not accomplish to do the conceptual work they are meant to, not only in the learning process but also in research where they have a dual role: they inform our study and are also the basis for us to inform others of our study [15]

In educational research where designing innovative interventions is very common, we must generate a guiding concept that envisages the emergent product and guides the research process. Concepts in social science encapsulate complex and organic processes that are perhaps product of spontaneous human actions embedded in everyday activities. In those cases the task to conceptualize becomes multifaceted, intricate and debated. That is the case with *'personal learning environment'* (PLE from now on), which is what my research aims to develop: the design principles for a scaffolding structure of a personal learning environment designed and shaped by the learner. Going back to Mcluhan's idea of technology (PLE in this particular case) as the extension of man [4].

A HISTORY OF THE DEVELOPMENT OF THE CONCEPT OF PERSONAL LEARNING ENVRIONMENTS

The first time PLE was mentioned as a concept was in 2001 in a paper by Oliver and Lieber [5] and from the first session in a JISC (Joint Information System Committee) conference in 2004 it has been influenced and affected by the on-going changes of web technologies [6][35]. The concept started to be discussed around the topic of virtual learning environments and how the web 2.0 was disrupting education with its flexibility, openness, usability and more then every thing else, the freedom with which those tools could be used by learners "crossing and merging multiple learning contexts by learners themselves" [7]. There are two main strands in the research of PLE; being the mainstream concerned with digital instrumentation of teaching and studying activities in higher education [8][10] (For more extended information look at [6][34]). This group of researchers acknowledges contradictions between the institutional technology provision and students own learning environment, being the major concern the technological difficulties of merging both environments [6]. I argue that the main difficulty does not lye in the technological issue per se but in the implications they have in the pedagogic vision of those institutions [10]. Is not a PLE about personal choices, preferences, ownership, *'my own'* and its implications in the learning experience?

Curating ones own learning environment is an important aspect regarding the ownership of the space, which in turn has positive consequences in the learning experience [7] . If young students have to become life long learners in order to be proactive citizens in a knowledge driven society, capable to adapt to the unexpected and cope with an overwhelming plethora of new social and digital tools, and if it is expected from them to be 'web makers' [11] that is, to read, write and participate effectively on the web, would not designing, crafting, and managing a PLE, for the learning of mathematics be a good catalyst for students in the learning and improvement of such skills? My answer is an intuitive and hypothesized yes for which my study will provide empirical evidence and a thoroughly researched answer. The PLE should be one of the learning outcomes, making it a powerful learning tool –a meta tool; a means for students to become digital competent in the academic field. Learning to learn, while at the same time learning mathematical knowledge is a much more compelling approach to learning [9] both under a social constructivist approach.

The other strand of research is concerned with the educational approach and not so much with the digital and technological instrumentation [12], [13], [14]. There vision is more oriented towards the learner's control and ownership; with the meaning of personal and personalization implicit in the PLE and how can student's agency (the human capacity to make choices and impose them on the world [7]) over the learning process be operationalized [6][12]. How can a PLE transform students in agents and co-creators of the learning process?

SEARCHING FOR SIGNPOSTS IN THE DIFFERENT CONCEPTUAL ROADWAYS

Gaining focus in any research activity is a permutation of keeping an eye on the road ahead, though remaining vigilant. Concepts –using this metaphor- will work as signposts, distinguishable features in the landscape[15]. In order to search what would be the most appropriate route for my research I will survey some of the different concepts of PLE as well as some of existing PLEs in different subjects including mathematics education. This will allow me to have a broader view of what is out there and what is missing and how my work could add new features to the concept of PLE hence proposing a blueprint for a new signpost: Rich Mathematics Empty **D**ynamic**S**pace, my personal version of a PLE for the learning of mathematics integrating history and culture context.

The definitions are taken from two compelling synthesis [6] [16] of important voices in PLE research. I will list different definitions and its author and at the end I will identify patterns and find commonalities with which I can start.

Different definitions of Personal Learning Environments

A personal learning center, a collection of interoperating applications. A node in a web of content. An environment rather than a system. (*Downes, S.*)

- Is a facility for an individual to access, aggregate, and manipulate digital artifacts of their ongoing learning experience. (*Lubensky R.)*
- Systems that help learners to set their own goals and manage their own learning. It is composed of one or more subsystems: as such it maybe a desktop application, one or more web-based services. (*Van Harmelen, M.)*
- A personal landscape. A connection tool. It can be part of something bigger like a knowledge ecology. (*Chatti, M.*)
- An ecosystem of connected educational resources facilitated by a set of tools and fuelled by collaboration opportunities facilitating the consumption of content that enables and increases understanding of specific knowledge domains. (*Kraus, L.)*
- Are not an entity they are collection of tools brought together under the construction of openness, interoperability, and learner control. They are comprised of two notions: the tools and the conceptual notions that drive why and how we select individual parts. It is a concept entity. (*Siemens, G.)*
- A potentially promising pedagogical approach for integrating formal and informal learning and supporting students self-regulated learning in higher education contexts (*Dabbagh and Kitsantas)*
- It is an outcome of learning. Customizable by the learners and heading towards providing an open set of learning tools, an unrestricted number of actors,

and an open corpus of artifacts either pre-existing or created by the learner. An end user development (*Wild et al.)*

- A collection of tools to foster self-regulated and collaborative learning (*Valtonen, et al.)*

Looking for patterns (simmilar signs in all signposts)

The idea of a new approach in the use of technology for learning is the overarching vision amongst most of the authors being the idea of a network and collection of tools and resources a common feature amongst many. Self-regulated learning is one of the functions of a PLE and personalisation is not about differentiated instruction is about the personal choices put into the design of the PLE and students choosing their own path to the learning of the subject. It is not very clear stated if the PLE must be build or not by the learner, it could be either an institutional initiative or not. This aspect is one of my particular interest as I do think that the pedagogical power of a PLE resides in part, in designing and building it [9]; there are digital skills embedded in the task that are powerful for the learning of mathematics and other important skills for the 21st century.

In line with this idea [12] developed a course in vocational education in Finland where students had the chance to build entirely their own PLE, considering ownership, personalization, student's control, and self-direction important attributes connected to PLE. In their view [12], personalization "emphasizes learning where students are encouraged to bring their unique ideas and background to the learning situation as resources that may be utilize… (p. 733)" highlighting the ownership of the PLE. An interesting point for discussion is the fact that students need to be aware with the ways in which they learn in order to choose the adequate tools and content to support their learning through the PLE. Pedagogical support is needed regarding the skills students need to have in order to self-regulate their learning, this is far for being evident for young and even adult students. "Instead of focus on technology, the emphasis ought to be on the pedagogical demands of PLEs in education" (p.738). The study revealed "how the assumptions related to using PLE in education are not necessarily reflected in practice…using PLEs in education is a fairly new phenomena thus it needs further research" (p.738).

Another case [13] that worked with the idea of students (prospective teachers) building their PLE concluded: "PLE include the mechanism that help him to rework and rebuild information and knowledge both in the phase of individual reflection and recreation as phase in which other people helps us reflecting for its reconstruction" (p.10). It can be seen that PLE in both of those examples is used as a meta-tool for the learning of self-regulated learning and digital and media tools as well as the subject knowledge involved in the course.

ROLE[1] is a European research project about responsive open learning environments. They where concerned mainly with digital instrumentation and self-regulated learning. One of their main goals was to create all the tools –widgets as they called them, in order to make a system that would be interoperable thus data could be shared and stored.

Khan Academy[2] is a mathematics online environment that is called 'personal learning adventure' by his founder. Although it is different from what the conceptualization of PLEs tells us, I consider it relevant because it is one of the most emblematic examples in the USA for personalized learning online environment. It is an already build system that contains all the mathematical topics covered in high school level in the USA. In the American version personalization is most of the times about differentiated instruction; the goal is to adapt to student's learning needs, prior knowledge and her/his level of expertise. It has nothing to do with what the learners brings into the environment in order to build it.

Another interesting example are the Massive Open Online Courses (MOOCs) a phenomenon that was born in the US and delivered by many higher education institutions in a common platform, Coursera. Mathematical Thinking is a relevant MOOC in mathematics education. The course is designed as a web application that is accessed through the browser. They are designed as standalone modules, learning objects, for which the learner would need to create (in my view) a PLE. Students need to organize and connect different resources, tools and interactions in order to manage the learning experience. In this case building a PLE is one of the actions a student need to perform being one of the learning outcomes of the whole process. MOOCs could be seen as a learning management system open to external students. Grasp[3] is a platform created for teacher and students to build their own PLE. Interesting because it is a PLE deconstructed in all its elements so it serves as a conceptual tool in order to understand their vision of a PLE.

In France at the Université de Moncton, a learning community CASMI[4] (Communaute´ d'apprentissages scientifiques et mathe´matiques interactifs) was created. It is conceptualized as an extension of the formal mathematical learning space and it aims to connect mathematics to other subjects. Participants are schoolchildren, teacher, parents, as well as students of the university enrolled in didactic courses who develop problems and guide students and teachers. Students where invited to create their e-portfolio with their individual contribution and share it with the community receiving feedback. It is an open learning environment with a touch of personalisation given by, on the one hand, the creation of an e-portfolio by participants and on the other, the freedom participants have to choose the problems they want to work on and to use any digital tool in order to perform the activity [17]. There are other similar initiatives with this format of online community and free joining with the idea of enriching the mathematical experience, knowledge, and skills in children and teachers. NRICH[5] is one of them. It has

1 ROLE www.role-project.eu

2 khanacademy.org
3 http://graasp.epfl.ch
4 www.umoncton.ca/casmi
5 http://nrich.maths.org

the underlying vision of CASMI. The mathforum[6] is another learning community of teachers, mathematicians, researchers, and students using the power of the Web to learn and improve. Some are just webpages as Mathigon.org –excellent one— that could serve as external resources for schools or even students on their own with a particular interest in mathematics. Nevertheless they are different from the PLE that I am envisioning. They lack many of the common features listed above. They are better catalogued under learning environments, standalone resources to enrich the learning, and community of practice.

I conclude that PLEs in mathematics education are scarce, at least PLEs that fall under the category of the cited definitions listed above: designed and build by the learner in order to guide and orchestrate their learning experience. Maybe some of them are not public projects per se but part of a bigger one?

PLEs are –as stated by [10],[12],[13]— a new approach to learning in general and even more to the learning of mathematics; so new, that finding relevant and illustrative examples has been a long and relative unfruitful search. It has been possible to search for some common aspects –signs, in the different definitions –signposts— as in some of the examples –roadways, but there is still a need to embed these features that characterizes a PLE in mathematics education. The how to is still part of empirical part of the research. I will start with a draft concept for a PLE for the learning of mathematics, a theoretical approach, a possible roadway I will take that will be refined during the learning experience in order to be more accurate and adjusted to the learners needs and particularities of the experience.

Towards a draft version of the Rich Multimedia Empty DynamicSpace (RME-DS) my vision of a PLE for the learning of mathematics

The idea is to design a learning intervention that will use the history of mathematics in its cultural context to enrich the mathematics content knowledge bringing students to build their PLE to orchestrate the learning experience and find connections between mathematics and the human, ideas and their context, past and present, solutions and problems, the individual and the collective. Harnessing the power of the flow of ideas, recognizing that the present is a moment in a continuing evolution. Orchestration is defined by [18] as the intentional organization by the teacher of various tools available in the learning environment; my proposal is to complement this with the student organizing their learning experience, choosing tools and resources through their PLE: Students orchestration.

Driven by the question of how are we preparing our students to be effective network learners engaged in the deep understanding of mathematical ideas immersed in its cultural and historical context and inspired in the seven principles of innovative learning [19][20] listed bellow, as well as in the futuristic study [21] done by the European Commission[7], and in FutureLab's[8] learner's charter for a PLE, I will illustrate in figure 1 the Rich Multimedia Empty **D**ynamic**S**pace for the learning of mathematics in high school level.

I aim to design a learning intervention that foster in students the need to create a personal learning environment with 7 duplets of attributes that depict at the same time the features of the learning space as well as some aspects of the mind-set of young students –the final users that are growing up in a participatory culture [22] [23]

- The seven principles of learning:
- The learner at the center
- The social nature of learning
- Emotions are integral to learning and key in achievement
- Recognising individual differences
- Stretching all students
- Assessment for learning
- Building horizontal connections

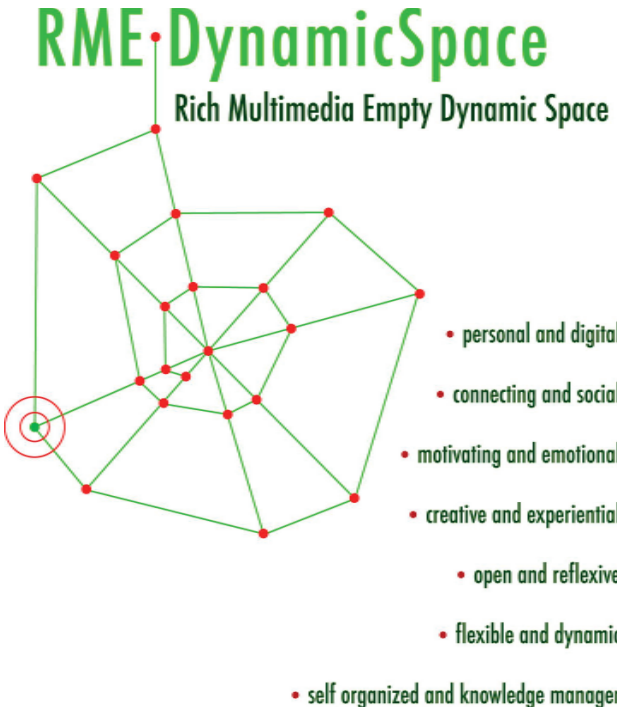

Figure 1. Rich Multimedia Empty DynamicSpace for the learning of mathematics, Kuhn, C (2014)

Connecting + social: Connectedness is one of the most accurate descriptors for young people [24]. Young people move without problems from one space to another –from visual to written, from virtual to physical, from public to private, from leisure to duty. Mathematics is also a very well connected corpus of knowledge that is a social production of its time. Finding those connections is at the core of the discipline.

Open + reflective: Young students are open to diversity, differences and to sharing with all, even the unknown. They live in an open web culture where digital artifacts are easily remixed, recreate, and shared again. Self-regulation

6 mathforum.org

7 http://ftp.jrc.es/EURdoc/JRC47412.pdf

8 http://archive.futurelab.org.uk/resources/documents/opening_education/Learners_Charter.pdf

is about reflecting about the learning goals, about creating a personal path for the learning in general and mathematics in particular. It is about getting and giving meaning to the 'whats' and 'hows' of learning and in doing so learning how to learn [14]. Reflectiveness is a core skill that will help students to not get lost in the overwhelming vastness of the open Web.

Creative + Experiential: Young people prefer to learn through discovery, exploring and finding out though in a structured way. They need some parameters, rules, and procedures knowing what would it take to achieve the goal. They prefer to learn by doing and not just by being told what to do. Re-invention of mathematical knowledge is about an experience driven by the learner and guided by the teacher. The affordances of digital tools allows for a performative paradigm, which is exactly the one knowledge re-invention requires.

Flexible + Dynamic: Learning is a dynamic process that needs different tools and different resources at different stages of the process. The space must be suitable for change and customisation of the process and the products in all its stages. Calculus is about the dynamic of change – fluxions- how Newton called it. A nice metaphor to work with in the RME-**D**ynamic**S**pace.

Self-organized + Knowledge Manager: Complex systems are self-organised. There is no outside control that leads the organisation of the community. It is a process that comes from within in order to accomplish a particular process [25] that occurs outside. In the learning experience with a PLE there will be such a process of self-organisation occurring in many layers. Building the space, choosing the interactions, crafting the groups and the activities, planning the learning outcomes, and the path to learning. Being the space a kind of hub where many and complex processes will take place. Knowledge will be managed from there, information will be transformed into knowledge that will be shared and exposed by students. It will serve as a center from where to departure and where to arrive.

Motivating + Emotional: Learning is multidimensional encompassing a variety of motives and emotional states. To engage in learning emotions and motivation has to be taking into account [19].

Personal + Digital: The space is the expression of each learner, an interpretation of what learning means to her/him and an operationalization of that process. Learners bring their unique experience and meaning, background and expectations making from their space a very personal environment that will enable the learning in general and of mathematics in particular. They are the authors, the designers, the crafters of this space. Being the format a digital one.

The overarching vision is one in which all the aspects of my approached to this learning experience function as a network. The red dots in fig. 1 are the nodes of the network that need to be connected in order to make it strong and efficient. Mathematics is a network where ideas and concepts (nodes) are deeply connected and intertwined. So is history. A network of time and mind-sets, problems and solutions, past and present, phenomena and laws; profoundly connected in a continuum (spiral form of our network). It serves as a tool that allow students to harness the power of the flow of ideas. Learning can also be seen through the network metaphor. It is a process of creating networks [25]. Our mind is also a network, ecology of resources: biological (neurons) and intellectual (cognitive processes); where adding new nodes creates new neural paths (connections) and increases our learning capacity. Human's mind work highly connected to adapt to the environment, or some times not only to adapt to it, but to create a new environment. In words of [26]: *New ecological niches.*

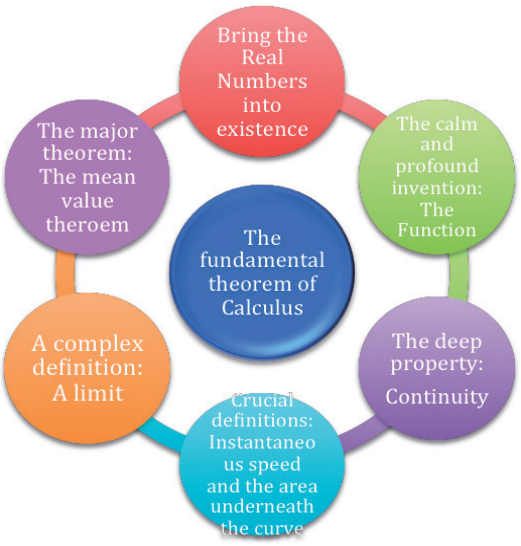

Figure 2: Connected elements of the calculus for high school level

Learners are encouraged to inquire into the mathematical and non-mathematical worlds and construct meanings for mathematical concepts, make explicit connections between mathematics ideas and other pieces of knowledge, history for instance, and by doing so promote more robust mathematical intuitions. There is also an external network that connects the learner with the external entities (nodes) e.g. people, books, data bases, experts, or any other source of information making meaningful connection between them in order to re-invent knowledge and construct knowledge artifacts in digital formats that again are new nodes to connect in other learning networks. An infinite process represented with the spiral shape of the network depicted in fig. 1.

The word 'empty' in the title is inspired by [27] with his idea of the 'empty reader', which refers to the fact that students should be the *authors* of the classroom textbook. In the RME-DS, the intention is that students are going to be co-creators of the experience and one of the learning outcomes is the variety of learning resources generated by the students throughout the learning process. The starting point of the classroom is student's questioning and uncertainties regarding the subject knowledge, organized in a way that teachers can be prepared but also open to learn with their students. A real process of co-construction of learning resources for the learning of mathematics. Moving away form teacher and text books as definitive and only sources of knowledge [28].

The learning activities and the design of the course

The learning intervention I aim to design is for the learning of calculus as an integral whole of connected – conceptual and historically— ideas and properties that had shaped one of the most pivotal mathematical concepts in modern history: The fundamental theorem of calculus. "The calculus is a blueprint in human thought" [29]. It has triggered major changes in our way of thinking and it opened up the road to modernism. It has lead man to great places –amongst other- to the moon. The learning activities I will design follow [30] ideas of knowledge re-invention and the ones of [31] who adds that in the process of knowledge re-invention the history could be a good ally for teacher as well as for students. I will study the development of the calculus and its elements using historical knowledge in order to look for creative ways to bind them together, to connect them and create a more meaningful way to teach the subject. In words of [31]: "Having a better understanding of the mathematical building: strange elements in its structure are well understood when the historical development of the building is clear." Calculus (for high school level) being the mathematical building I am trying to understand better through the historical development of its elements, which are depicted in fig.2. and inspired by the book: A Tour of Calculus [32].

One initial activity for students could be to research about the history of some of these elements mentioned above. Organise interviews to expert historians or organizing an online workshop using digital tools and online communication could be one of many options. Making a critical review of some of the videos of [33] regarding the history of calculus could be a different one. In any of the cases they have a twofold outcome: on one side to take a closer look into the history of mathematics in order to find connections between loose concepts regarding the calculus (at highs school level) and on the other hand foster student's role of co-creators producing learning resources for the calculus course, which will be called: A Universe of Knowledge, aligned with Newton's idea of understanding and uncovering the mathematical design of the universe.

This is much in its beginning and I am working on this aspect more in detail in this stage of my research. Nevertheless there is a clear overarching idea about what and how to teach that will serve as a guide for the design process of the learning intervention. I am very much inclined that more than a possibility, the Rich Multimedia Empty **D**ynamic**S**pace for the learning of mathematics is a reality.

Much work is still to be done in order to realize it and bring it into reality!

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