Multimedia in Maths and Science Education – Connecting Through Human Needs and Mobility

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Abstract
We are all connected in more ways than one. We share the same basic qualities and abilities that are the result of our human nature and the way our brains developed. We are also very social creatures and we learn better when we are able to communicate with other people. The technological advances have enabled us to create a message that is very well adjusted to the needs of our brains and human needs and a message that recreates the natural world almost identically and brings it to the student's desk. At the same time it also enabled an almost instant way of communicating without actually being at one another's presence but at the same time this ability has disrupted - in the eyes of many teachers and parents - the learning process. We decided to combine all these similarities and ways of connecting people and employ it to benefit the learning process by making it more attractive, mobile and effective. We chose mathematics and science for the first turn as they form the basis of our world and thinking and are the most sought skills on the employment market. Both science and mathematics are deeply related to our world, they are behind the everyday processes and structures that we interact with. And we do interact with them using all our senses. Therefore multimodal approach and interactivity in the education process turn out to solve many problems and make the learning much more attractive. That is what we have implemented in our products, based on extensive practice and academic research, both discussed in the paper.

Keywords
Learning, interactivity, education, math, science, multimedia, human development, brain, multimodality, multisensory input, mobility, mobile devices,

INTRODUCTION: MATHS AND SCIENCE
Mathematics is related to our everyday experience and it is based on metaphorical thinking that enables us to understand it (Reed, 2010). A lot of maths consists of visual patterns that our brain is able to make from the environment that surrounds us. The goal is for one to be able to understand those patterns and to make sense of them in such a way that will enable to solve everyday problems and meet one's needs. But the way that maths has been taught made it irrelevant and detached from reality. It is hard to see a connection between an algorithm and the world outside the classroom window. The same happened to science, therefore all the issues and demands made with regards to math, apply to science as well.

Mathematics is not about memorizing a set of rules but rather it is a way of thinking. We all need to develop a number sense, spatial sense and an ability to solve problems. We need to learn to make sense of the numbers, interpret the data and communicate effectively, develop critical ways of thinking, develop visual comprehension, understand relations between shapes, understand dimensions. But we do not
have to teach that through rote learning, algorithms and rules. Interestingly enough Einstein’s growing dependency on algorithms reduced his visual abilities and productivity (Pais, 1982).

In our school reality, maths is very much related to fluency in language. Very often the learners are required to understand long passages of text before embarking on solving the actual problem. It is though very hard to distinguish where the problem lies: in understanding the mathematical concept or in reading the problem. Therefore other forms of expression should be employed.

Learners need to be allowed to experiment, they should also be exposed to arithmetical problems as it gives them a chance to collect a series of strategies that they can later revise and apply the most efficient and appropriate for a particular problem (Sousa, 2008). Mathematical content must make sense to learners and it must have meaning. Unfortunately learners spend their time memorizing arithmetic tables and facts, losing the idea of the underlying arithmetical principles involved. They become little calculators. Computation is basically the only thing they learn (Wolfram, 2012).

So how do we teach maths and science? What we need to learn first is to understand how the brain works and how it learns and then see whether the newest inventions of technology could help us here. Because technology is just the tool that gives us tremendous possibilities but that can be misused without proper understanding of the bases of learning and may not be employed efficiently or effectively.

**HUMAN DEVELOPMENT AND LEARNING**

When we look into human development, we will see that we have always learnt on the go, applying all our senses, that have developed all at the same time. We developed with a lot of visual stimuli, that our brain had to process extremely fast as our life depended on it. Visual approach is perfect for patterns recognition and for solving problems. Unfortunately it has been long underestimated (West, 2004).

Recently verbal skills have been regarded and appreciated most but with the development of technology these skills will be the first to be replaced by technology itself. Visual skills, creativity and critical thinking will be in demand. Because this is what humans really excel in. And the rest can be replaced with automaticity.

It seems that children do their best learning before they go to school. And what is more interesting: it is then and only then, that they like the process of learning. They do it naturally until trained out of it. So what we need is to better understand what it is that keeps children engaged and curious, what makes them natural learners and then we will be able to improve the learning process (Holt, 1983). Children learn and want to get things right because they want to satisfy themselves, they want to solve the problems of the surrounding world and be able to control it. We should try to keep this internal motivation alive and burning, not extinguish it by forcing education upon them and give external gratifications before it is necessary.

We have been working with children for a long time, testing our products, asking them questions, watching them. What we found out is that children want to be able to make sense of the world, to understand it, figure it out and be able to manipulate it like the adults do. It is a strong desire but somehow the school approach kills it by serving detached pieces of information that seem not to have much to do with the world around. And it is especially true in mathematics. Who in the real life divides by fractions? Yet that is what we teach at school, often without much explanation about its real-life application. And when children ask what it is for, they learn that it serves the purpose of testing. And when you come from traditional schooling it may actually
be hard to realize that everything expressed in maths has its source in real life. Negative numbers for example are in temperatures, functions in identity numbers or cars' registration. And once you understand the concept, you are on your way to understanding the maths.

Multimedia can help in establishing this relation and explaining the concepts. Visualization allows the brain to see what your eyes see without the need to translating the relations into words. The fact that primates are visual animals is one of the reasons, among some scientists, that they entered the cognitive niche (Pinker, 1997).

**RESEARCH AND STUDIES**

A number of studies have shown that when people of any age and ability level face mathematical challenges that arise naturally in a real-world, meaningful context, where the outcome directly matters to them, they achieve a high level of competence (typically 98 percent). Those same people, when presented with the very same mathematical challenges in a traditional paper-and-pencil classroom fashion, perform at a lowly 37 percent level. So people can think mathematically. But they have enormous trouble doing it in a de-contextualized, abstract setting (Devlin, 2000).

Counting is correlated with the fingers motor control (Dehaene et al. 2004) which shows the way humans seem to have learnt to count but does not point into any direction as to the abstract concept of number understanding. Number sense is a survival skill but multiplication poses a huge challenge to our brain. Western languages seem to bring even more confusion into the play. The brain processes numerical symbols and number words in different locations. To comprehend other than small positive integers we need to construct mental models that provide understanding as they are not innate to our sense of numerosity (Sousa, 2008). Developing number sense is prerequisite for succeeding in mathematics. Number sense constitutes a way of thinking that should permeate all aspects of mathematics teaching and learning (Making sense, 2005).

In order for the data to move from immediate memory to working memory attention is required and for this data to move further to be retained in long term memory multiple rehearsals are necessary. Only elaborative (not rote) rehearsal can provide associations, connections to previous learning or relationships necessary for long storage. The working memory can deal with the information for a limited time (5 to 10 minutes for children and 10 to 20 for young adults). For the focus to continue a change must occur in the way the information is dealt with (Spitzer, 2007). Personal experience intensifies activation of the brain, its focus and concentration. The more elaborate the memory is in terms of sound, touch, vision, etc, the easier it is to access. Introduction allows the brain to detect and create patterns of meaning (Cercnone, 2006).

Learning should also be broken regularly. Constant focused learning is increasingly inefficient (Jensen, 2000). Multimedia seem to be the best solution for all these problems. Animation for example can promote learner understanding when used in ways that are consistent with the cognitive theory of multimedia learning (SEG Research, 2008). Animation has great potential to improve human learning – especially when the goal is to promote deep understanding (Mayer & Moreno, 2002). Animation appears to be most effective when presenting concepts or information that learners may difficulty envisioning (SEG Research, 2008).

Many theories and assumptions have been developed in regards to how people learn from words and pictures (Mayer, 2004). A lot of Principles of Multimedia Based
Multimedia can bring the natural setting back to school. They can enable an almost real recreation of the surrounding and the problems. They can simulate different solutions and show in real time the changes happening after certain measures are applied. Multimedia also enable combination of different aspects of the same problem into one presentation of a unified theme. They facilitate a project based learning, rather than approaching each problem separately, without any connection, without any pattern that our brain likes so much. Maths can be communicated through many means: written and spoken words, tables, diagrams, objects, symbols, graphs, animations, simulations and videos. Engaging more senses than one and allowing for the understanding of relations between the problems.

Multimedia allow for one more thing: Interactivity. And interactivity is the best way to learn as it resembles the natural interaction between the human and the world around. The only way humans have learnt. The activities should be interactive so that the learners have the feeling that they concern them directly. That is where motivation comes from as well.

Exploring how the world works should be what education is all about. And it should not be combined with fear of mistakes. Children learn by trial and error. Without trying there is no learning. They must be allowed mistakes but they need to see whether they are going in the right direction. Instant feedback is of utmost importance.

Multimedia can enable the differentiation of the learning content, which is so important for the attention that our brain can hold.

Emotions are extremely important at the learning process and they shouldn't be underestimated. Motivation is one of the most important aspect for knowledge absorption. People also need to feel encouraged and powerful about their tasks at hand. Those feelings should be cherished and paid attention to, worked on. The learning environment needs to be designed in a way that brings those feelings out, empowers the learner, engages them. Multimedia are engaging, they elicit emotions.

MOBILE DEVICES

Engagement often comes not just from the nature of the actual task itself but also from a self-initiation process. When unasked for, the teaching is often perceived as forced upon and seems to carry an insinuation of stupidity of the learner itself.

That is why the mobile devices are gaining such popularity. They are closer to our nature. To our mobile nature. But they also allow some control over the learning process. Students can choose when to learn, what to learn and how to do it. Such control increases attention (Cercone, 2006). Because when I learn when I choose to do it my brain reinforces the importance and attractiveness of such learning. And that is not all. The subscriptions and ownership of the devices grow exponentially. We cannot dismiss this popularity. And we have not. We asked some students what it was that made them desire the tablets or smartphones so strongly. The answers were surprising. According to many students the mobile devices force monotasking more than the PCs do and they are less distracting also thanks to the fact that they are quieter than many PCs. And since each brain is different, learning needs to be personalized. And mobile devices are extremely personal as they are customized by
the apps and content each individual keeps on them. At the same time they are very attractive and this quality makes them so desirable but at the same time it makes learning seem more attractive too. And since you can both learn and play on them, they are perceived as trustworthy. The feeling of ownership additionally increases willingness to use the device.

Mobile devices also facilitate communication. Students love to talk about the content of their devices, they love to exchange the results, compare the solutions and see what else is there. And since the devices are mobile it is as easy to communicate face to face with them as it is through chat, messaging or emails. Sometimes even easier as it costs less to actually meet in reality than in the virtual world, that requires data transfer which may turn out to be costly. And since the learning content is placed where the communication applications are as well, the more efficient it can be for the learning process when you share and exchange concepts and ideas.

Mobile devices also provide some consistency and allow students to fulfil one of their desires: to have everything gathered in one place that is easily portable, searchable and editable.

**PRACTICE**

Multimodal approach allows for elaboration which is crucial for retention (Degan, 2011). Repetition strengthens the connections between neurons and builds neuron clusters. Mobile devices allow for contextual elaboration and for space intervals which increases attention. At the same time chunking the knowledge makes the information easier to digest for the students. But multimodal approach provides something else besides elaboration and adding attractiveness: it requires a student to think, to draw conclusions, to discern patterns, to correlate them and to apply a piece of information gathered in one place to a completely different setting in order to answer the question. It teaches problem solving and creativity, developing fluid intelligence. How?

What we have learnt is that students in regular schooling learn certain routines and discover useful shortcuts often performing mindless repetitions. When the provided information is in a form of a written text and the questions are in the same form as well, then it is very easy to simply search through the text for a certain string of words from the question and then rewrite it word by word in the answer. However when the information is given in a form of animation then the answers need to be written from scratch, using student's own wisdom and the ability to connect facts and draw conclusions.

We noticed that when learning was freed there was more retention. Whatever we learn at our own accord, we tend to remember better. And we need to do it at our own pace, testing our own hunches and ideas about the subject. Immediate correcting kills the need to learn, to try, to make effort. Those ideas need strengthening and practice. Learners need to learn to trust themselves. Game environment usually facilitates that, therefore it needs to be copied into education. And so we have done that as well. Instead of correcting, we employed instant feedback.

When we look into everyday practice with mobile devices we will see that activities connected to gaming and communicating surpass everything else. Games are filled with multimedia, they give immediate feedback, they are engaging, provide adaptive challenge and are fun. But they often require considerable amount of effort on the player's side. Nevertheless players are continuing to progress and enjoy the process while at it. When challenges and skills are aligned and the activity is pleasurable then the attention grows which equals better learning (Csikszentmihalyi, 1991).
Communication is social. It allows for the exchange of ideas and for staying in touch with peers, enabling the knowledge about their activities, their level and interests. They exchange information about what is relevant to them and the information is always personalized. More and more so nowadays children and young adults learn very well from their peers. Peers are closer to the level of the learners and so it is worth trying to imitate what they know. Peers are not ‘over-competent’ as many adults may seem. They are less threatening. And they usually have a better "access" to relevant knowledge than many of the teachers.

But digitalization and mobile devices are still just tools that without proper content will be like empty vessels that you try to use to fill the container (which would be brain in this metaphor). As we have found out students are still using multiple textbooks as they are not comfortable with relying on the Internet. One textbook is usually not enough as it often presents only one point of view, one angle. And they find their notes to be very important. We wondered why that was the case. It seems that notes have more context and therefore provide more meaning than other texts that cannot be connected to any previous knowledge. Context allows for connections to be made and these facilitate learning.

We also wondered whether the form of the actual content plays any important role in the learning process. We showed several different layouts to students and asked them not only to choose the best and the worst but also to explain the reasons behind each choice. As it turned out white colour was really disliked among most of the students as it was associated with boredom. Also larger amount of text were not popular as they were found hard to follow and to understand and were usually associated with rote learning. The students were not in favour of empty spaces either and they definitely craved colours. They wanted divisions and were looking for separate chunks of information and easily-readable texts. They found information much easier to follow when there were photos or simulations embedded that showed how something worked and how it looked in reality. They wanted flashcards, highlighter, search function, 3D animations, bookmarks, progress report and an explanation why some piece of information was actually important or what it was necessary for. They wanted their materials to feel personal, private and familiar. They wanted context, relevance and connection to reality. The odd thing was the request of flashcards and the highlighter as these two features are quite ineffective for learning process. They promote rote learning rather than provide a chance for a meaningful elaboration. But this is what students got used to, as it these are the only tools that are useful (or even available) for the printed materials.

CONCLUSIONS
New technology allows for much more. Now we can expect learning to be embedded with life skills, something the learning can be useful for. Since learners are meaning seekers that embedment is of high importance. Different sensory inputs influence each other. It is called a multimodal reinforcement. So learning can be optimized this way, by employing more sensory inputs. Stimulating several senses at once improves learning. Combining sight and sound for example increases the learning process. Adding touch to visual stimuli increases the recognition. And mobile devices enable touch. Learning workload needs to be diversified and individualized. Learners need to be able to jump from subject to subject in their own pace and at their own interest. The best solution is to provide an abundance of materials that are cut in such a way that suits all different interests and approaches, so that everybody can choose from that what they desire. But the materials must all be of equal educational value. They need to provide equal educational guidance. And the learning material must be useful, must be of everyday-life-application value, bringing visi-
ble results. Teachers should use a variety of instructional methods and media to meet the different needs and learning styles of their learners. One way is to provide real-life simulations and interactive contextual learning.

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Biography

**Jolanta Galecka** is an Education Expert in Young Digital Planet, an educational e-content publisher. Responsible for the expertise in education, research, articles, scenarios and public speeches. Passionate about education, child development, human psychological development, brain development and its functioning. Studied psychology, sociology and graduated from law. When in United States volunteered and worked at different schools: taught in the Montessori School and a Spanish Immersion Academy. Involved in Waldorf education, Berlitz method and state-of-the-art educational materials. Worked at Microsoft as a Software Design Engineer in Test in Natural Languages Group and Tablet Team. Speaker and panellist at multiple educational conferences.

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