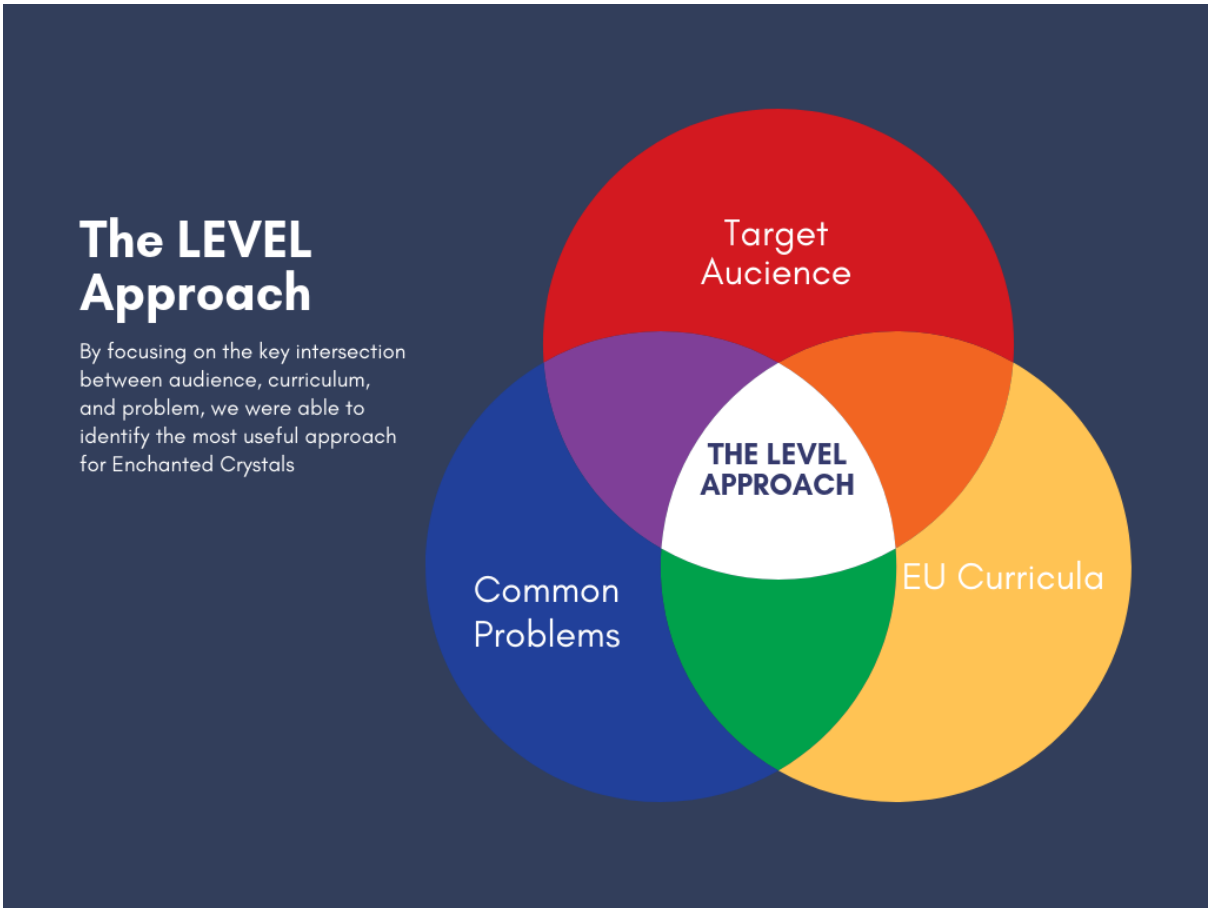
Looking for Enhancement of Virtual Environments for Learning

Math Training Concept

Background

The LEVEL project aims to improve the math skills of youths across Europe. We aimed to find a common problem area in math teaching that could be tackled via an evidence based, innovative approach to digital game based learning.

The didactic approach stemmed from our target age group (late pre-teens to early teens), target subject material (determined from an analysis of common curricula across our European partners) and key target problems (as determined from consultation with teachers.



Target Audience

We aim to improve the maths skills of pre-teens and early teens. In particular we want to appeal to and support learners who struggle with or dislike maths and disadvantaged learners.

We spoke with pupils and identified mobile phone games as a popular activity for almost all pupils. The idea of playing a game for maths instead of doing a worksheet proved very popular and supported the concept behind the project. Additionally we sought feedback from pupils for artwork, game characters and concepts to identify core themes that would engage them.

The result is that the Enchanted Crystals game focuses on two key audiences. Upper primary school aged pupils (9-10) who are still learning the core basic concepts for maths and lower secondary school aged pupils (11-13) who struggle with them.

Although the age difference may not seem large, there was a risk if we were to tailor the game at the extreme of either end of our age group. Media aimed squarely at 9 year olds differs quite a bit from that aimed at 13 year olds who may feel they are being talked down to. Because we are targeting a diverse range of abilities, any competitive elements in the game had to be self-competitive. Trying to beat one's own best effort would be motivating, a 9 year old trying to beat a 13 year old less so.

Our audience loves challenging games that require skill to master and enjoy fictional drama such as superhero and fantasy movies.

Curricula Focus

Teachers in each of our partner countries were consulted as to the core mathematical concepts they teach at different stages of the curriculum.

Whilst the overall taught content was the same, the age ranges for each aspect of mathematics varied significantly between the countries and within some partner countries, between different types of school.

We identified several areas of curricula that were areas of concern for teachers as well as problems for pupils in our age range:

- Math operations priority
- Negative numbers and rational numbers
- Transfer of knowledge between contexts (i.e. from abstract classroom learning to concrete problems)
- Mental Arithmetic

Common Problems

After discussing possible curriculum foci areas with teachers, a consensus emerged that often pupils in our target range struggle with these topics because they lack a solid understanding of prior fundamentals. Pupils who struggle with basic arithmetic such as addition, subtraction, division, and multiplication will not easily grasp concepts such as negative numbers

This has been borne out in several studies and simple single-digit mental arithmetic ability predicts high school math scores (see http://www.jneurosci.org/content/33/1/156 and http://discovery.ucl.ac.uk/10005971/1/Duckworth2007SchoolReadiness1428.pdf)

Focusing on more advanced areas such as operation priority would be useful and should be explored but the team felt strongly that the ubiquity of arithmetic in the higher level operations meant that the team would best spend its efforts focusing on helping pupils develop a strong base knowledge of mental arithmetic.

Pedagogic Strategy

The human brain is capable of incredible feats, but it achieves these to some extent by being *lazy*. Working memory can be thought of as being the “things we consciously are aware of” and it is very limited.

Most of the time when we go about our business or conduct our daily life we don’t *think* exactly. We mostly rely on our memory. You don't have to *think* about how to make a pot of tea, or how to drive to work... you just.. *do it.* (For more on this, see Daniel Kahneman's book Thinking Fast and Slow - https://amzn.to/2NWp60F)

When someone has to *count* their way to figuring out a basic operation such as “seven times 8” then they occupy their working memory with that process. People who don’t *just know* the answer to that operation may think their way to the answer through the following steps:

1. They *just know* that ten times seven is seventy.
2. They think to themselves that eight is two less than ten.
3. They think that two sevens is fourteen.
4. They think that seventy take away fourteen is sixty take away four.
5. They think that sixty take away four is 56.

In real world situations like calculating how to split a bill, or in advanced classroom operations like working on a complex equation by following a the order of operations, occupying the working memory with the trivial basics is mentally expensive, and can prevent someone from solving the larger problem, or at the very least slow them down.

The process of moving from *thinking through* some process like multiplication to *just knowing* the answer is not complicated, but it takes practice. Simply practicing multiplication tables,

division, addition and subtraction is all it takes but practicing is boring, and for pupils who struggle with maths (especially older pupils who have struggled for years), *another* worksheet can be very demotivating.

Therefore the pedagogic strategy that underpinned the concept of the LEVEL project was, broadly, to find a way to motivate pupils to carry out dozens of mental math operations whilst maintaining motivation through game mechanics and storytelling.

Pedagogic Implementation

We use novelty (the game is quite unique in math games in asking players to draw numbers with their fingers) and storytelling (the game features a “Harry Potter” style fantasy school for wizards) and disguises math operations as magic spells.

Each operation (addition, subtraction, multiplication, division, and combinations thereof) is mapped onto a different ‘spell’ in the game.

To ‘cast’ each spell, players must use the values of coloured crystals that are always on-screen and they must perform the arithmetic operation in their head before writing the answer with their finger on their phone screen.

Thus, in order to perform well at the game, players must continually perform mental arithmetic.

Each level of the game uses a combinations of operations by connecting each spell to a type of obstacle in the game.

For example, in order to not fall off a ledge:

The player must cast a spell (by multiplying the numbers in the crystals) which makes stairs appear as shown below:

As the game progresses the challenges vary and increase in difficulty.

By the time the player completes the game, they will have carried out several dozens of different mathematical operations. The game is replayable as the numbers are randomly chosen each time.

Because the game is aimed at pupils who may not enjoy maths, it is expected that ability levels will vary.

To account for this we have allowed players to set a difficulty level that will affect the range of numbers chosen for the operations as well as allow them to set a speed for the game. A slower speed gives the player more time to carry out the mental arithmetic before failing each challenge.

Due to the nature of the problem we are addressing, the Enchanted Crystals game made during this project may be best used as a homework activity. Pupils who are embarrassed by their poor maths performance in class or who struggle to complete traditional forms of homework in particular are one of the key demographics we expect to assist.

Future versions of the game may focus on two enhancements that would help integrate the pedagogical concept further.

Firstly, giving teachers the ability to design their own levels would allow for greater customisation and tailoring of the game to different pupil needs. One teacher may focus on addition and another multiplication for example.

Secondly, developing a mechanism to report player performance back to teachers would enhance the game by giving teachers more real-time feedback on their pupils' performance.