Turn it on its head! Juxtaposed Learning

TURN IT ON ITS HEAD! JUXTAPOSED LEARNING

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Abstract

It has been long understood that creative approaches can increase student engagement in learning. However, recent research has started to uncover a clear impact upon learning progression and transforming student understanding across disciplines. This paper details a series of case studies from the JuxtaLearn project conducted across Europe in schools and HE. The results show an increase in students' depth of understanding (deep learning) through creative juxtaposed approaches, in particular using participatory video making. For this research, an ecology of different devices (mobiles, tablets, tabletops, large screens and computers) was used to scaffold a juxtaposed collaborative learning process supporting a deeper understanding of 'tricky topics'. We have worked with >114 students in science, maths, technology, drama and religious education within schools and universities in the UK and across Europe. The findings identified issues around the process of storytelling learning topics and the tools that can inhibit and support that process being bound by norms of practice within that context. A discussion is presented of the role of creativity within the science, technology, engineering and methods disciplines (STEM).

Keywords

Theory of juxtaposing; storyboarding, comparative learning, transfer of learning, TC, surface to deep learning, dramaturgy

1. Introduction

For many years, educationalists have sought to increase engagement in learning. Creative teaching and learning approaches that have higher levels of participation have inevitably been used to motivate student involvement in learning activities. However, there is evidence that increasing creativity can also improve the quality of student understanding. Evidence for the value of creativity, can be seen in the research by Root-Bernstein (2004) who identify over 20 Nobel Prize winners for literature all of whom had some form of scientific training. However, this research characterises the iterative, ill-structured nature of engagement in creative work, by producing a framework of it as a process of exploratory learning (Simon, 1996). This work hasalso been related to the need to sustain flow experiences, that match challenge and skills (Csikszentmihalyi, 1996) through a reflective interaction with materials (Schön, 1983). Csikszentmihalyi (2009) has extended this work to highlight aspects of engagement in the process that he relates to creativity, enjoyment and a total involvement and thus engagement in life. Hooker and Csikszentmihalyi (2003) provide insight into the role of shared leadership within a group, and the impact of this on flow and creativity, which obviously relates to collaborative learning. They propose that shared leadership can not only increase flow but also increase creativity through this increased engagement. These theories were reviewed with regard to multiple disciplines and found to facilitate creativity when they incorporated a series of six conditions: valuing excellence in performance (as much as results), members have clear goals (not just long-term, but short-term), constant and timely feedback on performance, matching challenges and skills, decreased distractions and finally freedom and control (from goal selection to scheduling their learning).

Individual creativity must be placed within a social and cultural context in order to be recognised as creative (Csikszentmihalyi, 1999). This might be important when considering the audience for video making - those watching as you make it, a teacher's assessment of it as creative, and the audience that watches the performance all of whom may agree or disagree its creativity.

2. Background

In order to understand the value of creativity for learning we need to review models of creativity that are applicable Learning. It is then important to understand how these models can be applied to learning and in particular STEM learning for the JuxtaLearn practices.

2.1 Modelling creativity through knowledge transfer and boundary objects

Wallas (1926), breaks creativity down into stages of preparation, incubation, illumination and revision. Following this, inspirationalist models have conceptualised creativity as associative and evolutionary. This provides a means to conceive of how different elements merge to form novel ideas, such as Simonton's (1989) Chance-Configuration Theory, in which mental elements are combined in novel configurations, some of which are communicated and achieve social acceptance. As already noted some of the sociocultural models of creativity have had the biggest impact on pedagogical approaches. The Sociocultural Model (Csikszentmihalyi, 1996) provides a means to describe the relationships between an individual, their knowledge of a domain of creative work, and the gatekeepers and structures that steer and direct the domain over time, and a number of researchers including Florida (2002) have explored how characteristics of certain physical places offer attractive support for the 'creative classes' - the growing numbers of people occupied in creative work.

Creativity might be considered the ability to innovate or to arrive at a good idea when you need one (Claxton, 2011). Secondly, creativity requires "*the formation of associative elements into new patterns that either meet specified requirements or are useful*" (Hutton and Sundar, 2010: p294 citing Mednick, 1962). Thirdly, the process of creativity involves interpreting associations: Mednick (1962) defines the creative process as "*the forming of associative elements into useful new combinations*" (p221) and a creative answer as both useful within given requirements and original. Combining elements from different disciplines such as juxtaposing scientific ideas with creative skills provides opportunities for playful permutations. However, crossing boundaries between disciplines can be difficult because of different disciplinary knowledges.

Knowledge transfers over three types of knowledge boundaries (Carlile, 2002): syntactic, semantic and pragmatic. At syntactic boundaries, knowledge is transferred; at semantic boundaries, knowledge is translated; and at pragmatic boundaries knowledge is transformed (Carlile, 2004). Objects that are shared and sharable across different key parties are boundary objects (BO) (Carlile, 2002, Bechky, 2003, Star and Griesemer, 1989) and BOs can help solve problems in a context where diverse groups of people work, such as editors, performers, audience and writers. Franco (2013) indicates that good content is not enough to transform knowledge but that the object has to afford participant interaction; it has to be a boundary object-in-use (Levina and Vaast, 2005), which it can be, only if it allows people to traverse knowledge boundaries. Boundary objects in-use are "*plastic, reconfigurable (programmable) objects that each world can mould to its purpose*" (Star and Griesemer, 1989 p404) such as video scripts created through negotiation with others; abstract or concrete objects like storyboards and scripts. Boundary objects need to be tangible, associable (to allow creativity), mutable (to allow crossing of knowledge boundaries), traceable and analysable (to allow experimenting with knowing). Finally, a boundary object has to afford opportunities for interaction.

Interaction requires that meanings must be negotiated, so managing the boundaries of knowledge needs someone effective: the orchestration factor of teacher centrism guiding students, drawing their awareness to particular knowledge, because their discussion and creation of storyboards has drawn the teacher's awareness to their need for further guidance. Boundary objects that intermediate interaction cannot replace teacher intervention to orchestrate at the pragmatic knowledge boundaries, deciding when and whether to intervene; the teacher is essential to getting knowledge transformed at the pragmatic barrier.

Storyboards and scripts on paper are objects that make a participatory video making process visible because they make students and teachers aware of who is sharing what with whom. They should be associable, i.e. related to shared attributes that cross the boundaries that allow creativity (Mednick, 1962).

3. Comparative learning and juxtaposing

Educationalists have long recognised that transfer of learning is the most significant issue in teaching and learning. It not only supports application to various different questioning approaches that may occur in an exam, but furthers the question of durable transfer to life-long learning situations such as in the workplace. Added to this we argue that to transfer learning is a verification of students internalisation of the understanding and an acquisition through a 'deep learning' approach. Technology enhanced learning which facilitates this can transform students learning. Haskell (2001) presents experimental evidence of transfer as a neurocognitive mechanism that is the basis of learning from mental abstractions and analogical relations to the ability to classify, generalise and develop logical inferences. A long history of research has identified that some types of learning have long-term effects fostering generalised thinking (Judd, 1908) and the power to transform the individual (Mezirow, 1981). However, there has been much debate about the success of any educational methods in providing this durability and transferability. Haskell reviews the learning of science and transferability of understanding into different contexts. He highlights the difficulty of transfer beyond a discipline especially with regard to the sciences. However, deep learning and internalisation of concepts is also difficult but a necessary objective of learning to transform the students understand rather than simply mimicking an understanding and regurgitating information. Learning relational abstractions has been argued as fundamental to the development of knowledge' (Christie and Gentner, 2010). Christie & Gentner identify statistically significant advantages to developing understanding and meaning making through direct comparisons. Relational abstractions are often associated to the concepts of functional relationships (X is edible) biological cause relationships (X needs water to grow) mechanical causal relationships (X can move things) and spatial relationships (X is moving upwards / or above another object). Cross-situational learning suggests that there is benefit simply through the application of knowledge in different situations (Roeper, 2007). Christie and Gentner (2010) review how do we effectively develop these understandings and the learning processes through direct comparison. This has since been expanded upon by Kurtz et al(2013)) to highlight the value of comparison to promote learning and transfer of relational categories with undergraduate students. This research required the student to explicitly consider a co-presented item and implicitly engage in a joint evaluation of comparing the two. Evidence showed that this produced a statistically significant increase in learners' abilities to effectively codifying items into categories. The cross-category comparison also provided a beneficial opportunity for learning by contrast, those that do not fit within a category. Reflection is an obvious route to supporting this comparison in the learning process.

We have been trialling creative performance a project, called JuxtaLearn. Within the JuxtaLearn project there are the dual objectives of both inspiring curiosity through creative film making and developing understanding according to personalised conceptual needs. This occurs through scaffolding a juxtaposed teaching method. The juxtaposing occurs through reflections between formal representations of understanding and

creative juxtaposed applications of concepts. Both the formal and the creative juxtaposed representations are focused upon examinable concepts. However, the formal representations are focused upon an approach and style of writing which is acceptable for the exam within that domain. Students are given this formal representation and asked to creatively juxtapose it. To do this they need to take the formal representation and break it down into its creative elements, its story. As already noted this takes a dramaturgy approach to the learning. Within this breakdown the student identifies what are the characters in this story, what is the setting, what is the storyline. The assumption is that every-piece of learning has a story, a beginning, middle and an end. The story of an equation has a start and an ending result. A story for a science methodology has a hypothesis, procedures and results.

The form of performance that we have been exploring is creative, engaging and fun dramatic performance that is as different as possible from and juxtaposed with the initial teacher led activity. Performance may involve physical performance by the learners or they may use models, mime, puppets and on objects.

4. Methods

A wide variety of mixed methods in a pragmatic theoretical approach were taken to the research. This meant that a range of ethnographic to quantitative measures were taken. For this paper the observational data is analysed and presented in more detail. The Initial pilot studies were completed to refine the creative JuxtaLearn learning process with A'Level students in Chemistry and Drama (2014) and with primary school children for informal learning in religious education (August 2014 & August 2015)

4.1 2015 studies

Four studies were conducted in 2015 across two secondary schools in the UK. Two studies took place as a series of workshops held during normal classroom time. Two studies were run as whole-day workshops at the Open University. In addition, we ran a single two-hour session for university students. This has fed into further work (not detailed in this paper) conducted with school children in Portugal, Spain and Germany as well as University students in Spain and Sweden.

Table 1 : Study procedures

Date	Study ID	Participants	Structure	Resources
March 2015	OU	9 mature students & their programming tutor	Two-hour tutorial	Paper storyboards, written teaching materials
April/May 2015	SRA1_15	8 Yr 8 students aged 12/13 – at end of Yr8 Organised in 2 groups Bottom set ability 1 maths teacher	5 X 30 minute classes during lunchtime maths catch-up sessions Pre-quiz Storyboarding Video creation & sharing Post-quiz	Craft materials Paper storyboards 2 flip cameras 2 iPads
June 2015	RAD1_15	32 Yr 7 students aged 11/12 – at end of Yr7 Organised in 7 groups Top set ability 1 maths teacher	5 X 50 minute maths classes Pre-quiz Storyboarding Video creation & sharing Post-quiz	Craft materials Paper storyboards 1 flip camera 6 iPads

July 2015	RAD2_15OU	32 Yr7 students aged 11/12 – at end of Yr7 Organised in 6 groups Top set ability 2 maths teachers 1 teaching assistant	1* 50 minute class to take the pre-quiz and approaches to learning survey 1 day workshop at the OU 1* 50 minute class to take the post quiz	Craft materials Paper storyboards 6 iPads 1 table top with electronic storyboard
Sept 2015	RAD3_15OU	33 Yr7 students aged 11 – at start of Yr7 Organised in 6 groups 3rd set ability 2 maths teachers	1* 50 minute class to take the pre-quiz and approaches to learning survey 1 day workshop at the OU 1* 50 minute class to take the post quiz	Craft materials Paper storyboards 6 iPads 2 table tops with electronic storyboards and video editing capability

4.2 Methodology

Nearly all the studies followed the JuxtaLearn process. Studies SRA1_2015 and RAD1_2015 were run in school in classroom time. SRA1_2015 took place over five 30 minute lunchtime Maths catch-up classes and RAD1_2015 was run over seven 50 minute maths lessons. In studies RAD2_2015OU and RAD3_2015OU the students and their teachers were invited to spend a day (9:30am to 3:00pm) at the university where the creative activities could be run without interruption. The exception was study OU which concentrated purely on using the performance stage of the process.

At the start of the JuxtaLearn process, students took a diagnostic quiz to assess their understanding of the Tricky Topic and identify which stumbling blocks they needed to focus on. Students were then split into groups, each group having one iPad for filming and uploading videos to the central JuxtaLearn web space. In all studies, groups were provided with a paper storyboard with which to note down their characters and juxtaposed storyline.

In the two day-long OU workshop studies, table tops (see figure 1) were also available for the groups to work on their ideas. Each group had time to work collaboratively on the table top.

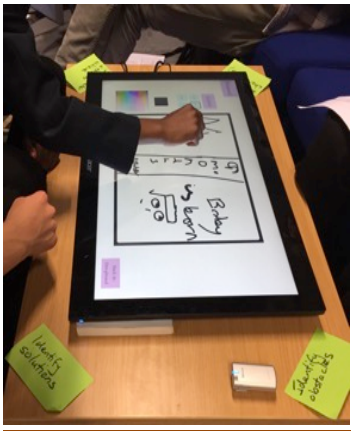

Figure 1 : tabletops support collaborative creativity

Flip cameras were used initially for shooting video in the SRA1_2015 trial, then iPads were introduced so that the students could use iMovie to compose their videos. iPads were used for shooting and composing videos by all groups in the RAD1_2015, RAD2_2015OU and RAD3_2015OU trials (see figure 2).

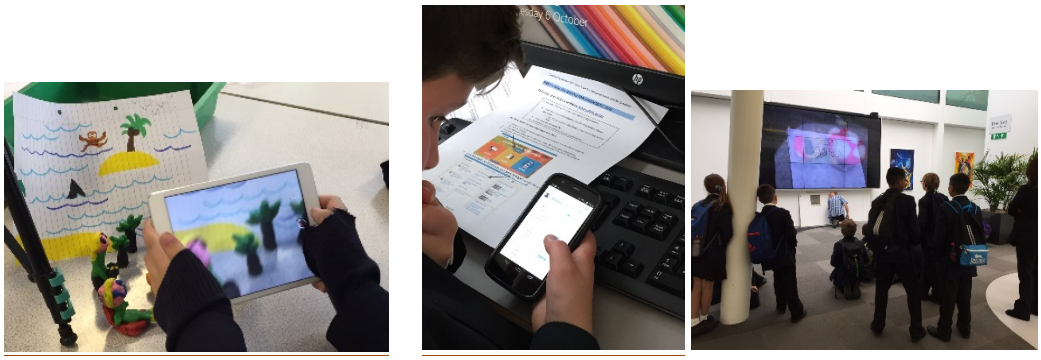

Figure 2 : tablets, mobiles and large screen displays

In the RAD3_2015OU trial, students also uploaded and shared their videos to the JuxtaLearn web space from their iPads and two groups used the table top software to edit and compose their videos. The videos were then shared and commented on via large screen displays and online (see figure 2).

Creative performance palette (CPP) cards with examples of genre and format are available, and the touch screen software incorporates their contents, but the physical cards can be used as a concrete stimulus to creativity if the software is not available.

After finishing the creative process, students took a post-diagnostic quiz to assess changes in understanding.

4.3 Analysis procedure

Whilst there were many different data sources used in these case-studies this paper has focused upon analysis of ethnographic field notes, video and audio data of case-study trials along with post-hoc interviews and focus groups. The analysis of the data was conducted using three stages. The initial stage identified critical incidents: learning breakthroughs and breakdowns that were facilitated or inhibited by the collaborative creative process. These incidents were analysed further using a thematic analysis. Next the analysis considered the role of devices and artefacts, social interactions as well as norms for the domain of study. Finally inter-rater code sharing for the data and its thematic groupings provided researchers within the team as different focal points on the data and verification of the analysis groupings. This process led to the development of key issues within the creative juxtaposing process.

Categories that were identified from the JuxtaLearn analysis were:

- emergence and iteration in the process of learning and creative performance,
- mismatch with reference to peers and teacher's explanations of the topic under study
- exploration and experimentation
- the role of the *JuxtaLearn* storyboard template in supporting creativity
- JuxtaLearn storyboard contents related to stumbling blocks *and* prompts for creativity

5. Findings

The research approach was focused upon implementing the concept of 'juxtaposed' creativity as a means to relate creative storytelling, owned and developed by the students, with the learning narratives in the subject being taught. This highlighted the issue of learning stories for some subjects not always being that clear when presented to students and thus causing problems for them to be able to play with and reinterpret in their own language. Also the medium of interaction was found to be a barrier to creativity, not because it was inhibiting in itself but that the medium combined with the context of study and expected norms of practice associated. For example a pen and paper within a chemistry class, had been imprinted on the students' minds as a writing device not a creative drawing tool. However, the process of creative storyboarding provided valuable collaborative reflection, which increased the quality of the students understanding. The use of devices such as a ipads and tabletops removed from the expected norms of practice also increased students ability to break free of norms and become creative in a way that owned by them, thus owning the learning itself to a greater degree.

5.1 Tools for a juxtaposed story

The research identified that a juxtaposed story is not simply a creative story but a creative story that contrasts with something else. The students' films should juxtapose with the teacher's example teaching activity. When creating a film, one of the first steps is to plan its scenes using a storyboard, a plan with a cells in which to draw pictures that build on a scenario of settings and characters who have obstacles to overcome. Students must find their characters and settings. Younger students know their fairy tales. For example, we had some 14-year-old students studying maths topics whom we advised,

"*Think about a fairy tale like Little Red Riding Hood. Who are the characters? What setting? Find the setting and characters in maths that they relate to. A character might be an equal symbol, and or you might want to turn the division symbol into a guillotine. You can be creative about how you can turn the bus stop method of division into an exciting and creative video.*"

One issues that we found in the research was that posed by the students 'What's the character's problem?' This research identified that problems turn characters and settings into stories. A group of students studying Java collections contrasted a teaching example with a wedding feast, where the characters were various guests who may or may not want to be sitting together on the same table. Prompts from Lahad (, 2000 p. 99) for identifying the ingredients of a story require identifying the main character of the story and the task of that character, who can help, and what obstacle is in the way. How does the main character go about the task and cope with the obstacle? What is the outcome? However, to juxtapose from a standard teaching story of maths requires the story, characters and setting to be clearly articulated in the first place. The case-studies highlighted that often students were unclear what the 'maths story' was before they could play with. However, through discussing and identifying what the teachers 'maths story' was and their re-interpretation of it help them to learn in a deeper way than had previously occurred.

Practical creative application in higher education has found benefits to using play-based methods to support communication with techniques that include drawing, using toys and storytelling (Ayling, 2012). A storyboard is a tool for the process. Storyboards not only support the creative participative video approach but also the learning process because they also require peer discussion, collaboration and presentation. Creative prompts for storyboarding include: identify an individual character; set the character a task to achieve; identify obstacles; identify solutions. For each prompt, draw a cartoon picture on the storyboard (Lahad, 2000).

In several storyboarding workshops, students used paper storyboards, usually writing words on the paper, but rarely drawing. Figure 3 shows the planning for a video about moles in A-level chemistry class which demonstrates the perceived constraints of this medium conceptualised in this particular subject.

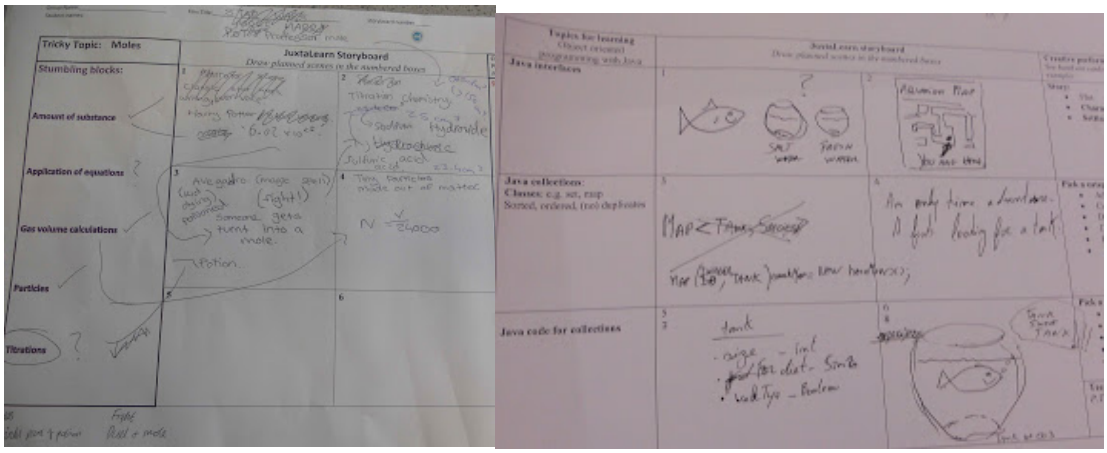

Figure 3: Textual planning moles compared to visual images for learning in programming

In later workshops, we prompted students for characters, and then drawings sometimes appeared, like Figure , a story of Nemo the Fish that aimed to juxtapose with an explanation of object-oriented collections.

One problem of paper storyboards was that students sometimes pled lack of artistic skills and left their drawing to one individual. To address this, we added a technological solution in the form of shareable touchscreen software that allows several students at once to create their storyboard. This touchscreen is about a metre by half a metre, connects to a laptop and can be laid on a table around which several students can congregate to work together. We ran a workshop with five small groups of students (three or four in each group) in which the students aimed to video a maths story juxtaposed with their teacher's explanation. Each group first drew, or more often *wrote* their storyboard, and then in turn gathered to use the touch screen.

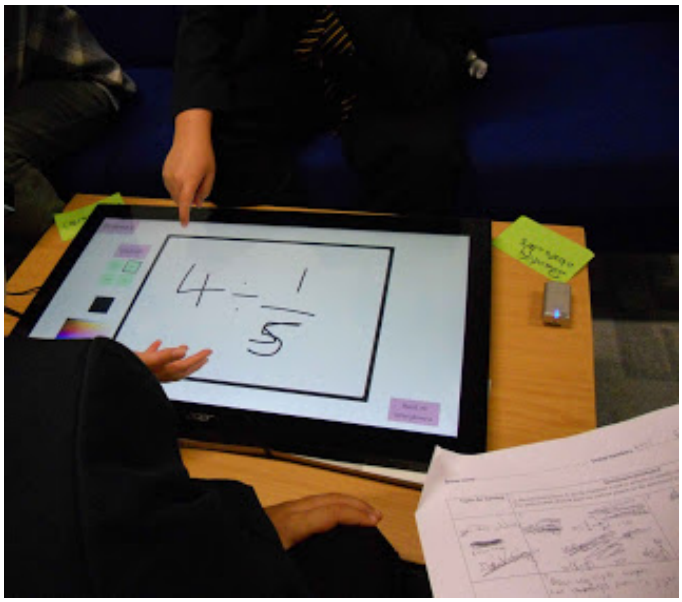

Figure 4: drawing a story with a group touch screen

Figure 4 shows a group beginning to work with the touch screen with hands from two students pointing at the screen thus demonstrating their verbal discussion of the story. The outputs from the table-top compared to pen an paper versions can be seen in Figure 5. These images shows the two versions of another group's storyboard. Their written paper storyboards became electronic pictures. The students show here a clear move from textual representations through the paper storyboard towards visualising their ideas in multiple dimensions on the tablet-top output, clearly representing an increase in their creativity. Notice the inclusion of musical notes in anticipation of adding sound. It was found during this table-top process that students often encountered 'light-bulb' moments of breakdown when they realised that their ideas on the topic were inaccurate 'we've got it wrong'. This clearly shows the value of creativity to increase the quality of the learning process.

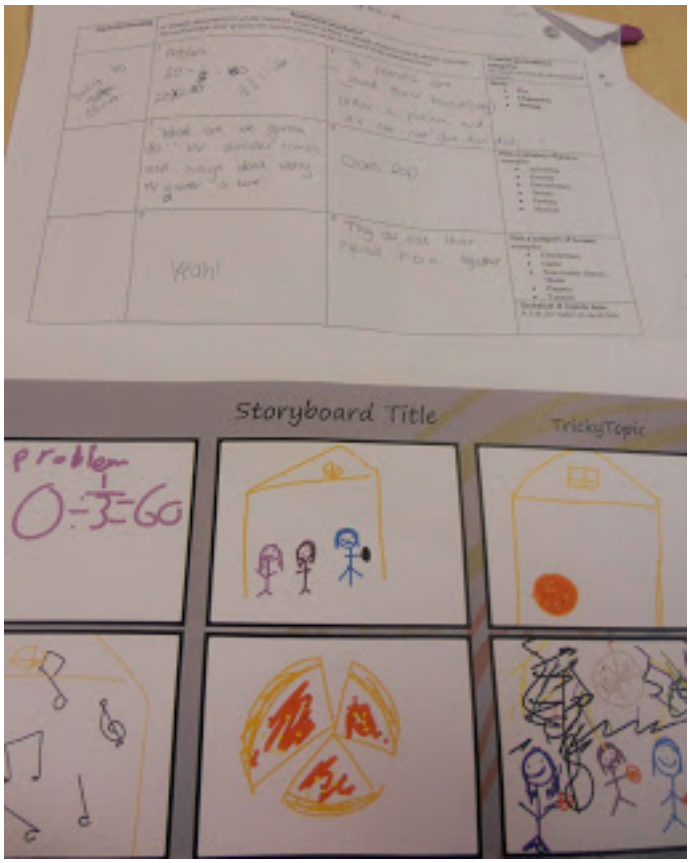

Figure 5: comparison of paper-drawn with touch screen drawn storyboard

Much learning of the topic went on as students developed their story, discussing and debating how to create the performance. A student asked why the process to divide by a fraction involved multiplication, "*I know 20 divided by a half is forty, but I don't understand why*". This student reflected, querying a fact and seeking deeper understanding. If one student did not understand, then another explained, as one later reported on his initial quiz result,

D: *I found it quite easy. Only like the few last ones like twenty divided by half. I get it now*
R: *cos I explained it to you*

This intuitive understanding that students share similar language to each other supports research from Stephens et al (2010) who found verbal communication to be a joint activity where the brain of the listener

mirrored the speech of the speaker. As student, Owen, when asked if watching their video would help others, described it as:

> *"because we're not that intelligent but older students are. We don't know as much of the subject as they do, so people our age maybe a bit younger will understand the way we think cos they're the same age as us"*

Teachers observed and recounted other advantages to collaborative video making such as teamwork, role-play and leadership.

Once the students have a story they can share it in some way, and another tool for creating stories is a script. Our project aimed at creating videos of the story, but an intermediate step requires finding the words to explain. In two-hour tutorial sessions, university students took their storyboards, stood before the class and spoke, sometimes using the classroom whiteboard to juxtapose their story with the topic. With more time, students discussed ideas with the teacher, ensuring they explained correctly. Sometimes they spoke from memory; sometimes they used a script. One group of young students knew the voice-over they wanted to go with their story for dividing their pizza. They wanted to use a well-known rap tune so they brain stormed looking for random words that would fit in with the topic of division, noting possibilities on paper which was developed into their full singing script is at Figure 2

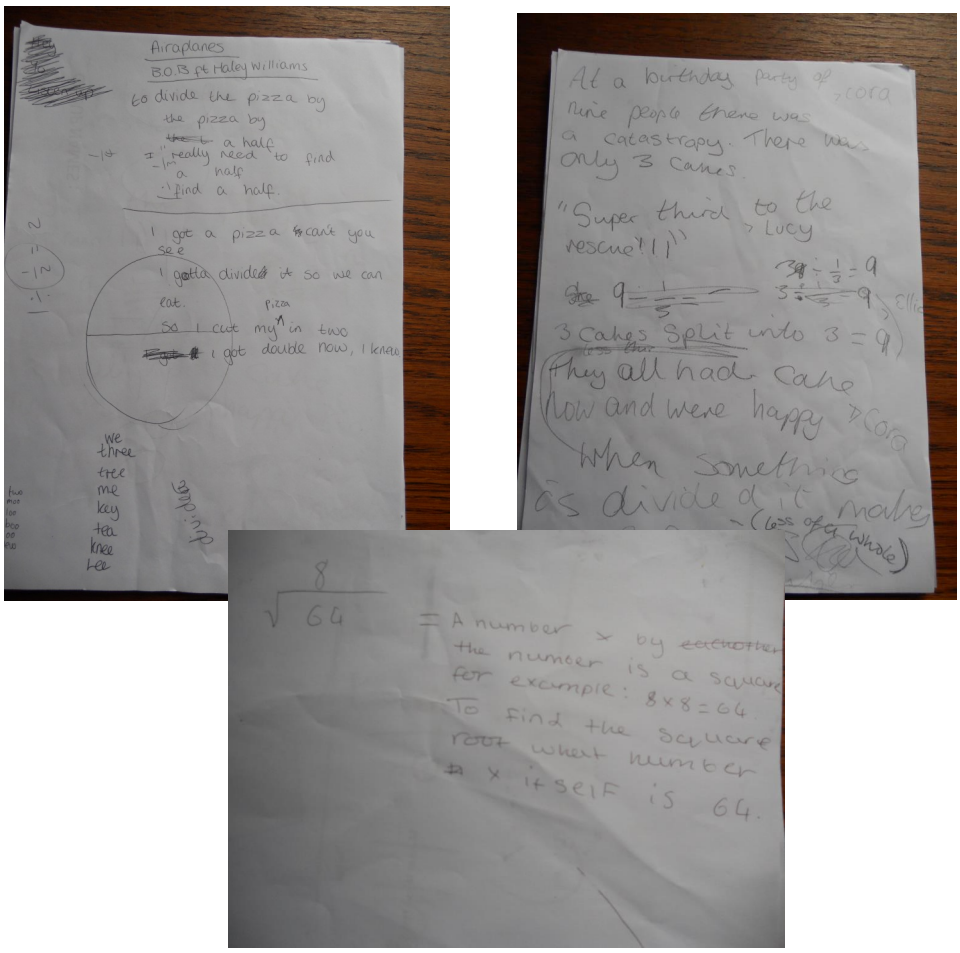

Figure 2: rap, division and square root scripts

Students would read their scripts again and again, partly to check them with each other and reword them; sometimes to perfect the timing of the audio to match the video. It is interesting to note that whilst they wouldn't consider this repetition was learning they were actually repeating concepts and internalising them to repeat within the video. This provided a vehicle for repeated viewing and reflecting on the concepts being used in the script.

6. Discussion

The research found whilst creative juxtaposing was a useful method to support internalising the learning it was the storyboards that mediated the learning process, acting as a boundary objects (Star and Griesemer, 1989) that allowed students to share knowledge. This supported previous understandings of a semantic boundary (Franco, 2013), for mutual knowledge transfer, and we observed knowledge transfer between:

1. students and students - those who can explain the tricky topic and those who can't verbalise it
2. students and teacher - the teacher knows the content and the terminology that has to be shared - the taxonomy and also the teacher learns how students are learning - so gains pedagogical knowledge as he/she realises what tricky topics the students are facing and how they misunderstand them

The table top technologies were found to act as valuable creative triggers to creative learning. These technical objects translated knowledge at semantic boundaries as the students recounted that they did not feel inhibited or judged by the output the way they felt with a pen and paper.

Groups can work well together. For example, in a well-juxtaposed video that explained the concept of division, a student group devised characters of Mr Root, Mrs Square and their baby Square Root. The video is available at http://clipit.es/ou/explore/view/2480. The characters were numbers and symbols, and settings included a school where character Number Nine beat up baby Square Root and a gym where the baby grew strong. Thus this story also revealed an obstacle that a character had to overcome – being beaten up. Students juxtaposed this story with their explanation to the camera, the script for which is in Figure 6: rap, division and square root scripts. This script demonstrates students' transformation of knowledge at the pragmatic boundary.

However, video participation itself is not enough to ensure learning. For storytelling, it is necessary to identify characters and setting. For example, a group of five girls created a video about called 'Horse jump division' but they did not identify any characters as related to or juxtaposed with the mathematics they were studying, and neither did any character face an obstacle, so no plot emerged. Three girls created the visual aspects of the video, and two others sat apart making Plasticine characters; neither sub-group talked about the mathematics. The resulting video, whilst showing some visual creativity does not juxtapose the storyline with the mathematics that the students were stumbling over and it is not clear that the students learned the underlying maths concepts.

6.1 An environment for juxtaposed learning

When reviewing creativity for learning the role of environment and contextual factors was an essential point for in learning; "*space is the opportunity; place is the understood reality*" (Harrison and Dourish, 1996 p69). It could be argued that this is why creativity happens in liminal spaces, as we move between boundaries of understanding. Through juxtaposing we use spaces and objects in different ways both traditionally as the learning spaces and tools and through play as a place to reinterpret understanding. Time in combination with space is also a crucial aspect of environment (Maaninen-Olsson and Müllern, 2009). Orlikowski suggests that knowing what happens over time can impact upon the learning "changing in form and function" (Orlikowski,

2006: 462). Ultimately there is an important issues around how learning supports us to interact with the world (Biggs, 1999) The findings from this study identified some interesting aspects of

In participative video, participants collaboratively present their message in video, which allows people to approach issues in a slightly different, perhaps more open manner, not imparting facts. People can impart facts but through this process, they can come to a collective or individual understanding of these facts – they have had a chance to 'test' these facts. Like this, they can also address wider social questions effectively– and be empowered. Participants have agency that can start thinking processes to challenge values and change people (Plush, 2012, Goldsmith, 2009). Participative video provides an opportunity to influence perceptions and debate, and it unleashes participants' potential to create and communicate. It is a layered process because not only can participants discuss the topic under study, but also they learn media and social skills. Participative video (PV) making is mandatory to the JuxtaLearn process, and student participation is essential to it. By encouraging group collaboration PV can provide a good medium in which to provoke conflict that facilitates learning (Jones, 1995). This has the advantage of encouraging iteration between performance and editing activities as students clarify their shared understanding, and as the teacher advises them. Negotiation and discussion are essential for reflection and learning. Through reflective listening students listen and restate in order to identify and clarify differences, and then reconcile them to accomplish task goals (White, 2003),

Apart from the video making itself, the JuxtaLearn process involves the students in project management activities like structuring the work, deciding on the assignment of roles that are vital to a video making process within the group and scheduling of milestones etc. Especially if the students are confronted with such a complex process for the first time, they need support to be able to conduct the whole process and to be able to reflect on their performance.

Writing participative video scripts is a collaborative form of writing. Thus, it requires discussion with peers about the topic to be performed and juxtaposed. Pegrum et al (2015) showed that making a podcast improved deep learning, as opposed to a surface approach to learning (Biggs and Australian Council for Educational Research, (Biggs and Australian Council for Educational Research, 1987)). We set up the conditions for learning by providing a process mediated using storyboards (paper and touch screen), craft materials and video cameras that allowed students to explain a tricky topic in their own terms by creating a story about it. We asked them to juxtapose their story with the teacher's example activity. In their environment, students initially used paper storyboards, on which we encouraged them to draw, but often just one student wrote, not drew. With the table-top software, they drew more and several students drew, not just one.

7. Conclusion

Creativity has often been devalued as a tool for progressing understanding. It is often noted as a facilitator for engagement, curiosity and confidence building. This research highlights the powerful connection between creativity and deep learning. Surface learning is reliant upon memorisation and can result in simple regurgitation of facts that are forgotten soon after they are learnt. Students creating links between knowledge domains and their own expression of this understanding support a deeper approach to learning where concepts are internalised. Ultimately this research proposes the value of creative approaches to learning across the disciplines, especially in those subjects that retain counterintuitive knowledge. However, this requires a shift in teaching and learning practices. The key barrier to this shift is an understanding of the value of these approaches and methods as well as support for teachers to undertake this approach. Whilst this research project has developed some teacher training approaches, some of which are being utilised for teacher training in Portugal, there needs to be a shift in the silo-mind-set to allow creativity to increase the quality of teaching in STEM subjects.

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