CO-DESIGNING ELECTRONIC BOOKS: BOUNDARY OBJECTS FOR SOCIAL CREATIVITY

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The European 'MC-squared' project has a number of 'Communities of Interest' (CoI) (Fischer, 2001) in European countries that work on digital, interactive, creative, mathematics textbooks, called cBooks. A community of interest consists of several stakeholders from various 'Communities of Practice' (Wenger, 1998). In this paper we outline the creation of an English CoI describing the development of a cBook on numbers and equivalence. We use a design-based research methodology approach for teachers, designers, researchers, teacher-educators jointly working on cBooks as 'boundary objects' (Akkerman & Bakker, 2011) to facilitate thinking about creative mathematical thinking and social creativity. We illustrate our design-based approach through the example artefacts created during the different stages of development of the cBooks. The details of our approach provide a blueprint for the formation of CoI's by working on digital, interactive, creative, mathematics textbooks.

Keywords: digital textbook, interactive textbook, e-textbook, creative mathematical thinking, creativity

INTRODUCTION

This paper describes how the European MC-squared project[1] is creating a new generation of digital, interactive, creative mathematics electronic textbooks, called *cBooks*. To analyse our findings we use literature from communities of practice and communities of interest. cBooks are potential boundary objects that are used to cross boundaries between different stakeholders. This paper describes the formation of the communities of interest (CoI) in England.

THEORETICAL FRAMEWORK

The theoretical framework for the project is provided through the lens of communities of practices, CoP's (Wenger, 1998) and communities of interest, CoI's (Fischer, 2001). Teachers who co-design and use resources for teaching, can contribute to their own professional development (e.g., Jaworski, 2006). As these designs eventually are used in classrooms, students are included as actors in the framework. Members of the CoI are seen as *boundary crossers*. In this view, a boundary is defined as "a socio-cultural difference leading to discontinuity in action of interaction" (Akkerman & Bakker, 2011, p. 133). Boundary

[1] See for more information http://www.mc2-project.eu/

crossing usually refers to a person's transitions and interactions across different sites (Suchman, 1994). Boundary *objects* refer to artifacts doing the crossing by fulfilling a bridging function (Star, 1989). In the context of this project, it can be hypothesized that a cBook is as a boundary object that brings different CoP representatives together and hence functions as a catalyst for crossing boundaries. A cBook enables group members to work together and scaffolds the "collaboration" fostering the opportunity for creativity.

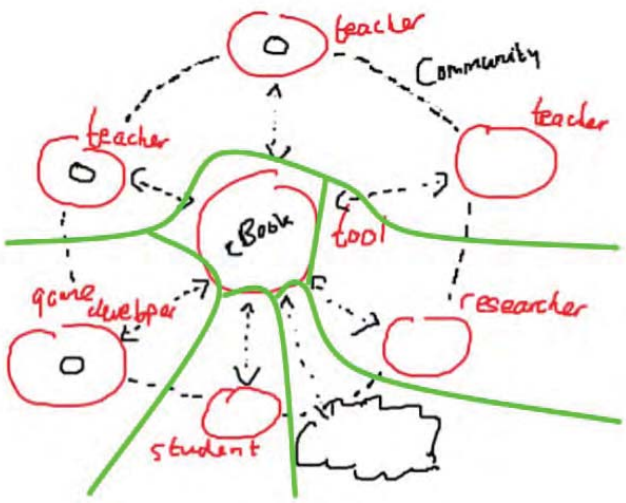

Figure 1: visualization of a community of interest consisting of several communities of practice, working on a boundary object cBook. The green lines denote the boundaries.

The MC-squared project aims to harness the structure of these CoI's to stimulate social creativity (SC) and creative mathematical thinking (CMT): human creativity emerges from activities that take place in contexts in which there is interaction among people and artifacts that embody knowledge from various communities (e.g. Csikszentmihalyi, 1996; Engeström, 2001). With regard to CMT the project aims to not impose a fixed definition of what CMT means but to let the members of the CoI decide and define it for themselves. The remainder of the paper will describe the evolution of a cBook about numbers, expressions and equivalence, linking it to our research lens.

CREATION OF A C-BOOK

This section described how the CoI developed an idea from the first embryonic stage to a first prototypical version of a cBook.

Birth of the idea: a catalyst for creativity

During the first meeting we used a strategy that the English CoI set out to use throughout, namely to ask CoP representatives (CoI members) what challenges there are in their daily classroom or in English maths education that need addressing. The idea behind this is that CoI members not only think about 'low hanging fruit' but also about actual applications of cBooks that address challenging issues in the classroom. By taking a real example, creative solutions are required. In addition it enables CPD and deep learning for the teacher experience as well as considering other creative solutions. Taking the culture of English classrooms into account it is imperative for adoption that the cBooks that come from this project are rooted in genuine challenges rather than 'nice activities at the side'. The process of thinking about these

challenges involved using poster format papers to express ideas and opinions. One of the ideas concerned a number challenge. The idea was that to stimulate creative mathematical thinking (CMT) students should not be restricted to one 'good answer' but be made aware of the different ways you can obtain an answer. It was envisaged that by posing a number students could be asked to find as many ways as possible to write 36, with 36 in the center and possible solutions pointing outward.

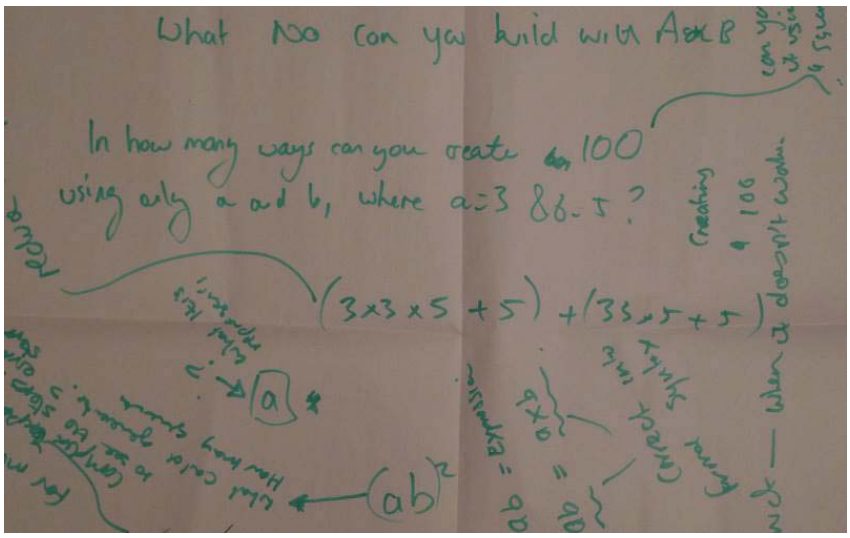

Figure 2: drawing during the first CoI meeting

Building on the initial idea

The initial idea was then extended on a larger paper poster. Several aspects were incorporated in the elaboration:

- The general topic was equivalence and involved several ‘layers’: target audiences could be both at primary school and secondary school;
- A progression (scaffolding) in task types was needed;
- The cBook should 'force' the use of certain operations;
- Software should give pupils feedback on the 'correctness' of inputs;
- The cBook should address understanding the order of operations;
- It was reiterated that an important feature should be that pupils would be free in the answer they could give

Another group developed numbers ideas that focused more on expressions. These ideas were merged with the initial idea. After a short introduction to the software, a first prototype of an activity was authored. This prototype was developed further after the meeting[2].

Further developing the prototype

A cBook of the prototype was developed using DME authoring environment. During these developments several suggestions were made by fellow CoI members in the communication workspace within the software. Amongst others, the social process in the CoI led to several additions and modifications:

[2] Development was done by the first author and not the CoI creator.

- Randomization. Every instance of the book is slightly different.
- Equivalence checking and feedback on whether the answer is correct.
- An early contribution to the discussion emphasised the need for a problem posing element: pupils could be asked to make up their own activity and appropriate text. An open textbox and drawing widgets were integrated in that version.
- Further ideas about fractions were added by two CoI members. This shows the 'network' nature of evolving ideas, as this idea was also mentioned by another participating teacher. Equivalence of fractions is a topic that fits both in 'fractions' as a topic as well as this activity about equivalence relations. It could very well be that these ideas will converge in the future.
- Another comment concerned the first page, which needs an attractive introduction that explains the importance of being able to find equivalent expressions and why this is useful.
- Subsequent comments seem to be converging to an agreement about the status of the book and starting raising detailed questions about terminology, usage in the classroom, and the care that one would need to take when introducing the topic to children due to implicit assumptions.
- At this stage there was a quick action-reaction cycle in the c-Book: one CoI member responded further, causing more reactions etcetera. The comments were evaluated and either led to revisions or a rejection of the idea(s). Some proposed ideas or changes were harder to implement than others and therefore we 'stored' those for a while for (i) further reflection on how we could implement them, or (ii) future implementation. The latter includes ideas about game-like elements, isomorphisms and more feedback.

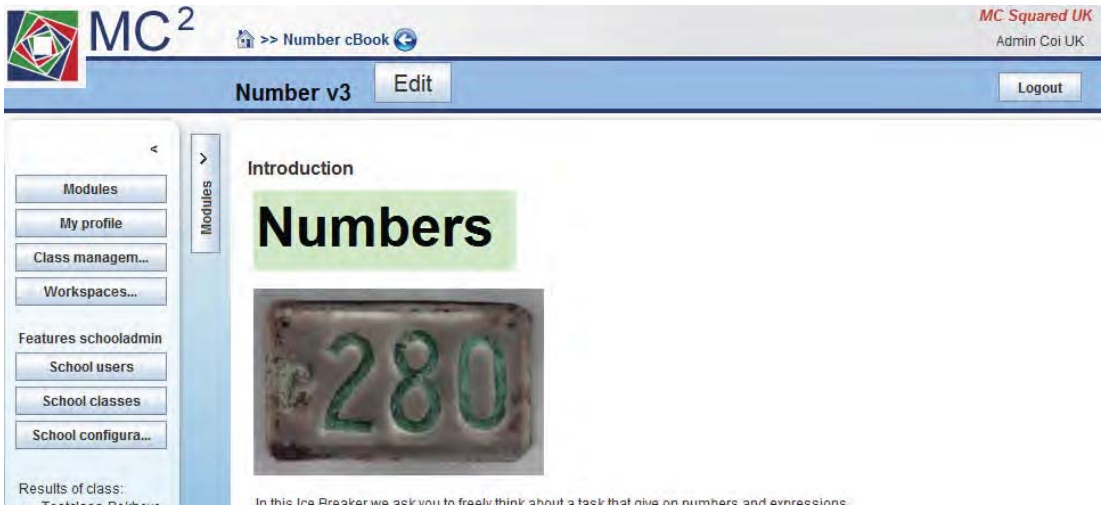

Figure 3: introduction c-book Numbers

The end result of the CoI process was a Numbers cBook with seven pages: an introduction, two tasks asking students to construct expressions that were equivalent to a randomized number, two tasks asking students to construct expressions that were equivalent with an algebraic expressions, an open problem posing task asking students to make up a task for a fellow student and share. The end ‘product’ is not finished yet and will be developed further, but the final version shows how the SC process has contributed to its evolution.

EVALUATION AND DISCUSSION

The CoI formation and authoring of cBooks is only in its initial phase but it is already possible to reflect and draw conclusions on the creative process and its outcomes. It is worth noting that the UK CoI is a heterogeneous group of professionals with different backgrounds, which is promising as this may lead to innovative and creative exchanges and developments. These different backgrounds can certainly be seen as different 'Communities of Practice' with every individual representing it. Together they make up a 'Community of Interest' that functions as a springboard for new resources to be used and developed to facilitate exchange, integration and thus creative thinking and working. The boundaries between the different CoI members are apparent as well: teachers are very much in a different environment than, for example, researchers. Working together on a cBook provides a useful boundary object to cross these boundaries. Not only do CoI members work on CMT, as described before, boundary crossing within the CoI also is an important source and trigger of social creativity (Fischer 2001). Obviously these are not the only boundaries, in principle every new CoP that joins the CoI provides a new potential boundary that can contribute to the evolution of the cBook. This certainly will be one of the foci in the course of the project. Central in the project are cBooks, which in this case example, can be viewed as boundary object: through their successive versions cBooks act as boundary objects allowing and supporting the CoI's boundary crossing efforts. This is demonstrated in figure 4, an excerpt of the communication within the authoring tool.

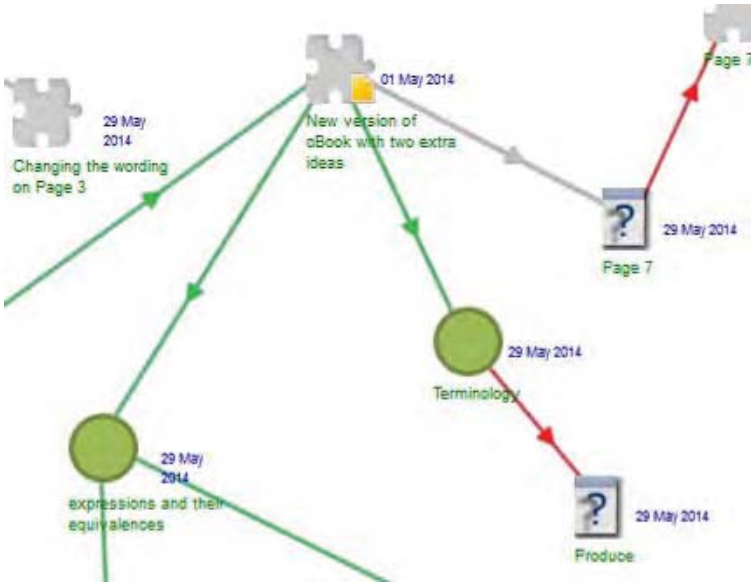

Figure 4: small anonymized excerpt of the communication about the cBook.

The example of the numbers cBook evolution in our view demonstrates how this process augmented SC, as the book evolved: (i) first one idea from one individual; (ii) this led to discussing this idea with one other person in the CoI; (iii) a CoI member took those ideas and made it into the first prototype in the tool (see Bokhove et al., 2014 for more on the authoring tool); (iv) this was disseminated to the rest of the CoI, critiqued and co-edited with improvements. One challenge in using the cBook as boundary object is that of an apparent process-product dichotomy: are we working on new books or are we working on processes?

How do the different stages of the cBook demonstrate the SC process? From figure 4 we can certainly see that the CoI gave rise to new, creative feature, but it will be interesting to see whether and how this process changes over time. The evolution of the cBook has confirmed and deepened some aspects of our CMT approach. Rather than giving a list of expressions and students having to identify whether they are equivalent or not the main aim is to let pupils themselves decide what numbers and/or expressions they want to enter. This philosophy of not providing a question with an answer but leaving the 'correct' answer open underpins these activities. In conclusion, this paper describes some of the first cautious steps of the MC-squared project in which new, creative, electronic maths book are created. Although we are still at the initial stages we are already observing that that these cBooks function well as boundary objects for a Community of Interest. Furthermore, they seem to be able to function as catalysts for augmenting social creativity and creative mathematical thinking.

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