CROSS-CASE DESIGN IN USING DIGITAL TECHNOLOGIES: TWO COMMUNITIES OF INTEREST DESIGNING A C-BOOK UNIT

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This paper focuses on the process of collaborative design of a new digital learning resource, called c-book unit (c for creativity), by two different communities of interest (CoI) with different profiles in terms of designers, teachers, researchers, technology developers, and students. In this paper, we present the work developed by the two Col, the Greek and the Spanish ones, working together in an iterative process of design, analysis and redesign of a c-book unit called ‘Viral Behaviour of Social Networks’. Using cross-analyses and design methodologies, we identify the influences of the ‘design context’ on the task design process of the c-book unit. In particular, we focus on how the academic and empirical settings (pedagogical, school, didactic conditions) of one CoI are recontextualized by the other CoI in the process of redesign of the original unit.

INTRODUCTION

The main focus of this paper is the collaborative design of a new kind of digital educational resources named c-books (c for creativity). Designers of different background, expertise and interests jointly design c-books aiming to foster Creative Mathematical Thinking (CMT) to the final users. This study took place in the context of a European R&D project called ‘M C Squared’ focusing on technologies supporting creativity both in collaborative authoring designs and in developing the ‘c-book units’ to engage users in creative mathematical thinking. Since this kind of resource constitutes an innovative approach to mediating mathematical content, we are particularly interested in studying both the process of task design as well as the affordances of the product itself, in order to identify their characteristics and their potential for the teaching and learning of mathematics.

In this research, we define c-book as an entity that extends the current e-book technologies to include diverse dynamic widgets, interoperability, and an authorable data analytics engine. The c-book units have been thought to be designed collectively by teams holding a diversity of disciplinary backgrounds, expertise, history and membership in different communities of practice, which are defined as Communities of Interest (CoI) (Fisher, 2001). This diversity ensures the richness and complementarity of knowledge domains, cultures, perspectives, adding to the CoI a creative potential and productivity in relation to the anticipated task. We concentrate on a design phase which involves two CoI interacting as follows: (a) one CoI acts as the primary-designer of a c-book unit, then (b) a different CoI adopts this alien resource and evaluates its CMT potential, (c) this CoI acts as secondary-designer of the c-book unit. They will accomplish the redesign of the unit according to their own approach, but also interacting with some of the initial designers. Finally, (d) the initial CoI takes back the redesigned c-book and evaluates its CMT potential.
The interaction among the CoI members, as well as between both CoI took place using an infrastructure for the design of the c-book unit, through two parallel interfaces, offering to the users the possibility of switching from one to the other. The first interface is the space for authoring, where a sequenced page-structure can include different kinds of widgets (i.e., small pieces of software which can be included into c-books via the c-book environment in order to allow interactive content) accompanied by a narrative (Fig. 1). The second one is a threaded forum discussion view and a mind-map view, giving the designers the space for the collaborative design in the form of conceptual trees where nodes are ideas, comments, evolutions and versions of the c-book (Fig. 2).

In this framework of cross-design and cross-analysis of a c-book unit, it is expected that there are characteristics that influence design in the *academic setting* and there are characteristics in the *empirical setting* that influence how the media is perceived by the users (Lagrange & Kynigos, 2014). This means that through the adoption of an alien c-book unit, the secondary designers have the chance to identify contextual characteristics that when seen in their own setting offer potentiality for evolution resulting in re-contextualization of modalities that issued from the primary designers’ context. Moreover, this provides the opportunity for each designing team to become...
familiar with the context of the other designing team, something considered non trivial. More specifically, in this paper we discuss the work developed by a specific CoI-pair, the Greek and the Spanish ones, along the process of designing, analysing and redesigning the c-book unit called: ‘Viral Behaviour of Social Networks’.

THE CROSS-CASE DESIGN OF THE C-BOOK UNIT

In the cross-case design process two CoI subgroups participated in the design and redesign of the c-book unit. Five people from different profiles composed the Spanish subgroup who acted as the primary-designers of the c-book unit called ‘Viral Behaviour of Social Networks’\(^1\). The Spanish sub-CoI (two researchers in Mathematics Education, two Mathematics teachers in Secondary school and one expert in modelling), although diverse, was characterized by their common aim of putting forth an interdisciplinary approach where mathematics would provide tools for analysing social phenomena. In particular, about the theme and topic of the c-book unit, they decided to focus on the use of the exponential growth properties to describe and to model the behaviour and evolution of the number of users in a social network, drawing upon real data provided by Facebook. Furthermore, they agreed to put at the core of the c-book unit a sequence of linked questions of real interest for the students, related to the exponential growth of social networks, their viral behaviour and their power to connect people around the world, which constitutes the rationale of the mathematical tools to be built. Also, mathematical modelling was considered as a crucial approach to cope with most of the extra-mathematical questions, and progressively build up mathematical models to study the complexity of the questions posed along the unit, linking and articulating the models appearing at each step.

Both the academic and empirical settings were important in laying down the design context of the c-book unit. In relation to the academic setting, there were two researchers in the designing team who framed the task design process according to the characteristics of the Study and Research Paths (SRP) proposal (see for instance, Barquero, Serrano & Serrano, 2013, Barquero & Bosch, 2015), which guided the mathematical and didactic design of the c-book unit. More specifically, (i) the starting point of the c-book unit was based on an initial question \(Q_0\) about the social networks viral behaviour. A public announcement about a party organised by a Dutch girl using Facebook constitute the first real data to work with, which opens the main issues to study along the unit about the ‘virality’ of this phenomenon; (ii) the c-book structure (phases and pages) is organised around a series of subsequent questions \((Q_1, Q_2, \ldots, Q_n)\) derived from the initial question \(Q_0\), guiding the study process with the aim to provide at each step a more complete answer to \(Q_0\), and (iii) the c-book unit emphasise on an interdisciplinary study where mathematics (mainly, arithmetic and pre-algebraic modelling) provide tools to analyse social phenomena related to social networks and its power to connect people around the world.

For the empirical setting, the two Secondary school teachers who were members of the designing team played the main role to pay attention to the conditions and constraints, assumed in the c-book unit design, in relation to whether it is feasible for this c-book unit to be used in real Secondary school classrooms, a decisions that would be made in conjunction with the rest of the designers. For

the school level and targeted audience, they decided to focus on a lower Secondary school education (14-15 year-old students, Grade-9), according to the Spanish curriculum at this level. For the didactic and pedagogical settings, the designers’ team envisioned a future implementation where the teacher would guide and orchestrate students’ work (in teams or individually), by organising, comparing and discussing each student’s proposal in the classroom. The ideal organisation for the classroom would be to work in teams of 2 or 3 students. They would be asked to follow the phases, questions and sub-questions sketched in the c-book unit and to use the c-book technology (widgets, virtual and video explanations, etc.) included in its design to go through most of the activities and to deliver reports (individually or in teams) at the end of each phase (three in total).

For the disciplinary and cross-disciplinary goals, as it has already been mentioned, the designers’ team wanted the students to face questions of real interest for them, where mathematics appear as a ‘service subject’ to analyse real data, relations and patterns on real data, fit and test mathematical models to provide forecasts about real data tendencies, and so on. This is why mathematical modelling was central in the study process proposed in the c-book unit and the whole design puts effort on getting the best way (which questions, real data, models, simulations, etc.) to involve mathematical modelling in this unit as well as in the future students’ learning experience. The Spanish designers’ team was very well complemented with an expert on modelling, who provided an external view by proposing many ideas about the conditions that would be proper for the real modelling to occur and the best way to foster its development.

Then, this c-book unit was adopted by the members of the Greek CoI in order to evaluate its CMT affordances, followed then by its re-design according to their CMT representations. Four people (a researcher in Mathematics Education (ME), a PhD student in ME, a secondary school teacher and a primary school teacher both holding a PhD in ME) constituted the Greek sub-CoI. The evaluation made by the Greek CoI gave the main emphasis to the necessity for the presence of constructionist activities in the c-book unit, and left aside aspects such as problematization (or questioning), modelling, and validation, which were among the main criteria used by the Spanish CoI. Then, the Greek CoI went through a process of de- and re-contextualization of both the empirical and academic setting.

For the empirical setting the re-design of this c-book unit did not come as a result of a total re-contextualization.

For the theme and topic/areas/disciplines aspects, the theme of Facebook and the related topics were kept the same as in the initial version of the c-book unit. The c-book however, was enriched in terms of some selected issues. Therefore, Geography was added as a new disciplinary lens to the theme, and a world map was used to investigate degrees of friendship. Actually the map was used to make visible the connection between friends in various places. By trying to track down the networking relationships of the users on the map, a path is created and since the map depicts a 2D representation of Earth the path happens sometimes to end on the right side of the map, and then continues to the left, which actually indicates the way we are moving on earth.

For the school level and targeted audience there was also a change that can be attributed mainly to the rather different curriculum between Greece and Spain. So, the initial c-book unit was designed
for Grade-9 students (14-15 year old). But, the re-designed version works in two levels: One part (out of three) of the revised c-book unit is addressed to Grades 6-9, whereas the remaining two parts deal with more advanced mathematics and are addressed -at least- to Grade 11 students.

For the disciplinary and cross-disciplinary goals the focus remained the same, seen however through different lenses. So, the emphasis now is on helping students to realize the functionality of applied mathematics, to identify a pattern in a real life situation, and use the rule of the pattern to interpret statements or check statements and conjectures. There was also an effort to put a stronger emphasis on a cross-disciplinary level, by showing how the dynamic character of communication through the new media of social networking affects the “distance” between people.

Finally, for the didactic and pedagogical settings the whole issue of re-contextualization for this aspect can be mainly summarized in terms of orchestration. Emphasis was given in a kind of multi-modality. Parts of the c-book unit can be implemented in the Computer Lab since it is necessary for the students to search for data and use their Facebook accounts. Other parts can be implemented in classroom, working at the same time on the interactive board and on worksheets. Finally, there are parts that can be addressed either individually or in groups, at school or at home.

The process of the re-contextualization in academic setting must be seen also in conjunction with the initial context. One main characteristic of the initial version of the c-book unit was that the starting point consisted of an initial question and then the whole structure was organized around a series of questions stemming from the initial one. Instead, the Greek Col made an attempt to enrich the constructionist element in the adapted c-book unit. The fact is that the theme of the c-book unit limited the possibility to design many constructionist activities. One example that could be mentioned is an activity in the redesigned book inviting students to construct a friendship network. An additional choice was to enhance the openness. This can be referring either to multiplicity of solutions and/or strategies or the multiplicity of interconnected representations. For example, there are more than one ways for the reader to construct the network of friendship. At the same time, this notion of friendship is introduced through a variety of representations such as circles, segment lines, world map and tree diagrams (Fig. 3).

![Fig.3 Different representations of the notion of friendship](image)
Finally, after the re-design of the adopted c-book unit, this was again evaluated by the primary-designers (the Spanish sub-CoI) and there was cross-communication between the two CoI discussing and asking for common aspects and differences.

**REFLECTING ON THE CROSS-CASE DESIGN AND EVALUATION**

The exchange between the CoI-pair raised the issue of the role and impact of the *design context*. More precisely, the way the redesigned c-book unit was approached cannot be separated from the specific design context, from the academic and empirical setting where each evaluation took place. The cross-design process included a twofold evaluation. The initial evaluation, made by the Greek CoI when they received the c-book unit produced by the Spanish CoI as primary-designers, guided to a great extend the redesign of this c-book unit. Then, the Spanish CoI received again the redesigned unit and went on with the second evaluation. A horizontal analysis of these two evaluations made evident the aspects that both CoI agree about their potentiality to contribute to the students’ CMT while at the same time highlighted the strong and weak points of the c-book unit (Papadopoulos, Barquero, Richter, Daskolia, Barajas & Kynigos, 2015). Moreover, the comparative analysis gave us several examples of the importance of the design context of each CoI. Besides, it is reasonable to expect that each CoI would tend to approach the redesign and evaluation of the c-book unit through the lenses of its academic and empirical setting. Therefore, it can be said that this cross-case design and analysis raises three issues.

1. **Recognizing shared design principles:** It was made clear that redesigning does not mean a total re-contextualization of the initial unit. The interaction that took place between the two CoI revealed that there were some shared design principles. Therefore, both CoI considered important to include real-life problems and offer a cross-disciplinary approach to the tasks. They also expressed their appreciation to the presence of problem-posing activities (even though this presence was limited due to the structure of the c-book unit itself and the linear way of following the pages that did not give priority to offering opportunities to the students for posing their own questions). Equally important was considered by both CoI to include opportunities for mathematical conjecturing and exploration by providing proper tools to the students.

2. **Impact of academic and empirical setting on design principles:** It has already been mentioned that the evaluation made by each CoI cannot be separated from the specific academic setting within this evaluation took place. It was evident that the theoretical orientation of each CoI determined the design principles of each version of the c-book unit (e.g., modelling activities for the Spanish CoI, constructionist activities for the Greek one). For instance, the Spanish CoI gave emphasis to include aspects such as the ‘problematization/questioning’ (enabling students to question the assumptions under which models are built, or question the validity of models in relation to real data, etc.) or ‘simulation’ (exploration and simulation of models to test their validity) because this is crucial for modelling activities progress. The Greek CoI, on the contrary, did not mention these aspects neither during the first evaluation nor during the redesign. More specifically, the Greek CoI gave the main emphasis to the necessity for the presence of constructionist activities. This constructionist aspect is very much based on the previous experience and educational tradition of the Greek CoI members because of their involvement in wide scale initiatives based on the relevant epistemology. So, in the spirit of constructionism, preferred to offer partially completed activities that had to be completed
by the students. For example, they use a half-made network of friendship that must be finished by the students on the basis of certain constraints. This influence of the theoretical orientation of each designing team is perhaps the most central characteristic of the academic setting. But, of course, this is not something visible to the end-user. What is visible to them is the design choices related to the empirical setting since this influences the digital outcome (the c-book unit and its content, the list of the used widgets, the kinds of activities, the modality of use, etc.). The existed differences between the two empirical setting perhaps are indicative of the fact that the design principles in each context gives emphasis on different aspects of students’ use of the c-book unit affordances. For example, the two teams chose different systems of representing the notion of friendship. The Spanish CoI chose mainly the use of tree-diagrams (based on the Probability trees widget of the Freudenthal Institute). The aim was to use these as models to explore and understand the exponential growth properties in order to describe the evolution of the users in a social network, enabling to later evolve towards more advanced models (as in terms of geometric sequences). On the other hand, the Greek CoI used Geogebra to create networks or circles of friendship (Fig. 3) trying to approach the “Theory of Six Degrees of Separation” and understand how dynamic characteristics in the forms of communication (i.e., social networks) affect the ‘distance’ between the users.

3. Co-working on the borders of different settings: Despite that each CoI started the design process from different origin, it seems that the exchange between the CoI offers chances for reconsidering their own context, identifying contextual characteristics, and move from de-contextualizing to re-contextualizing. In the meanwhile it happens the teams to be influenced to a certain degree by this exchange. In our case, there are instances that show that both CoI were influenced because of this exchange. So, on the one hand, some of the traits for the design of the SRP matched very well with the perspective of the constructionism approach, and this is why the relevant activities concerning networks of friendships that were used in the redesign are aligned with the notion of modelling. On the other hand, during the cross-case design the Greek CoI suggested to the Spanish CoI the inclusion of activities where students would construct instead of only observe and analyse a simulation. This was taken into account by the Spanish team and new activities were added in which students would be able to use dynamic manipulation tools for modelling purposes. Thus, the spirit of the co-existence of both constructionism and modelling was present in the new c-book unit. This highlights that the main idea is to work in common in order to identify design principles and elements that exist or emerge in one setting and which might be interesting and be used in other settings. In this case this new design element that draws the attention of the other designers’ team (CoI) actually crosses the boundaries and becomes object of thought for this CoI (Akkerman & Bakker, 2011). Thus, this approach results in a situation where the members of both CoI co-work at the boundaries of the two settings. This becomes more interesting since the members of each CoI are of different expertise. Therefore, the crossing of the boundaries takes place not only between different educational contexts but also between different research approaches and epistemologies, and between objects of thought of different communities of practice, from researchers to teachers or math educators, for instance, and vice versa.

The usage of two distinct socio-technical environments corresponding to two different design contexts made it reasonable to expect diversity on the way CMT is conceived by each CoI and the
task design context they consider. The information obtained separately for each CoI deepens our awareness of the role of the design context diversity both by the exercise of de-contextualizing the findings and by using synthetic knowledge to later try to re-contextualize generic findings (Lagrange & Kynigos, 2014). Our understanding of this process of de-contextualization and re-contextualization is sharpened by studying pairs in different educational contexts cross-analysing the same data (Morgan & Kynigos, 2014, Lagrange & Kynigos, 2014). Moreover it allows to identify and examine instances of boundary crossing. So, it seems to be potentially a promising methodological tool for networking theoretical approaches and this is why such interactions between different CoI are deemed necessary.

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