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Summary

This deliverable reports on the second cycle of the redesign process that took place among two co-pair communities of interest (CoI): the French-Spanish and the community English-Greek. During the second phase of WP7, each CoI did selected, put in use, translated to the in-house language, evaluated, redesigned and re-constructed an alien resource previously developed in WP6’s Cycle 2. This implied a process of peer-reviewing, evaluating, and enhancing four c-book units produced during Cycle 3 of WP6 by other CoIs on a cross-experimentation context.

The selection of the alien c-book units and the formation of the CoI co-pairs participating in the redesign opens Section 2 of this Deliverable. This implied the production of an internal work plan, the tasks distribution and moderation strategies to follow in the socio-technical environment, which was fully operational. Section 3 deals with the description of the initial processes of the redesign, which implied the external evaluation of the alien c-book unit, to set up the basis for its improvement, according to the contextual characteristics of the new setting, as well as the didactical approaches of the CoIs adopting the alien c-book unit. Section 4 is devoted to the description of the four redesigned c-book units: a) ‘Musical plane’, redesigned by the French CoI; b) ‘Limits’, redesigned by the Spanish CoI on the one hand, and c)‘Generalization’ redesigned by the Greek CoI; and)‘Windmills II’ redesigned by the UK CoI,. Section 5 deals with the cross-case evaluation of the CMT potential of the redesigned c-book units, in which the first action was the evaluation of the new units by each co-pair. This phase has been crucial, since in the comparative analysis on the results of the evaluation of the CMT potential of the alien c-book unit vs the redesigned c-book unit presented, we see whether the units have improved or not in terms of CMT affordances (all cognitive processes, such as fluency, flexibility, originality and elaboration, as well as social and affective aspects). We present the results both graphically and quantitatively, which demonstrate a significant gain in all the redesigned units. Section 6 is devoted to the analyses of and reflections on SC during the different stages of the redesign processes, in which two quantitative methodologies were used for measuring social creativity. The analysis is completed from a qualitative point of view; the approach taken was based on the emergence of new creative ideas in the cross-design process, the use of the socio-technical environment facilitating the redesign, and the identification of ‘critical’ episodes. The c-book units redesign process led to new insights, content redesigns, and disruptive changes when two different CoIs worked together in the same CoICode environment.

Finally, the section on Results, in which we discuss the main findings as well as the methodologies used for measuring CMT and SC, finding ways to connect both measures and processes. The results are suggesting that, using different methods for measuring CMT, in all cases CMT affordances improved as a consequence of the cross-CoI collaboration for the re-contextualisation of the c-book units. All cognitive processes increased their value in the redesigned c-book unit, as well as Social and Affective Aspects, with the addition of better aesthetics, attractive narrative, and new widgets responding to the emergence of new creative ideas. Although not conclusively, these results suggest also that higher social interaction and exchange of different approaches and theoretical frameworks between CoI-pairs (Social Creativity processes) has produced c-book units with improved CMT affordances.
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1 Introduction to Deliverable 7.2

Deliverable 7.2 is the second of two corresponding to the work done in WP7. The basis for the work done in stands on the cross-experimentation approach, in which the dynamic digital artefacts used in the design, would be influenced by the contextual characteristics of two different CoI working together (Kynigos & Psycharis, 2009; Bottino & Kynigos, 2009), allowing for boundary-crossing. From this cross-experimentation perspective, this deliverable reports, on how the cross-CoI's worked in Cycle 2 took place, describing the collaboration processes involved in the redesign of four c-book units selected by two co-pairs. This phase took place from M18 till M130. By the time this task began, the socio-technical environment was mature for all the operations put in place. This work corresponds to the task:

T7.2: Cross-case external evaluation of the c-book resources and cross-case redesign - Cycle 2 (Leader: UB, Contributing Partners: CTI, TAL, LKL, NEL, UCBL, ARI, Duration: 16M.

During the second phase of WP7, each CoI did select, put in use, translated to the in-house language, evaluated, redesigned and re-constructed an alien resource previously developed in WP6’s Cycle 2. This implied a process of peer-reviewing, evaluating, and enhancing other c-book units produced during Cycle 2 of WP6 by other CoI on a cross-experimentation context. After that, the new units were re-evaluated in terms of CMT (Creative Mathematical Thinking) potential and social creativity processes. At the end of Cycle 2 (i.e. end of WP6 cycle 3), four reports on cross-CoI work were submitted by the corresponding CoI leaders. In this case the same reporting tools were used, once a consensus was reached by the partners. This did not precluded the fact that some of the methods used (i.e. measurement of social creativity) applied, were different. Data from this Deliverable contributes for the theory development on creativity and its measurement.

Figure 1.1 Connections between Work Packages

The procedure for this exercise was as follows: two pairs, different from the previous round, were formed this time (ES-FR, and GR-UK), and started a two-way collaboration. Each one closely collaborated with one another, with the task of taking one resource from the other, call it 'alien resource', evaluating and changing it, to make it their own 'in-house resource'. The criterion for pairing was done on the basis of augmenting information on CMT and SC. The contextual characteristics of the CoI were influencing the co-design process, since the CoI reflected on a specific alien c-book resource, then creatively redesigned it, so as to adapt it according to their national context and theoretical conceptions, and finally reconstructing it to become a new in-house resource.

The process of redesign was supported by the CoI pair that was the original author of the unit according to its own perspective and framework, and then their feedback was considered in order to make changes in the redesigned c-book unit. Finally the redesigned unit was evaluated by members of the two co-pairs different
(when possible) than those who participated in the design-redesign process, so aiming at having a more objective view of CMT in the final unit. Each CoI did therefore have a dual role to play: to act as the 'External Evaluator' of another CoI's creative work, and as the 'secondary developer' of this CoI's work. As in the previous Deliverable, cross-communication has been key in working in the redesign and reconstruction of the alien resources. CoICode has been used for this matter, together with other communication channels (such as Skype or emails, and face-to-face meetings). Results of these interactions were gathered, so to feed into theory-building in WP2, by comparing the approaches taken both within the national CoIs, but especially within the cross-CoI collaboration that took place among the two CoI pairs formed.

Finally, this report brings data and inquiries about the following aspects:

a) Reflect on the methodology used for measuring CMT and SC by the CoI-pairs, and how this influences the measurement of CMT and SC.

b) Evaluate the extent to which the alien resource improves on CMT after the redesign process, in accordance with the different contextual characteristics of CMT by the CoI pairs.

c) Inquiry about the relationship between the CMT and SC components as a result of the CoI pairs working in the redesign of the units.

As a whole, Deliverable 7.2 describes the work done originating from the inter-CoI collaboration activities previously mentioned, constituting a process of cross-experimentation and cross-case analyses. Additionally, the report provides data to theory building on WP2 in terms of CMT and SC.
2 CoI-pairs formation, selection of c-book units and implementation

2.1 Procedure: interest in the adopted c-book units and criteria for the formation of the CoI-pairs

Before the wp7-cycle 2 began (in May 2015), the four CoI: the French CoI, the Spanish CoI, the Greek CoI, and the UK CoI, were asked to select two c-book units produced in wp6-cycle 2 from the two CoI that they had not worked together in wp7-cycle1. Then, their selection was presented in an special Use & Evaluation meeting (end of May 2015) where they also had to assign a preference between the two c-book units. All partners participated in this process and CoI-pairs were decided based on CoI’s interest and preferences on particular c-book units. Finally, the c-book units that were selected by the CoI were: Limits (from the French CoI as primary-designers), Musical plane (from the Spanish CoI), Windmills (from the Greek CoI) and Generalisation (from the UK CoI). Each CoI could work with a c-book unit that had been chosen. The following tables show the justification of the interest that each CoI expressed about their c-book unit selection:

<table>
<thead>
<tr>
<th>French CoI</th>
<th>Spanish CoI</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ The theme of the unit was very rich. The technical aspects of getting to work with widgets that manipulate sounds were as well appealing.</td>
<td>▪ The theme of fractals constitutes an attractive topic to develop with a lot of possibilities to explore.</td>
</tr>
<tr>
<td>▪ Our ears are more sensitive to differences than our eyes and we thought that combining maths and sounds was a very good idea. Sound is a very rich subject and restricting it to tone production was a good way to slim down lots of complicated mathematics to integer numbers manipulation with a hint to simple functions.</td>
<td>▪ Moreover, some of the activities about the discussion of the notion of infinity results highly interesting, which could pose many questions related to fractals, functions and limit tendencies.</td>
</tr>
<tr>
<td>▪ We also wanted to use the notion of scales to explain them mathematically and also use more notions about musical rules related to math to enable users to play with them.</td>
<td>▪ Dealing with topics like fractals and limits may allow us to use and combine different widgets: Geogebra, EpsilonValue, among others.</td>
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Table 2.1.1. Justification of the c-book unit selection by the French- Spanish CoI-pair.

<table>
<thead>
<tr>
<th>Greek CoI</th>
<th>UK CoI</th>
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<tbody>
<tr>
<td>▪ The main mathematical topic of the c-book is “generalization” which constitutes a central mathematical topic of the math curriculum across all grades. Additionally, is a topic that can be approached in a variety of ways.</td>
<td>▪ The functional relationships aspect seems appropriate for the UK curriculum (as was demonstrated by the transformations of graphs c-book).</td>
</tr>
<tr>
<td>▪ It is possible to extend and shift the focus from algebraic generalization to the geometric one mainly based on the usage of patterns.</td>
<td>▪ The c-book includes a widget factory we are not very familiar with, thus providing another learning opportunity.</td>
</tr>
<tr>
<td>▪ It is also possible to involve more widget in the redesign of the c-book compared to the ones already used in the current version.</td>
<td>▪ There is potential for engaging with the feedback and learning analytics functionalities.</td>
</tr>
</tbody>
</table>

Table 2.1.2. Justification of the c-book unit selection by the Greek-English CoI-pair.
At the end of first phase, once the formation of CoI-pairs and the particular c-book units to be adopted were clear, each primary designer translated their in-house c-book unit into English. These initial versions, produced by the primary-designer CoI, are available into their English version at:

<table>
<thead>
<tr>
<th>Limits</th>
<th><a href="http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;courseViewNr=5155396549345280">http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;courseViewNr=5155396549345280</a></th>
</tr>
</thead>
</table>

Table 2.1.3. Links to the initial versions of the c-book units adopted by each corresponding CoI.

For each of the CoI-pairs, two new c-books were created as well as common spaces to share these c-book units and to begin with the following phase of WP7.

### 2.2 CoI-pairs composition and roles developed

#### 2.2.1 The case of the French-Spanish CoI-pair

The c-book unit of *Musical plane*, initially designed by the Spanish CoI (in wp6-cycle2), was presented to the French CoI subgroup who was in charge of its redesign. Two members of the French CoI, both of them with experience in Math Education research, composed the internal designers’ team, who would lead the redesign of the c-book unit. In the next stage of cross-case redesign of the c-book unit, three new members of the Spanish team participated in the cross-design team, suggesting ideas and changes to the first redesigned version of the c-book unit presented by the French internal team. Moreover, in the last phases, of the final CMT evaluation, new members from both CoIs were involved. In particular, one from the French CoI who had not been directly involved in the redesign process and two more from the Spanish CoI who had participated in the first design of the musical plane c-book unit (in wp6-cycle2). In the following Fig. 2.2.1.1, one can see the distribution of CoI-pair members involved as designers (internal and/or cross-design work) or reviewers.

![Figure 2.2.1.1. Composition of the designers and reviewers team for the ‘Musical plane’ c-book unit.](image)

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In the case of the c-book unit *Limits* initially designed by the French CoI and adopted and redesigned by the Spanish CoI and in order to set up the designers’ and evaluators’ CoI-pair subgroup, the Spanish CoI decided to assign the role of main designers and moderator role to a CoI member who was not in the research team. The internal designer’s team, composed by four Spanish CoI members, wanted to give a more functional and extra-mathematical approach to the c-book unit, and therefore the option of a main designer with a background in industrial engineering, working as secondary school teacher, was considered very appropriate. Once the first complete version of the redesigned c-book unit was ready, the cross-Col design phase began, when two new members of the French CoI were involved adding some comments and suggestions for further changes to the c-book unit. On the last stage of the final CMT evaluation, four new members (two from each CoI) were incorporated. In particular, the two from the French CoI had been part of the designers’ team of the original version of the Limits unit.

![Figure 2.2.1.2. Composition of the designers and reviewers team for the ‘Limits’ c-book unit.](image)

### 2.2.2 The case of the Greek-UK CoI-pair

In the case of the UK CoI, eight CoI members were involved in the initial evaluation of the c-book unit Windmills, initially designed by the Greek CoI. Their profiles were maths teacher educators and researchers. In the redesign and communication five of the initial UK subgroup carried on with the process.

In the case of the c-book unit “Generalization” adopted by the Greek sub-CoI, four CoI members were involved in its redesign that resulted in the production of the “Alice in PatternLand” c-book unit. All the four members had experience in Mathematics Education research. During the cross-case redesign three members from the UK CoI were involved in the discussion that took place in the CoICode making suggestions to improve the redesigned c-book unit. In the phase of evaluation one more member from the Greek CoI was invited to participate. Six CoI members from the UK CoI participated also in the evaluation of Alice. Only one of them was involved as a primary designer in the initial version (Generalization) of the c-book unit.

### 2.3 Implementation: internal work-plan and CoI-pair tasks distribution

After the CoI-pairs formation and the selection of the c-book units for its redesign, all CoI went through the following phases (corresponding to the main four phases wp7-structure), with the corresponding tasks:

- **Phase 1** with the adoption of the alien c-book unit, each primary designer translated their in-house c-book unit into English to enable its adoption by its CoI-pair. Two new c-book units were created, one for each CoI-pair (the French-Spanish c-book and the Greek-UK c-book). The translated versions of the c-book unit to be adopted by each CoI-pair were incorporated its corresponding c-book. CoI members from both CoIs had access to the shared c-book.
- **Phase 2**, in which the main objective was to proceed with the initial evaluation of the CMT affordances of the ‘alien’ c-book unit by the CoI acting as the secondary-designers. In this second cycle of WP7, all CoIs used the same tools for the CMT affordances evaluation, the grid template, that each of them could adapt according to their CMT approach by adding items to the grid template. According to the results summarized by each CoI, only the local CoI (not its corresponding CoI-pair) got involved in this phase. Each CoI selected the evaluators who later became members of the redesigners’ team of the c-book unit. Based on this evaluation, all CoI members could frame the particular changes and the aspects to change (based on their own approach) in the redesign of the c-book unit. The results related to this second phase can be found in section 3 of this report.

- **Phase 3**, focused on the process of redesigning the alien c-book unit, becoming the in-house resource. The two CoI-pair followed the same process: first, each CoI acted independently to produce a first version of the c-book unit to be redesigned, using an internal workspace for this first stage of redesign; second, as soon as an initial complete version of the redesigned c-book unit was ready, it was shared with the other CoI-pair members collaborating in its redesign. A new workspace was created in each c-book for this cross-CoI communication to facilitate the fluent communication among CoI-pair members working together to finish the c-book unit redesign. This phase ends with the final (global) version of the redesigned c-book unit.

- **Phase 4**, devoted to the final evaluation of the CMT potential of the redesigned c-book unit by evaluators from both CoI. They used the same grid template they had used in Phase 2, to facilitate the comparative analysis between both CMT evaluations. This rich analysis emerged in this last phase will be further extended in section 4 – D7.2.

### 2.4 Socio-technical infrastructure for supporting the cross-CoI communication

The main axes used to organise, moderate and support cross-communication and collaboration between CoI-pairs were:

- The creation of two new schools and c-books: the French-Spanish c-book and the Greek-UK one. In each, the translated versions of the two alien c-book units to adopt and redesign were joined. Members from both CoIs who participate in the redesign and/or evaluation had access to the corresponding c-book.
- The administration of the common c-book, with one moderator per CoI, facilitating the cross-communication between CoI-pairs.
- The creation of workspaces in the common schools for the *intra-CoI communication*. These were mainly used for phases 1, 2 and initial stage of phase 3 of the above described phases.
- The creation of shared workspaces for the *cross-CoI communication* mainly devoted to collecting comments and suggestions in the last stage of phase 3 of the redesign of the c-book units, and phase 4 with the final CMT evaluation.

### 3 The cross-case external CMT evaluation of the ‘alien’ c-book units

This section describes the common approach taken by all partners for evaluating the CMT potential of the alien c-book unit received.

Subsection 3.1 gives a detailed explanation of this approach. Subsection 3.2 includes the results from the corresponding analysis done by each partner of the alien c-book unit, as well as the lines of action on the redesign of each c-book unit decided by each partner. Finally, Subsection 3.3 reflects on the use of this
3.1 **Approach taken by the CoI-pairs for the external evaluation of CMT potential**

By the end of Cycle 2 of the WP6 the four CoI decided to agree on a common way of evaluation of the CMT potential, based on the different approaches followed by each partner in relation to the concept of Creativity, and how to measure its potentiality on a particular c-book unit. In this Deliverable we follow the same approach as in D6.3 (Trgalova et al., 2016). The resulting approach considers three main axes, which we present below.

The first axis (*Affordances*) is formed by 11 common features that may motivate CMT in users/students. The potentiality of each feature is graded in a 1-to-4 scale (where 1 means “strongly disagree” and 4 means “strongly agree”) by means of the four classical cognitive processes, that is, *Fluency* (generating quantities of ideas), *Flexibility* (creating different categories of ideas), *Originality* (generating new and unique ideas that others are not likely to generate), and *Elaboration* (redefining a problem to create others by changing one or more aspects). There was additionally an extra option called N/A in case a process was not applicable for the specific item. From now on, we will refer to these cognitive processes as *FFOE*.

The second and third axes deal with the social and affective aspects of the c-book unit that may improve CMT for c-book unit users. There are three different items to consider in each of them. These features are also graded in the same 1-to-4 scale. Evaluators are also invited to add, in any of the three axes of evaluation, any other feature that they think it must be considered in this specific c-book unit.

In Annex B one may find the grid containing the principles of the evaluation of the CMT potential.

3.2 **Analysis of the CMT affordances and decisions made on changes for the redesign of the c-book units**

**France: c-book unit Musical plane**

The French CoI organized an individual evaluation that produced a very heterogeneous result. With respect to the items considered in “Affordances”, they have added two more items (numbered 12 and 13) that may be found at the Appendix. The following graph (Figure 3.2.1) shows the evaluation of the cognitive aspects of CMT, where the height of the bars represents the mean value of each component (*FFOE*), while the thickness represents the mean between the four aspects for each question. Hence according to the reviewers, the c-book unit does not include half-baked constructs calling for intervention from students (item 13). On the contrary, the evaluators consider that the c-book unit includes constructions that require mathematical thinking from students (item 3) and there are chances to establish connections between different disciplines and mathematics (item 4).

![Musical Plane CMT Evaluation](image)
In addition, a general view of the graph tells that *Fluency* seems the lowest graded cognitive process in the whole c-book unit, while the other three are more balanced. This agrees with the respective means of each component (1.44 for *Fluency*, 2.12 for *Flexibility* and *Originality* and 2 for *Elaboration*). Hence, all components are in general in the range of “weak to good” affordances, but *Fluency*. With respect to this one, we should remark that in items 10 and 11 it has been highly graded (the reviewers admit stronger *Fluency* on generalising and applying Mathematics to problems based in reality). These valuations, together to the ones given to *Social* and *Affective Aspects*, are represented in Figure 3.2.2.

The radar graph here shows which aspect of CMT is most likely to be enhanced by the use of the c-book unit. We should underline here the potential to strongly impact on CMT of the *Affective Aspects* of the c-book unit, since it was the most graded one. On the other hand, *Social Aspects* seem to fail here, according to the reviewers.

Finally, the French CoI analysed the correlation between the four cognitive processes, but they turned out to be non-significant.

With respect to the technology added value of the c-book unit, the reviewers valuate the design as exploratory and experimental, especially regarding the Cinderella central widget of it. This applet let students make connections between music and mathematics, and also between a function formula and its graph. Moreover, the use of the widget in the structure if the c-book unit makes also students use their strategies to compose their pieces, which recalls the Elaboration component, and reflect on and self-evaluate own work. Without this kind of technology, it would not be possible to be able to develop Flexibility, Originality and Elaboration in the same way the c-book unit affords.
Decisions made for the redesign:

- Enhance fluency, and flexibility by means of:
  - Fluency: Compose more examples in order to build chords or a melody, Have all the half-tones (a very fine grained dodecaphonic musical plane).
  - Flexibility: Explain a melody with an algorithm, Work on straight line equations. Include problem posing.
- Foster originality and social aspects.
- Enable the users to elaborate think of symmetries and leaving affine functions.
- Use a narration as a guideline to keep the unity of the c-book unit.
- Compare the pixels of the screen to the squares of the musical plane.
- Enhance aesthetics aspects.
- Allow more feedback from the DME system by adding: check text answer box and small formula check answer box.

Spain: c-book unit Limits

The evaluation of the CMT potential of the c-book unit was done by four members of the Spanish CoI. The CMT potential evaluation grid was sent to them in .xlsx format. They were asked to fill it in independently with their grades and comments. In addition they were asked to inform the other evaluators if they wanted to consider additional items in any of the three sections of evaluation (actually they considered also items 12 and 13 from the grid, see Annex B). The Moderator collected the data (see Figure 3.2.4) did the corresponding analysis.

As in Del 6.3, in order to simplify it the Spanish CoI decided to cluster the affordances and make 5 different categories:

- Category 1: Openness, Versatility and Generalisation (items 1, 3, 9, 11)
- Category 2: ‘Problematisation’ (item 2, 12)
- Category 3: Connections (items 4, 5, 6)
- Category 4: Conjecturing and Exploration (items 7, 8, 13)
- Category 5: Validation and Evaluation (item 10)

With respect to the affordances, as one may see in Table 3.2.5, Elaboration is the highest graded in this c-book unit, with quite unanimous opinions on it. Regarding Fluency and Flexibility, the reviewers think they are weak affordance with more heterogeneous opinions about them. Finally, Originality is the weakest process, particularly never graded with a 4 in any item, quite unanimous opinions.
The boxplot graphs below shows an overview of these results. The thick bar represents the median in each boxplot, where one can appreciate the homogeneity/heterogeneity in the reviewers’ answers.

Table 3.2.7 contains the quantitative analysis regarding the 5 categories of the analysis of the Spanish CoI.

Focusing on the grades and comments of the reviewers, they disagree with the achievement of Openness, Versatility and Generalisation in the c-book unit. Nevertheless, some positive aspects stand out, as generalization or the possibility of creating problems for other students, but in general reviewers miss a more structured narrative of the unit and some novelty in the way the questions are stated. Problematisation is very unanimous graded low, due also to the lack of originality. About Connections, the reviewers value positively the ones between several representations of limits, but also think that this should be deeply enjoyed and not missing connections with other disciplines. With respect to Conjecturing and Exploration, they disagree on the extent to which it is present in the c-book unit, but highlight the potential of some of the widgets used for fostering exploration. Finally, Validation and Evaluation is the highly graded one, due to the fact that on the last phase students can check their knowledge and compare with the results of their partners several times.
Regarding *Social Aspects*, the reviewers agreed that the c-book unit fosters them (*Mean*=2.70, *Mdn*=3), but with quite heterogeneous opinions (*IQR*=2). The reviewers coincide strongly on the usefulness of the *EpsilonChat* widget in order to share their mathematical answers and develop their mathematical communication skills. With respect to *Affective Aspects*, the reviewers disagree about the items considered in the grid (*Mean*=1.92, *Mdn*=2), with quite unanimous opinions (*IQR*=1). They chiefly underline the lack of connections of the unit with everyday life, and agreed in exploring better more aesthetical possibilities of the c-book unit.

Finally, the Spanish CoI represented the CMT potential of the c-book unit in the radar chart of Figure 3.1.9.

*Decisions made for the redesign:*
Figure 3.2.10. Initial workspace for the re-design of the c-book unit “Limits”.

- Change the starting point of the unit, exchanging phases 1 and 2 of the original c-book unit.
- Keep phase 4 as an amusing activity, and extend it.
- Look for other challenges that can motivate students in the most repetitive phases (1 and 3).
- Keep Epsilon-writer widgets and improving them, if possible.
- Allow students to analyse the geometrical characteristics of the Pythagorean tree, and then construct it.
- Give more freedom to promote different solutions and strategies in some problems.
- Add other representations more intuitive for the students to work with the concept of infinity (functions).
- Improve connections with reality, motivating students to look for information about fractals, even in nature.
- Look for a general and also more explicit narrative of the unit, in order to link better the different phases of the c-book unit.
- Look for some more connections with reality that has to do with infinite processes (population dynamics in nature, for example).
- Add activities to reflect and summarize the mathematical work already developed.
- Improve the aesthetic aspect (with fractals, but also with more connections with real life showing the beauty of fractals, such as in art or in nature).
- Add suggestions or hints for students to motivate their creativity and not finishing always in the last page of the unit.
- In order to trigger CMT, find a balance between self-evaluation exercises and open exercises.

**Greece: c-book unit Generalisation**

The CMT potential evaluation grid was sent to a subgroup (four members) of the Greek CoI, mathematicians or members of the mathematics education community. Respondents (who actually will later redesign the c-book unit) were invited by email to use the grid to evaluate the UK c-book unit. The grid was filled individually as respondents were asked to avoid any private conversations about the c-book prior to their evaluation, so as to keep the evaluation based on their own perception without being influenced by their peers. They were also prompted to comment on each item to make explicit the reasons for their evaluation. It
is important to remark here that they have also considered items 12 and 13 in the Affordances section of the grid.

Regarding the FFOE affordances analysis, the frequencies of the grades collected for each one of the four cognitive processes can be seen in Figure 3.2.11.

![Figure 3.2.11. Frequencies of FFOE grades of the c-book unit “Generalisation”.

The results show that there was not unanimous decision about these cognitive processes. So, it seems that the CoI members do not agree that the c-book unit has the potential to foster Fluency, Flexibility, nor Originality ($Mdn=2$, $IQR=2$). However, this decision is not unanimous since the IQR is more than 1. They came up with the same decision in relation to the Elaboration process, but with more unanimous opinions ($Mdn=2$, $IQR=1$). This information is depicted in Figure 3.2.12.

![Figure 3.2.12. Box plot of the FFOE score of the c-book unit “Generalisation”.

Analysing the comments of the members of the Greek CoI, it seems that they emphasized the general absence of open problems (Item 1 problem posing (Item 2) as well as the absence of a call for constructing (Item 3). About the different connections, they find them to everyday activities but this is not crucial for coping with the tasks (Item 4), they are divided in their responses about the connected mathematical topics (Item 5). Besides, two of them appreciate the connection between Geometry/patterns and Algebra/operations and variables whereas the remaining two claim that this connection is rather superficial. The same holds for Item 6 of the interconnected representations. They appreciate the exploratory activity of Phidias (Item 7) and agree that the c-book unit asks students to make conjectures (Item 8). Even though the eXpresser widget is able to support multiple solutions (for certain activities) students are not encouraged to do that (Item 9). The c-book unit engages students in evaluation processes but in most of the cases this is about true/false questions (Item 10). Finally, all the CoI members agree that there is a call for generalization (actually this is
the main goal of the c-book) but they think that this aim is not strongly supported. The only exception is the invitation for obtaining abstract algebraic formulas (Item 11). Two of them consider that playing with patterns and finding rules is a kind of non-standard tasks whereas the remaining two claim that these are rather typical tasks (item 12). Finally, all of them agree that the Phidias activity (eXpresso) deals with half-baked constructs (item 13), but the questions that accompany the task do not engage students in its reconstruction.

Regarding Social Aspects, it seems to be the weakest point of the c-book unit. There is strong agreement between the CoI members that the c-book unit does not promote collaboration/cooperation (S1) between the students (Mdn=1, IQR=0.75). There is no explicit invitation for collaboration and it depends only on the teacher. The CoI members strongly disagree that the c-book unit promotes the mathematical communicative skills (S2) of the students (Mdn=1, IQR=1). Finally they almost disagree (in the middle of disagree and strongly disagree) (Mdn=1.5, IQR=1.5), that the c-book unit offers opportunities for competition since there is absence of suitable questions that would promote competition and therefore this is leaved on the teachers’ initiative.

Instead, Affective Aspects seem to be the strongest point of the c-book unit. The CoI members unanimously accepted that the c-book unit promotes engagement through the perception of the usefulness of mathematics (A1) (Mdn=3, IQR=0.25), by means of the connections between algebra and football and between geometric patterns and algebra. They also agree in the promotion of engagement through the generation of a feeling of pleasure/fun/challenge (A2) (Mdn=3, IQR=0.5), due to its well written, fun and playful narrative and also the use of eXpresso as a game task that incorporates mathematics. Finally, there is also agreement with the generation of a feeling of aesthetic pleasure from the contact with the mathematics concepts (A3) (Mdn=3, IQR=0) by means of the connection of mathematics with art/architecture and design in a meaningful way, and also the creation of patterns.

**Decisions made for the redesign:**

- In order to enhance multiplicity in the solutions and/or strategies the CoI members propose:
  - More open questions
  - Exploitation of the widget factories used (especially eXpresso) which can support multiple solutions.
- In order to enhance reflection on the mathematical work the CoI members propose to establish an interaction between the various activities.
- In order to enhance the engagement through a feeling of pleasure the CoI members propose to use narrative that is no so similar to the one used in mathematical textbooks.
- In order to enhance exploration and experimentation the CoI members propose to use more intriguing questions calling students to create their own patterns or design patterns that correspond to certain formulas. The affordances of eXpresso and ‘Algebra Arrows’ allow elaborating answers through experimentation.

**UK: c-book unit Windmills II**

The CMT potential evaluation grid was filled in by four members of the UK CoI. The grid was filled individually as respondents were asked to avoid any private conversations about the c-book prior to their evaluation, so as to keep the evaluation based on their own perception without being influenced by their
peers. Comments were also collected. Only the common elements were filled in by the respondents. Under the view of the English team, the fact that there were only 4 respondents makes mean, median, inter-quartile range, minimum or maximum not yield very relevant numbers. Nevertheless, for consistency, we add the metrics here:

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>IQR</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENCY</td>
<td>2.5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>2.8</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ORIGINALITY</td>
<td>2.5</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>2.6</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>SOCIAL ASPECTS</td>
<td>1.0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AFFECTIVE ASPECTS</td>
<td>3.1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

**Table 3.2.13.** Average, Median and Interquartile Range of the FFOE score of the c-book unit “Windmills II”.

Regarding Fluency, Flexibility, Originality and Elaboration (FFOE), the frequencies of all the collected judgements collected for each one of FFOE can be seen in the Figure below.

**Table 3.2.14.** Frequencies of FFOE grades of the c-book unit “Windmills II”.

The results show that there was not unanimous decision about these cognitive processes. The highest scoring aspect was that of ‘Elaboration’. Especially the item “(7) The c-book unit stimulates/encourages users’ exploratory activity and users’ experimentation.” scored high. The figure shows this as well with a relative high number of 4s for this aspect. It must also be noted that many respondents found it difficult to say something about fluency (see the number of N/A’s).

**Social Aspects** scored low or were not ‘applicable’. One illustrative comment said “There were not any indicative comments/questions of cooperation. I would imagine interaction between students would be done informally in terms of discussing difficulties encountered.” **Affective Aspects** items, however, scored higher, namely 3s and 4s. Some typical comments were “The activity promotes a challenge through its narrative and asking for help. The activities were engaging” and “The logo tasks encourage a perception of the aesthetic component of mathematics”. However, it was also noted that the open ended character might make it less “clear what the point was so this could be a bit boring for students.”

Overall, the c-book was seen as a very open and stimulating book, perhaps with less guidance than would be appropriate. The aim of the c-book was not always clear, partly caused by the narrative.

**Decisions made for the redesign:**

---

D7.2: Page 21 of 76
- Extend the *Geogebra* tasks to allow for more elaborate student answers, and originality.
- Page 1 might be more motivating if it was animated.
- Page 2 could include more explicit discussion (or questions) about differences in the structure of windmills especially that upcoming tasks require familiarity with the structure of a windmill.
- The page “There is a strong wind” could move to the beginning of the last chapter of the c-book (Don Quixote wind mill is operational) because it is more logical and talks about rotation of the blades.
- In page 5 of Hurt opponents: it was not clear whether the question involved constructing either the roof for the broken windmill or a new windmill. Also it wasn’t clear whether these dimensions reached are to be used for the next page to build the storage room.
- Perhaps since page 5 of Hurt opponents talks about constructing a cone shaped roof, maybe a question could be added about the materials needed to construct that roof and involves modelling of the cost/amount needed with the outer area of the cone.
- Having pictures which were not interactive was frustrating especially in the last chapter (Don Quixote’s wind mill is operational)
- Could add percentages/amount to the storage unit in page 6 in (Don Quixote’s wind mill is operational) and also the triangle drawn in the right
- There could be a more explicit space for student note taking and responses. This could allow also reviewing from them and the teachers.
- A question could consider the mathematical modelling limitations about the production in the wind mill (especially after Don Quixote windmill is operation page 6) i.e. what might limit the production rate?
- Explore problem posing around windmills.
- Adding objectives at the beginning of each chapter in the form of a question (like page 3 in windmills and constructions)
- Hints should be in appropriate places like near a question.
- Part 3 - Windmills and constructions. First page with movies is active and nice. Of course the movies are ‘recipes’. Second page origami paper. Nice idea, very nice component but not clear what to do. Interface ‘off’. Third page back to story. It is not clear what the chapters refer to?
- Part 4. The hurt opponents’ story seems a bit contrived and it is not clear what to do.
- Part 5. The goal of the *Geogebra* construction (to fix) is not clear.
- Some checking of solutions.
- Book might evaluate a formula of production or maybe a table (several representations). Can also add algebra arrows with cross-widget communication e.g. when you move time the rotors turn but also table filled for which you then try to find a formula.
4 Cross-case redesign and reconstruction of the ‘alien’ c-book units

This section focuses on the description of the cross-case redesign and reconstruction processes of the ‘alien’ c-book units. It includes comparison between the key characteristics of the two units, the original, and the redesigned one. This comparison allows placing the unit into the new local setting in terms of empirical and academic aspects.

The redesigned c-book units, produced by each CoI pair, are available in their java and the HTML5 versions in the following links:

<table>
<thead>
<tr>
<th>The musical plane</th>
<th>JAVA</th>
<th><a href="http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course">http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course</a> ViewNr=5701015772856320</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HTML5</td>
<td><a href="http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5701">http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5701</a> 015772856320</td>
</tr>
<tr>
<td>Limits</td>
<td>JAVA</td>
<td><a href="http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course">http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course</a> ViewNr=5673108786642944</td>
</tr>
<tr>
<td></td>
<td>HTML5</td>
<td><a href="http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5673">http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5673</a> 108786642944</td>
</tr>
<tr>
<td>Alice in PatternLand</td>
<td>JAVA</td>
<td><a href="http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course">http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course</a> ViewNr=5698001880219648</td>
</tr>
<tr>
<td></td>
<td>HTML5</td>
<td><a href="http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5698">http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5698</a> 001880219648</td>
</tr>
<tr>
<td>Windmills II</td>
<td>JAVA</td>
<td><a href="http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course">http://mc2dme.appspot.com:80/dwo/dwo.jsp?profile=78&amp;language=en&amp;course</a> ViewNr=5687962125729792</td>
</tr>
<tr>
<td></td>
<td>HTML5</td>
<td><a href="http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5687">http://mc2dme.appspot.com:80/mcs/tablet/DWOplayer.html?locale=en#c:5687</a> 962125729792</td>
</tr>
</tbody>
</table>

Table 4.1. Links to the redesigned c-book units.

More details about the redesigned c-book units may be found in the Annex of this deliverable.

4.1 Redesign of the c-book unit ‘Musical plane’ by the French CoI

The main mathematical content of this c-book is the study of the line and piecewise-defined linear functions, its elements and a variety of their representations. This content is related to music, representing points in a musical plane and analysing the influence of the elements of a line on its musical representation.

Now, the c-book unit Musical Plane is structured in three parts:

1) The main objective of part 1 is to get used to the musical plane and to find out its structure. The mathematical challenge is to define an appropriate way to identify points in the plane. There is an analogy between the Cartesian plane and the musical plane.

---

1 We should note that at the time of writing this document, all the c-books are complete and fully functional in Java, yet the HTML5 versions are under finalisation, due to technical matters.
2) The second part focuses on the understanding of a line with multiple representations such as the ones offered by the musical plane, the Cartesian plane or its algebraic representation. This part also links each of the elements of a line in the Cartesian plane (slope and y-intercept) with its musical interpretation.

3) The third part introduces different patterns one can find in a melody and its mathematical representation. Different piecewise-defined functions are studied and listened.

![Figure 4.1.1. First page of the phase 1 to the Musical plane c-book unit](image)

<table>
<thead>
<tr>
<th>Original c-book unit</th>
<th>Redesigned c-book unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disciplines / areas / theme and topic</strong></td>
<td><strong>Disciplines / areas / theme and topic</strong></td>
</tr>
<tr>
<td>Music and lines and piecewise-defined linear functions.</td>
<td>We have kept the topic of the c-book unit, which was music and math, but we have chosen to extend the musical and mathematical domains and to use some physics knowledge.</td>
</tr>
<tr>
<td><strong>School level and target audience</strong></td>
<td><strong>School level and target audience</strong></td>
</tr>
<tr>
<td>Grade 2 – 3</td>
<td>The target audience is 10 grade students instead of younger students.</td>
</tr>
<tr>
<td><strong>Disciplinary and cross-disciplinary learning goals</strong></td>
<td><strong>Disciplinary and cross-disciplinary learning goals</strong></td>
</tr>
<tr>
<td>- Cartesian coordinates.</td>
<td>- Cartesian coordinates.</td>
</tr>
<tr>
<td>- Linear equation (algebra and characteristics: slope and points of intersection of the function and the axes).</td>
<td>- Linear equation (algebra and characteristics: slope and points of intersection of the function and the axes).</td>
</tr>
<tr>
<td>- Piecewise-defined linear function (domain and</td>
<td>- Piecewise-defined linear function (domain and</td>
</tr>
</tbody>
</table>
- Piecewise-defined linear function (domain and intervals of definition).
- Algebra.

**Cross-disciplinary learning goals**
- Description of a melody.
- Different representations of points and functions (algebraic, graphical, musical, numerical values).
- Finding patterns and using the mathematical language to describe and interpret non-mathematical situations.

**Didactic and pedagogical settings**

The c-book unit allows formalizing mathematical contents that can be introduced along the units in order to improve students' vocabulary and expression and work deeper in the activities. So the c-book unit can alternate moments of students' independent work with other moments guided by the teacher offering more formal explanations. Many parts accept work in pairs/groups, while others are suitable to share and compare students' outputs.

The c-book unit is intended to be used in the classroom, under the orchestration of the teacher to work on coordinates, straight line equations with which students usually have difficulties and to introduce symmetries and translations in a playful way. We have added EpsilonChat in some pages to afford discussions, sharing and collaboration among the students and a game to enhance affective and social aspects. Feedback from the technical environment allows the students performing some tasks in autonomy.

**Table 4.1.2. Reconstruction of the Musical plane c-book unit.**

### 4.2 Redesign of the c-book unit ‘Limits’ by the Spanish CoI

The aim of this c-book unit is to give students a new and alternative way of learning mathematical calculations in a transversal view of the conception of infinity. For this purpose, dynamic tools in DME are essential in order to attract the attention of the students and showing then the pleasure of solving mathematical problems using the artistic approach of Fractals and working in cooperative teams. Now, the c-book unit is organised in four phases: the first and second ones show two different approaches of the idea of infinity; the third phase (assisting calculators, dynamic graphics and intelligent coloured tables), give an innovative way to understand the calculation of polynomial and rational functions; the last phase invites students to have fun challenging their skills in a contest.

**Re-contextualization of the c-book unit:**

Based on this previous analysis, the moderator of this phase proposed some features of the unit to evaluate and improve. In order to agree with the improvable aspects, to collect new ideas for the redesign, and to identify strong and weak points, the members of the CoI interacted in the CoI Code workspace. Some ideas that arose from this process are listed below:

— Changing the starting point of the unit, exchanging phases 1 and 2 of the original c-book unit.
— Keeping phase 4 as an amusing activity, and extend it.
— Looking for other challenges that can motivate students in the most repetitive phases (1 and 3).
— Keeping Epsilon-writer widgets and improving them, if possible.

Figure 4.2.1. First page of Phase 1, “The Pythagorean tree”, to the *Limits* c-book unit.

— Allowing students to analyse the geometrical characteristics of the Pythagorean tree, and then construct it.
— Giving more freedom to promote different solutions and strategies in some problems.
— Adding other more intuitive representations for the students to work with the concept of infinity (functions).
— Improving connections with reality, motivating students to look for information about fractals, even in nature.
— Looking for a general, and also, more explicit narrative of the unit, in order to link better the different phases of the c-book unit.
— Looking for some more connections with reality, having to do with infinite processes (population dynamics in nature, for example).
— Adding activities to reflect and summarize the mathematical work already developed.
— Improving the aesthetic aspect (with fractals, but also with more connections with real life), showing the beauty of fractals, such as in art or in nature.
— Adding suggestions or hints for students to motivate their creativity and not finishing always in the last page of the unit.
— In order to trigger CMT, trying to find a balance between self-evaluation exercises and open exercises.

The table below shows the characteristics that the redesigned c-book unit should eventually have in mind:

<table>
<thead>
<tr>
<th>Original c-book unit</th>
<th>Redesigned c-book unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disciplines / areas / theme and topic</td>
<td>Disciplines / areas / theme and topic</td>
</tr>
<tr>
<td>Original c-book unit</td>
<td>Redesigned c-book unit</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------------------</td>
</tr>
</tbody>
</table>
| Notion of infinity through equations, Geometric Sequence and Limits of real functions. | Extension, and more connection, of areas, themes and topics covered in the c-book unit:  
*Phase 1*, main focus on Fractals, use of Geometric sequences as models of Fractals structures;  
*Phase 2* about Equations, their finite of infinite number of solutions,  
*Phase 3* based on polynomial and exponential functions and the limits calculation of polynomial and rational functions |

**School level and target audience**

Secondary school, technical school or university (17-20 years old students)  
The content of the c-book unit could be implemented in Secondary school level, according to Spanish curricula. More concretely, Phase 1 and Phase 2 are designed for 15-16 years old students, while Phase 3 and Phase 4 should be addressed to higher school (as the original c-book unit).

**Disciplinary and cross-disciplinary learning goals**

**Disciplinary learning goals:**
Give sense to the notion of infinity and to limits in calculus.

**Cross-disciplinary learning goals:**
Develop communication skills.

**Disciplinary learning goals:**
The redesigned c-book unit should be focused on providing students new and alternative ways of learning using mathematical advanced notions (as limits, solutions of an equation, graphical techniques to discuss equation, etc.), most of them included in the curricula of Secondary school level. In particular, the team identified the following disciplinary learning goals:
- Identify geometrical figures in a fractals,
- Understand the infinity concept and be able to value different sizes of infinities,
- Recognize geometric progressions and calculate their common ratios,
- Analyse the convergence and divergence of geometrical series,
- Identify the relation between parameters and number of solutions in an equation,
- Solve equations through graphical techniques,
- Compare graphical, numerical and analytical methods to solve limits

**Cross-disciplinary learning goals:**
The main cross-disciplinary learning goal is to address some advanced mathematical contents to be used to understand and model patterns of behaviour and of tendency in the infinity. Among others to:
- Urge students to investigate a question that has to do with fractals, with cell phone password (e.g. the problem of the 9 points), etc.
- Engage students in recognizing patterns in the process of
Original c-book unit | Redesigned c-book unit
---|---
mathematisation of a real problem (cell phone security codes, fractals structures in nature, etc.) and in using the corresponding mathematical relations to check the truth of a suggestion or conjecture in its context. Good examples of this can be found in phase 1 or at the beginning of phase 2.
- Appreciate the beauty of fractals, and see the influence of mathematics in these artworks
- Recognize the infinity concept in real situations.

<table>
<thead>
<tr>
<th>Didactic and pedagogical settings</th>
</tr>
</thead>
</table>
As the French CoI explain (wp6-cycle 2), the c-book unit *Limits* is supposed to be used by the students in a classroom, which means that it should be orchestrated by a teacher. The students interact with the c-book individually in order to anticipate the answers to the questions and make conjectures and they are then invited to discuss their conjectures in small groups, mostly through EpsilonChat. The teacher has to foresee at which moments whole class discussions would the most appropriate for discussing the students’ procedures, validating their conjectures and institutionalizing the learning outcomes.

Both modalities, in and out of classroom work, are suggested for this c-book unit. The ideal organisation would be a team of 3-4 persons. The teacher participates to guide and orchestrate the activity, but students are asked to study questions by themselves, to deliver and report their own work and, up to some point, to debate and discuss with other their conjectures and answers. It could be done by EpsilonChat widgets or in a face-to-face session, according to teacher(s)’s criteria on which would be the most appropriate moment for a whole class discussion. Parts of the c-book unit can be implemented in the Computer Lab, other parts can be implemented in classroom. Finally, there are parts (for example phase 4, the limits’ game) that can be addressed either individually or in groups, in school or at home. It would be also important to show that some activities could be implemented and extended at different school level. For instance, students in lower Secondary school level (14-16) could also approach a simpler version of the problems included and the corresponding concepts through an appropriate teacher’s design. Or, the same c-book unit could be easily extended and implemented in first-year courses at university level.

| Table 4.2.2. Reconstruction of the *Limits* c-book unit. |

### 4.3 Redesign of the c-book unit ‘Generalization’ by the Greek CoI

The storyline of this c-book unit is inspired from the famous fantasy novel ‘Alice’s Adventures in Wonderland’ written by Lewis Carrol (a pseudonym of Charles Lutwidge Dodgson). In our story a girl named Alice is falling through a rabbit hole into a fantasy world filled with Patterns. In this world she meets a smiling cat that speaks like a human, a sculptor named Mr. Phidias and Manny, the local handy man. Each one of these characters is connected to pattern-related challenge. The narrative aims to motivate the reader to work with Alice in her efforts to answer the cat’s questions and help Mr. Phidias and Manny. The tasks she encounters are related with patterns, but in a variety of ways. As the reader goes back and forth between images/dynamic icons of patterns to algebraic formulas and functions, he/she makes connections between
different representations of them and uses mathematics to accomplish the challenges that emerge between the lines.

**Figure 4.3.1.** Introduction to the *Alice in Patternland* c-book unit.

### Re-contextualization of the c-book unit:

The redesign of this c-book unit did not come as a result of a total re-contextualization. The Greek CoI members decided to keep many aspects of the initial design as fulfilling the aim of the c-book unit in a satisfying manner.

<table>
<thead>
<tr>
<th>Original c-book unit</th>
<th>Redesigned c-book unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disciplines / areas / theme and topic</strong></td>
<td><strong>Disciplines / areas / theme and topic</strong></td>
</tr>
<tr>
<td>Arithmetical expressions, the concept of variable, and the concept of function as a relationship that uniquely associates members of one set with members of another set.</td>
<td>Geometric patterns area added as well as the usage of graphs for certain functions. Therefore we broadened the disciplinary view of the c-book unit by including Geometry in co-existence with Algebra.</td>
</tr>
<tr>
<td><strong>School level and target audience</strong></td>
<td><strong>School level and target audience</strong></td>
</tr>
<tr>
<td>Pupils on beginning secondary school (11 to 12 years old), potentially late primary especially towards the end of the year as an introduction to algebra.</td>
<td>Secondary school: Grade-8 to Grade-9 as well as upper primary school grades during their introduction to algebra.</td>
</tr>
<tr>
<td><strong>Disciplinary and cross-disciplinary learning goals</strong></td>
<td><strong>Disciplinary and cross-disciplinary learning goals</strong></td>
</tr>
<tr>
<td><strong>Disciplinary learning goals:</strong></td>
<td><strong>Disciplinary learning goals:</strong></td>
</tr>
<tr>
<td>- Learn to find general rules for any term in a figural sequence,</td>
<td>- Deconstruct the pictorial representations of a pattern to its structural units.</td>
</tr>
<tr>
<td>- Identify and distinguish between constants and variables,</td>
<td>- Translating the patterns to symbolic representation, using variables.</td>
</tr>
<tr>
<td>- Learn to focus on the structure of a pattern to derive a general rule,</td>
<td>- Use algebraic formulae to answer questions that refer to a specific patterns’ pictorial representation.</td>
</tr>
<tr>
<td>- Appreciate the limitation of “pattern-</td>
<td>- Find relations between variables representing the</td>
</tr>
</tbody>
</table>
spotting’ techniques (i.e. deriving rules based on the numbers of the sequence rather than its structure),
- Use justification strategies to discuss the correctness and equivalence of general rules.

Cross-disciplinary learning goals:
- Algebraic ways of thinking
- The book has an underlying narrative that attempts to provide a rationale to the need for algebra in different situations but also as an important thinking skill.
- The CoI considered an underlying narrative in two different contexts financial and sports but have just only introduced them at the beginning leaving the book open to interpretation or for different versions subject to further development.

Cross-disciplinary learning goals:
- The connection of algebra to everyday situations (patterns as convenient ways to predict and calculate)
- Connection of Algebra with literature (Alice in wonderland as an inspiration), art and architecture (Parthenon and its frieze)

<table>
<thead>
<tr>
<th>Original c-book unit</th>
<th>Redesigned c-book unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>spotting’ techniques (i.e. deriving rules based only on the numbers of the sequence rather than its structure), Use justification strategies to discuss the correctness and equivalence of general rules.</td>
<td>structural principles of a pattern and use them in order to simplify the relevant algebraic formula. - Use different representations of a function (iconic, graphical and algebraic). - Use the concept of angle as a change of direction between two repeated instances of the same geometrical structure</td>
</tr>
</tbody>
</table>

**Didactic and pedagogical settings**

The UK CoI suggested a blended approach. Classroom familiarisation, then homework with plenary discussions in classroom, storing the students’ work and encouraging them to make connections between pages.

We see the redesigned c-book unit mainly used in the computer lab, by groups of students in order to enhance the notion of multiplicity of algebraic expressions that may be identified by some students. At the same time, the whole content was disconnected from its initial ‘curriculum’ approach that was a main criterion for the UK CoI. We choose to work on the theme and combine as many mathematical ideas as possible around the theme.

Table 4.3.2. Reconstruction of the Generalisation v.2 c-book unit.

### 4.4 Redesign of the c-book unit ‘Windmills II’ by the UK CoI

The c-book follows the same structure as the Windmills II version as it was offered for ‘redesign’. The final redesigned version had the five parts bellow:

1. Don Quixote and the windmills (2 pages)
2. There’s a strong wind… (1 page)
3. Windmills and constructions (4 pages)
4. Charge and build (7 pages)
5. Don Quixote’s windmill is operational! (6 pages)

**Re-contextualization of the c-book unit:**

We would summarise our redesign process as follows:

---We changed the layout significantly.
---We reduced the text for the narrative, but tried to keep the story in place, for example by using a video in the beginning.
— We tried to replace or add some new widgets (e.g. the JavaLogo widget) as alternative for other widgets.

![Image](image.png)

Figure 4.2.1. Detail of Introduction (example of movie) to the *Windmills II* c-book unit.

— We tried to make the tasks more interactive, with answer checking and feedback.

— We added a page authored with the WP5 authoring tool for feedback on exploratory activities (AuthELO) like the Geogebra one on page 6 that asks students to reconstruct the windmill.

— Every location where drag elements or text boxes with feedback could be added, we wanted to add them. Of course, this is only possible when the socio-technical environment allows you to do that.

<table>
<thead>
<tr>
<th>Original c-book unit</th>
<th>Redesigned c-book unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disciplines / areas / theme and topic</strong></td>
<td>This c-book unit takes the narrative of Don Quixote to deal with several topics concerning windmills e.g. rate of production, revolutions of blades etc.</td>
</tr>
<tr>
<td>• Algebra: Direct proportional amounts, functions and graphs on Cartesian plane: linear, quadratic, trigonometric and multi-branch functions; Rate of change; Trigonometric numbers and relations.</td>
<td>The theme and topic stayed the same of the original c-book unit but the wording and focus of some activities was changed slightly so it fits in existing curricular elements in the UK. However, it felt a bit strange to completely change the narrative, so we kept that, even though some evaluators commented on the challenges of a narrative for the English context.</td>
</tr>
</tbody>
</table>

| **School level and target audience** | |
| The present c-book unit was designed with the aim to deal with several topics concerning windmills e.g. rate of production, revolutions of blades etc. | It seems that in the UK the topic of windmills (or |
Disciplinary and cross-disciplinary learning goals

Disciplinary learning goals
The main aim underlying the design of this c-book unit is to facilitate students to identify, explore and use mathematical concepts and relations behind the construction and operation of Windmills. The vehicle for attracting the students’ interest and fostering the development of their creative mathematical thinking is the combination of a new (different from the one conceived for Windmills I of 1st cycle) and more fascinating narrative for Windmills II. Through this new concept and underlying pedagogical principles the students are expected to get engaged with investigating windmills’ shapes and the function. To this end, both ‘constructionist’ and ‘de-constructionist’ activities were designed and included.

In ‘constructionist’ activities, the students are expected to create parts of a windmill such as their sails and their wheel. The students will be asked to construct logo codes in Turtleworlds or make half-baked logo codes to work (by modifying or completing them), in order to represent geometric figures. Through this process the students are anticipated to explore, discover and use angular and side properties of these figures and broaden their conceptual fields regarding the corresponding notions (isosceles and equilateral triangle, parallelograms, regular polygons). The repetition of a geometrical figure in conjunction with the possibility of rotating it with the use of the variation tool of Turtleworlds is anticipated to develop students’ understandings around more complicated mathematical concepts/properties, such as rotational rather, the mathematical context we think we envisaged) might be aimed at an older target audience, probably end year 11 or even A-level. As the original c-book encompassed many different topics related to windmills, we expect that the target audience could be quite broad.

We expect this c-book to be particularly useful for lower secondary school.
symmetry, which is in the border of the formal Greek curriculum. There are also ‘constructionist’ activities in which students have to build in 3d space, using the DME widget “Drawing in space”. Here, the goal is to help students to develop their spatial abilities.

In ‘de-constructionist’ activities, the students are expected to experiment with models in Geogebra, representing the windmill’s operation as evolved in time. The observation of the model in conjunction with the use of the available tools is expected to help students to discover functional relations, such as linear, quadratic and trigonometric, as well as their combination in multi-branch functions. There are also activities that engage students in completing a model of a ruined windmill. Here the goal is to help students think, recognize and use properties of solid shapes (cylinders, cones, cuboids) in order to represent them in the 2d plane, developing thus their spatial skills. Another goal is the perception of a solid shape as resulting from the turn of a plane shape in 3d space.

Cross-disciplinary learning goals

From an environmental education perspective, the goal is to introduce the idea of alternative energy sources to the students and stir reflection on how dependent modern people and societies are on conventional energy sources, having a major role in current environmental pollution and global warming, although nature provides us with many inexpensive and renewable energy resources to exploit with minimal environmental burden. Students will also realize the importance in using local environmental resources and the advantage of identifying and learning from traditional wisdom and practice (i.e. local architecture and previous generations everyday practices).

Cross-disciplinary learning goals

The working of windmills, and the role they might play in society.

Didactic and pedagogical settings

This c-book unit includes activities, which can be implemented both inside and outside the classroom. For example, the activities with the use of Turtleworlds could be implemented in the school lab, where the students can work in groups of two. Alternatively, the exploration of the model in

The didactical/pedagogical setting has stayed the same. The c-book can be used both in the classroom and individual setting. However, it is expected that some framing from a teacher will be needed.
Geogebra can be implemented with the use of the interactive board of the classroom, in which a student can move the sliders, while the other students jointly observe, discuss and write their findings in the worksheet. The teacher can make use of parts of this c-book unit to introduce new concepts, or to apply a concept in different contexts, or to connect concepts from different subject domains. For example, the exploration of the model in Geogebra can be used for the introduction of the concept of multiple-branch functions. This c-book unit could also be used as supporting material in a wider project on the theme of windmills.

<table>
<thead>
<tr>
<th>Table 4.4.2.</th>
<th>Reconstruction of the <em>Windmills II</em> c-book unit.</th>
</tr>
</thead>
</table>

D7.2: Page 34 of 76
5 Cross-case evaluation of the CMT potential of the redesigned c-book units

This section deals with the evaluation of the CMT potential of the four c-book units that were redesigned by the four CoI-related research teams. In previous phases of the project, it has been recognised the importance of CoI-pair work at the time of evaluating the CMT representations of the CoI-pair teams once they have been operationalized in the redesign (Papadopoulos et al., 2015), and the importance of the ‘design context’ on the task design process of the redesigned c-book units (Barquero et al., 2016)

After the redesign, each new c-book unit was again evaluated in relation to its CMT affordances using the common grid (see Annex B) as the evaluation tool. Members from both CoI (primary and secondary designers) formed the group of evaluators.

For the sake of objectivity and enrichment of the analysis of the CMT potential of each c-book unit, the CoI’s agreed on trying to select (if possible) reviewers that had not participated in the redesign of the c-book unit. In the case of the French-Spanish CoI pair the reviewers did not participate in the process of redesign of the c-book unit. In the case of the Greek-English CoI pair, one reviewer (out of four) of the Greek CoI and four (out of seven) from the UK CoI did not participate in the redesign process.

The results of this evaluation are presented in section 5.1, while section 5.2 is devoted to a comparative analysis between the corresponding CMT potential evaluations of each c-book unit before and after its redesign.

5.1 Results of the evaluation of the CMT potential of the redesigned c-book unit

5.1.1 French-Spanish CoI pair: Evaluation of the redesigned c-book unit Musical plane

The analysis was done by 4 members, 2 from the Spanish CoI and 2 of the French CoI, who were involved neither in the design nor in the redesign. The analysis was done independently by all the reviewers by means of a Google survey, and the Moderator collected the data to make the analysis presented below.

The quantitative analysis of the CMT potential of the redesigned c-book unit gives the following statistical measures:

<table>
<thead>
<tr>
<th></th>
<th>FLU</th>
<th>FLE</th>
<th>ORI</th>
<th>ELA</th>
<th>SOCIAL</th>
<th>AFFECTIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.40</td>
<td>3.19</td>
<td>3.57</td>
<td>3.51</td>
<td>3.41</td>
<td>3.58</td>
</tr>
</tbody>
</table>

*Table 5.1.1.1. Quantitative analysis of the CMT potential of the c-book unit “Musical Plane”.*

Regarding the affordances, the results of the four cognitive processes are almost uniformly distributed among the items, as one may observe in Figure 5.1.1.2 (the height of the bars represents the distribution of the FFOE components for each item while the thickness represents the mean between the four aspects for each question).
As for the correlation among the four cognitive components of CMT, the following table shows that there is strong correlation among three of the cognitive aspects. It means that if the c-book unit can foster one of the cognitive components, it can most likely enhance the other two as well. This appears as positive, since all values are higher than 0.70, but for the pair Originality-Elaboration.

<table>
<thead>
<tr>
<th></th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Elaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluency</td>
<td>1.00</td>
<td>0.83</td>
<td>0.82</td>
<td>0.78</td>
</tr>
<tr>
<td>Flexibility</td>
<td>0.83</td>
<td>1.00</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td>Originality</td>
<td>0.82</td>
<td>0.84</td>
<td>1.00</td>
<td>0.61</td>
</tr>
<tr>
<td>Elaboration</td>
<td>0.78</td>
<td>0.78</td>
<td>0.61</td>
<td>1.00</td>
</tr>
</tbody>
</table>

In conclusion, the evaluation of the CMT affordances based on the quantitative data shows affordances that enhance the cognitive aspects of CMT (especially Originality) in the new c-book unit, allowing students to develop new ideas, solutions to mathematical problems or challenges. On the Affective side, the c-book achieved a high value. There are no comments giving a justification to the high evaluation of Affective aspects (3.58), but an overview on the comments during the redesign may make us think that the reviewers valued the aesthetics as well as the challenge spirit of the c-book unit. However, the following sections present the qualitative evaluation, in which evaluators gave their feedback on each aspect. The radar chart in Figure 5.1.1.3 shows the distribution of the evaluation among the categories.
Table 5.1.1.3. Radar chart of the CMT potential of the c-book unit “Musical Plane”.

5.1.2 Spanish-French CoI pair: Evaluation of the redesigned c-book unit *Limits*

The evaluation of the CMT potential of the c-book unit was done by five reviewers, three from the Spanish CoI and two from the French CoI, who were involved, neither in the design nor in the redesign. The grid of the CMT potential evaluation was sent to each reviewer; they filled it in independently and sent it to the Moderator, who did the analysis below.

In order to organize a qualitative analysis of the evaluation of these items, the Spanish CoI decided to gather the affordances evaluated into 5 different categories, presented also here in Section 3.2. The quantitative analysis of the CMT potential of the redesigned c-book unit gives the following statistical measures:

<table>
<thead>
<tr>
<th>Affordances</th>
<th>Mean</th>
<th>Median</th>
<th>IQR</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENCY</td>
<td>2.88</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>3.08</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ORIGINALITY</td>
<td>2.64</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>3.07</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>SOCIAL ASPECTS</td>
<td>3.50</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>AFFECTIVE ASPECTS</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5.1.2.1. Quantitative analysis of the CMT potential of the c-book unit “Limits”.

Regarding the Affordances, the reviewers agreed that the four processes are enhanced by the c-book unit (*Mdn*=3). Flexibility and Elaboration have been slightly higher evaluated than the other two, and the opinions on Originality and Elaboration are more homogenous, but also with a significant level of disagreement with the presence of it in the C-book unit (*Mean*=2.64). This analysis may be represented in Figure 5.1.2.2 by the corresponding box plots.
Focusing on the grades and comments of the reviewers, they think that *Validation and Evaluation* (Category 5) are the strongest features of the c-unit (*Mean* = 3.81, *Mdn* = 4), with a very homogeneous opinion about it (*IQR*=0), due to the many occasions along the c-book unit in which students have to reflect about the knowledge and summarize their work. Nevertheless, they miss different ways of validating their conjectures. *Connections* (Category 3) have been also highly graded (*Mean* = 2.92, *Mdn* = 3) but the value was not homogenous for all the items (*IQR* = 2). Here the reviewers highlight the intra-mathematical connections between several mathematical contents but, unfortunately, they find a lack of connections with extra-mathematical areas. Likewise, *Openness, Versatility and Generalisation* (Category 1) has a high grade (*Mean* = 2.90, *Mdn* = 3) but more heterogeneous opinions (*IQR* = 2). Actually, in this case the positive comments refer to *Versatility* and *Generalisation*, and the negative ones to *Openness*, since only in a few cases the activities have more than one right solution or students could choose more than one strategy to find the way to answer the questions. The reviewers agree that the c-book unit provides opportunities to students of *Conjecturing and Exploring* (Category 4) along the c-book unit (*Mean* = 2.84, *Mdn* = 3, *IQR* = 1) thanks to the technology added value, since several interactive widgets are included along the unit. Finally, *Problematisation* (Category 2) is the lower graded category (*Mean* = 2.63, *Mdn* = 3), since they find a lack of problem posing and the only one non-standard problem in the unit is “the Pythagorean tree”.

About *Social Aspects*, reviewers strongly agree that the c-book unit fosters them (*Mdn*=4, *Mean*=3.50), with quite unanimous opinions (*IQR*=1). The reviewers underlined the interaction of the students as one of the strongest features of the c-book unit, especially through the *EpsilonChat* widget. Besides, students are encouraged to use a new terminology but the reviewers miss some feedback to stimulate the acquisition of new communicative skills. With respect to competitiveness, it is underlined the potentiality of the last phase for it.

Regarding *Affective Aspects*, the reviewers agreed that the items considered in the grid (*Mean*=3, *Mdn*=3) are fostered by the c-book unit, without a strong consensus (*IQR*=2). They complained about the lack of explicit connections of the contents of the unit with everyday life, although they appreciated the aesthetical design of the unit and the potentiality of several activities (Pythagorean tree, 9 dots challenge, game activities…) to stimulate students.
Finally the Spanish CoI represents the CMT potential of the c-book unit in the radar chart in Figure 5.1.2.4.

![Box plot of Social and Affective aspects.](image)

**Figure 5.1.2.3.** Box plot of Social and Affective aspects.

Figure 5.1.2.4. Radar chart of the CMT potential evaluation of the c-book unit “Limits”.

### 5.1.3 Greece-UK CoI-pair: Evaluation of the redesigned c-book unit *Alice in Pattern-Land*

The evaluation was done independently by four members of the Greek CoI and seven members of the UK CoI. The quantitative analysis of the CMT potential of the redesigned c-book unit gives the following statistical measures:

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>IQR</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENCY</td>
<td>2.75</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>2.77</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ORIGINALITY</td>
<td>2.73</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>2.78</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>SOCIAL ASPECTS</td>
<td>2.2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>AFFECTIVE ASPECTS</td>
<td>3.37</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

*Table 5.1.3.1. Quantitative analysis of the CMT potential of the c-book unit “Alice in Pattern-Land”.*

Regarding the *Affordances*, the frequencies of the grades collected for each one of the four cognitive processes are represented in Figure 5.1.3.1. In addition Figure 5.1.3.2 contains the corresponding box plot of each cognitive process.
According to the comments of the reviewers this new version of the c-book unit includes open problems that are “original and interesting” and that “it is possible for students to elaborate further”, as the construction of geometric patterns using Turtleworld or eXpresser (Item-1). All but one noticed the absence of problem posing (Item-2) activities yet there are some chances in the open-ended questions. The aspect of construction (Item-3) is enhanced especially in the ‘Helping Phidias’ activity. All the CoI members appreciated the interdisciplinary connections of mathematics with decoration, programming, literature and their ‘real-life application’ (Item-4). They also emphasized the connection between various mathematical topics such as “patterns and functions”, “algebra and geometry”, “algebraic concepts and other aspects of number operations”, “visual pattern and numbers”, as well as other connections that appear in the ‘Helping Manny’ task (Item-5). Equally important they found the co-existence of multiple and interconnected representations within the same page by means of the technology added in the c-book unit, as the combination of Algebra Arrows with dynamic manipulated patterns in Cinderella in ‘Smiling Faces’ and the opportunity to combine symbolic with graphical representations in ‘Helping Manny’ (Item-6). The c-book unit fosters an exploratory attitude yet this is an aspect the book could be improved further (Item-7). At the same time students are encouraged to form and check conjectures by means of textboxes inviting students to write down their ideas and some instant feedback to correct their incorrect answers (Item-8). As far as the issue of multiple solutions is concerned the CoI members think that there is more potential for this since it is not explicit in the tasks, for example in ‘Smiling Faces’ or ‘Helping Phidias’ (Item-9). There are very often prompts that encourage students to use textboxes for reflection (Item-10). Item-11 is the core item for this specific c-book unit, so it is highly valued by the reviewers.

The Greek research team added Items 12 and 13 to the evaluation. About Item-12 the reviewers agree that the problems are non-standard at least in the conceptual field of patterns, as well as the way they are posed. The last item deals with the presence of half-baked constructs, that may be found in ‘Helping Phidias’, for example.
Social Aspects still remains its weak point. There is strong agreement between the CoI members that the c-book unit does not promote collaboration/cooperation (S1) between the students \( (Mdn=1.5, IQR=1) \). However, the CoI members rated higher the aspect concerning the call (and promotion) for mathematical communicative skills (S2) of the students \( (Mdn=3, IQR=1) \). The students are asked to write formulas and express their mathematical ideas in terms of Logo code, as well as some reasoning encourage them to write in a mathematical language. Finally, they rather disagree \( (Mdn=2, IQR=1.75) \), that the c-book unit offers opportunities for competition by the lack of suitable questions, although they think there are chances for creating a level of competition.

Instead, Affective Aspects seems to be the strongest point of the c-book unit. The CoI members unanimously accepted that the c-book unit promotes the perception of the usefulness of mathematics (A1) \( (Mdn=3, IQR=0) \), by means of the questions related to Design and Architecture; it promotes also the generation of a feeling of pleasure/fun/challenge (A2) \( (Mdn=4, IQR=1) \), based on the originality of the narrative and the widgets itself; and also through the generation of a feeling of aesthetic pleasure (A3) \( (Mdn=3, IQR=1) \), defined as “the strength” of the c-book unit.

### 5.1.4 UK-Greece CoI-pair: Evaluation of the redesigned c-book unit *Windmills II*

The evaluation was done independently by four members of both Greek and UK CoI.

The quantitative analysis of the CMT potential of the redesigned c-book unit gives the following statistical measures although, as we said in Section 3.2, does not considered representative by the UK CoI.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>IQR</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLUENCY</td>
<td>2.9</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>3.0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ORIGINALITY</td>
<td>3.0</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>2.9</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>SOCIAL ASPECTS</td>
<td>2.2</td>
<td>2.5</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>AFFECTIVE ASPECTS</td>
<td>3.5</td>
<td>3.5</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

*Table 5.1.4.1. Quantitative analysis of the CMT potential of the c-book unit “Windmills II”.*

Regarding the Affordances, the frequencies of the grades collected for each one of the four cognitive processes are represented in Figure 5.1.4.2.

![Figure 5.1.4.2. Bar chart of FFOE scores of the c-book unit “Windmills II”](image)

The results show that there was not unanimous decision about these cognitive processes, but there is a balance in the scores for the four dimensions. This also was apparent from the table with all scoring around a
3 on average now. The highest scoring item again was “(7) The c-book unit stimulates/encourages users’ exploratory activity and users’ experimentation”, with “(3) The c-book unit includes calling for students’ / users’ constructions that call for mathematical thinking.” scoring just below.

Social Aspects still scored relatively low or ‘not applicable’. Upon qualitative analysis of the comments it, however, was not really clear why the scores were higher this time, as the substantive comments on the whole still expressed the opinion the c-book unit did not do much for the social component. Affective Aspects are scored higher now, namely 3s and 4s. The comments seemed to indicate that the redesign had managed to integrate the originally somewhat disjointed story with the activities in a more meaningful and successful way. In addition, the visual appeal of the c-book seemed improved.

### 5.2 Comparative analysis on the results of the evaluation of the CMT potential of the alien c-book unit versus the redesigned c-book unit

All the CoI’s initially expected an improvement of the CMT potential of the redesigned unit with respect to the original design. Since the analysis of both of them has been done using common criteria, a comparison of these analyses makes sense for this last phase of WP7.

In the case of the c-book unit “Musical Plane”, initially designed by the Spanish CoI and then redesigned by the French CoI, a visual comparison may come from the corresponding radar graphs, below in Figure 5.2.1.

![Radar chart of the original design (done in WP6, left) and the redesign (done in WP7, right) of the CMT potential evaluation of the c-book unit “Musical Plane”](image)

Figure 5.2.1. Radar chart of the original design (done in WP6, left) and the redesign (done in WP7, right) of the CMT potential evaluation of the c-book unit “Musical Plane”.

In order to understand the graph properly one may focus on the scales of each of them to conclude that there was an improvement in all components, mainly in Social Aspects (2.91 in average) and Fluency (1.96 in average). Moreover, the shape of the graph changed, showing that in the original design, Flexibility and Originality were the cognitive components most enhanced, whereas in the redesigned version, Flexibility enhancement has the lowest increase compared to the other components (0.73 in average, the only improvement less than 1). One may check the means of each category in Table 5.2.2.

<table>
<thead>
<tr>
<th>Components</th>
<th>Original version (mean)</th>
<th>Redesigned version (mean)</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluency</td>
<td>1.44</td>
<td>3.40</td>
<td>1.96</td>
</tr>
<tr>
<td>Flexibility</td>
<td>2.46</td>
<td>3.19</td>
<td>0.73</td>
</tr>
<tr>
<td>Originality</td>
<td>2.11</td>
<td>3.57</td>
<td>1.46</td>
</tr>
<tr>
<td>Elaboration</td>
<td>2</td>
<td>3.51</td>
<td>1.51</td>
</tr>
<tr>
<td>Social</td>
<td>0.5</td>
<td>3.41</td>
<td>2.91</td>
</tr>
</tbody>
</table>
Table 5.2.2. Table of means of the original design and the redesign of the CMT potential evaluation of the c-book unit “Musical Plane”.

<table>
<thead>
<tr>
<th>Affective</th>
<th>2.41</th>
<th>3.58</th>
<th>1.17</th>
</tr>
</thead>
</table>

Regarding the c-book unit “Limits”, original from the French CoI and redesigned by the Spanish CoI, we may use the same tool to visualise the general improvement of the CMT potential of the c-book unit, according to the corresponding evaluations (see Figure 5.2.3). The graph shows that the CMT potential of the c-book unit has increased in the redesign. As we can see, Social Aspects keeps being the most enhanced feature of the analysis by the reviewers, although its improvement is slightly smaller than in other features (for example, Flexibility or Affective Aspects).

![Radar chart of the original design (orange) and the redesign (purple) of the CMT potential evaluation of the c-book unit “Limits”.

Figure 5.2.3.](image)

A comparative quantitative analysis may be done using data from Table 5.2.4. The opinion of the reviewers about all the categories change from “not agree” to “agree”, or from “agree” to “strongly agree”, but Elaboration, is kept in the “agree” level. Focusing on the Mean, we may assert that the redesign of the unit has improved fostering the four cognitive processes and both aspects, increasing the average of each category between 0.5 and 1 point approximately. With respect to the IQR, we may say that the variety of valuations remains in the four cognitive processes, but there seems to be more unanimity with respect to Social Aspects in the redesign rather than in the original CMT potential analysis. Conversely, the grades seem to be more heterogeneous about Affective Aspects in the redesign than in the pre-redesign CMT potential evaluation.

<table>
<thead>
<tr>
<th></th>
<th>ORIGINAL VERSION</th>
<th>REDESIGNED VERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>FLUENCY</td>
<td>1.99</td>
<td>2</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>2.01</td>
<td>2</td>
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<tr>
<td>ORIGINALITY</td>
<td>1.72</td>
<td>2</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>2.48</td>
<td>3</td>
</tr>
<tr>
<td>SOCIAL ASPECTS</td>
<td>2.70</td>
<td>3</td>
</tr>
<tr>
<td>AFFECTIVE ASPECTS</td>
<td>1.92</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5.2.4. Comparison of both CMT potential analyses of the c-book unit “Limits”.

The reasons that may explain these results may be the inclusion of several non-standard problems, the changes in the narrative and the images of the c-book unit, and the decision of keeping collaborative-type problems. Moreover, the fact that the unit seems too intra-mathematical affects also the evaluation of Fluency and Originality.
Let us focus now on the c-book unit “Alice in Patternland”, original from the UKCoI (with the name “Generalisation II”) and redesigned by the Greek CoI. Overall, the redesigned c-book unit found to be improved in comparison to its initial version since the median for the four cognitive processes has been increased from “disagree” to “agree” (see Table 5.3.5). In the redesign open problems are added but still it lacks activities of problem posing. There is an acknowledgement that there was noticeable improvement concerning the call for constructions, the inter- and intra- disciplinary character of the c-book unit, and the issue of the multiple connected representations. The c-book continues on keeping its exploratory character and its call for conjecturing, whereas a slight improvement seems to be obtained in the issue of problems with multiple solutions. The call for making generalizations was strengthened through activities that are not non-standard but very often ‘force’ the students to analyse and fix them.

With respect to Social, the redesigned version of the c-book unit still remains poor, just improving in activities concerning the call for mathematical communicative skills (from “totally disagree” to “agree”). Instead, Affective Aspects keep being the strongest point of the c-book unit, even improving the feeling of pleasure/fun/challenge, attributed mainly to the entertaining narrative (from “agree” to “totally agree”).

![Table 5.2.5. Comparison of the cognitive processes for the CMT potential analyses of the c-book unit “Alice in Patternland”.

<table>
<thead>
<tr>
<th></th>
<th>ORIGINAL VERSION</th>
<th>REDESIGNED VERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>IQR</td>
</tr>
<tr>
<td>FLUENCY</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>ORIGINALITY</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Let us finish with the c-book unit “Windmills II”, original from the Greek CoI and redesigned by the UK CoI. The only one really significant change in the CMT evaluation corresponds to Social Aspects, that has increased more than one point, although is not enough to be fostered by the redesigned c-book unit. All the other features have improved slightly according to the reviewers, but they don’t strongly agree that they are enhanced by the c-book unit. See Table 5.2.6.

![Table 5.2.6. Comparison of bothCMT potential analyses of the c-book unit “Windmills II”.

<table>
<thead>
<tr>
<th></th>
<th>ORIGINAL VERSION</th>
<th>REDESIGNED VERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>FLUENCY</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>FLEXIBILITY</td>
<td>2.8</td>
<td>3</td>
</tr>
<tr>
<td>ORIGINALITY</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>ELABORATION</td>
<td>2.6</td>
<td>3</td>
</tr>
<tr>
<td>SOCIAL ASPECTS</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>AFFECTIVE ASPECTS</td>
<td>3.1</td>
<td>3</td>
</tr>
</tbody>
</table>

According to the comments, main improvements concerned visual matters, which should be more attractive for ‘sparking’ CMT, as well as more feedback questions.

We should remark here that the UK CoI thinks that comparisons between both units (the original design and the redesign) are very hard to make, due to the poor significance of the results (very few evaluators) and the difference between both sets of evaluators (of the original design and the redesign). Anyway, their analysis
admits some improvements in several aspects (as one may see in Figure 5.2.7), although many of the features highly valued by the reviewers were still in the original c-book.

![Line chart for comparing both CMT potential analyses of the c-book unit “Windmills II”](image)

**Figure 5.2.7.** Line chart for comparing both CMT potential analyses of the c-book unit “Windmills II”.

### 5.3 Results on the main research questions related to CMT

Each team posed some similar research questions with respect to CMT, and some different ones, considering their contexts and theoretical approach. Here we present the main results of each team.

**French team**

**S.R.Q1:** Which of the four cognitive components of CMT (fluency, flexibility, originality, elaboration), social and affective aspects have been integrated and promoted through the design of the c-book units? That is, what affordances are perceived by the evaluators as enhancers of these components?

Firstly, the evaluators raised the multidisciplinary aspect of the c-book unit saying that the musical theme is not quite taken into account in mathematics, despite the fact that it allows a lot of rich interactions. Originality and Elaboration were prevalent about the internal connections as there is a number of unique constructions to be made, sometimes with focus on equations or coordinators, sometimes with focus on geometrical properties like symmetry. The way the visual and geometrical points of view are linked with chat or writing expressions with *EpsilonWriter* is nearly constant through the unit. The creative constructions are almost always asked in the “Musical plane” c-book unit. However, the evaluators raised the need of integrating more different widgets. Also, other connections could be established, in addition to geometry and functions, such as irrational numbers (e.g. $6\times2^{\frac{1}{2}}$ is the proportion between 1-tone separated notes, the reason is the solution of an equation).

The evaluators consider the affective aspect as the most affordable in the c-book unit since the connectivity of mathematics and music is very strong. The possibility of interacting with sounds and at the same time connecting mathematical concepts with what is being perceived by hearing can be considered as a motivating factor on the c-book unit.

As we mentioned above, the CMT components evolved from the initial to the redesigned version of the c-book unit. The reason of this improvement is that the designers drew on the evaluation of the CMT of the initial unit and aimed at improving the affordances that were pointed out as weak.

In conclusion, the CMT affordances of the c-book unit improved, generally, from "weak affordance" to "strong affordance". We can see it very well regarding the social aspects, from what the evaluators said: “The students have to express their music patterns with mathematical expressions and to communicate them with the chat. This is done several times with an increasing complexity of the task”. The presence of the *EpsilonChat* widget plays a main role in improving the social aspects. The affective aspect was increased by adding pictures, and strengthening the relationships between music and mathematics.
**Spanish team**

**S.R.Q1**: How does the first CMT evaluation (made by the secondary-developers of the c-book unit) help the CoI-pair to face the process of redesigning the c-book unit? How criteria/principles of CMT potential evolve and change in the different phases of the redesign?

As one may see in the last part of Section 5.2, the main changes proposed by the reviewers and designers of the Spanish CoI as a consequence of the evaluation of the CMT potential analysis of the alien c-book unit were integrated in the redesign of the c-book unit “Limits”. Actually, since the redesign was divided in two different phases (intra-CoI and cross-CoI), the majority of these changes identified in the first evaluation were drawn in the c-book unit before the French CoI pair started participating in the redesign.

Despite this, the contributions of both CoIs during the cross-CoI were relevant for the final result of the unit. As an example, the phase 1 of the redesigned unit was originally a second phase. Its new location was proposed by the Spanish CoI in the intra-CoI phase of redesign, but the French CoI contributed with ideas in the design and a new widget (in the c-book, the one in page 9 of phase 1). As a result, this phase is referred in many of the most positive comments about the unit of reviewers of both CoI’s.

In general, we could say, according to the comments in the common CoI workspace, as well as in the corresponding evaluations, that the criteria/principles for evaluating the CMT potential of the c-book unit of each CoI were not very far, although each team used to tend to focus in different aspects. For example, the French CoI referred many times to changes or new activities that may foster *Fluency* and *Flexibility*, while the Spanish CoI, with an underlined versant in Math Modelling, seems to be more focused on improving *Originality* and *Social and Affective Aspects*, for instance, in improving the role of extra-mathematical contexts (fractals in nature, cellular security code, etc.) in some initial stages of the c-book unit that could provide new questions to face along the unit and that could get students more involved and attracted by the creation of a nearer context. The iteration between both CoI’s made them take into consideration the view of the other team. Hence, some of the comments of the Spanish CoI highlight the role of some activities (the first ones of the second phase, or the activities that students must propose in phase 3) on fostering *Fluency* and *Flexibility*, while the reviewers of the French team also underline how the changes on the structure and the appearance of the unit may make students enjoy the unit more.

In conclusion, we may assert that the particular CMT representations of one partner cross the boundaries and become an object of thought for the other partner. As a result, all cognitive processes increase their presence in the c-book unit (from "disagree" to "agree" or from "agree" to "totally agree" level, as one may check in Table 5.2.1) as well as Social and Affective Aspects.

**S.R.Q2**: What are the main commonalities and changes on the initial criteria that the primary-designers agreed as important to foster and promote CMT when the c-book unit is adopted by another CoI?

First of all, one may note that the tools to evaluate the CMT affordances of the c-book unit have changed from cycle 2 to cycle 3. Figure 5.3.1. shows the results of the evaluation of the first design of the c-book unit made by the French CoI, according to their CMT representation. Although the tools to evaluate the CMT potential have evolved, we may observe some commonalities between both evaluations: the French one, provided at the end of wp6-cycle2, and the CoI-pair cross-evaluation at the end of wp7-cycle 2, when the c-book unit had been redesigned.

An overview of the conclusions about the CMT potential of the original design of the c-book unit "Limits" is presented in Figure 5.3.1 (taken from the deliverable D6.2, Mercat et al., 2015).
The first aspect to remark is that the scores of each cognitive process are different from the ones given by the Spanish CoI when analyzing the unit before the redesign. This may be due to the fact that all four cognitive processes were now evaluated according to several (at least 11) questions (Affordances), while the evaluation was more general in the first analysis. This also shows the necessity of creating a common language and methodology in order to be able to make comparisons. For instance, the grid item asks about the sufficient presence of open questions. The ‘sufficiency’ however, perhaps is conceived differently by each CoI. Nevertheless, a careful read on the comments in both analyses shows some (qualitative) commonalities in the evaluation of Fluency (lack of activities with open or multiple answers) and Originality (the topics, mainly limits calculation, are treated from a classical point of view). Instead, the French CoI valued highly Flexibility and Elaboration. With respect to both of them, the Spanish analysis agreed with the French CoI in the strength given the different representations of the concept of limit by means of the widgets designed for the c-book unit, but the Spanish CoI missed activities with different solutions, as well as ways of proposing variations on the problems stated in the c-book unit. This was partially solved with the inclusion of some activities in the last page of phase 1 of the c-book (changing the initial condition of the Pythagorean tree), and at the beginning of phase 2 (adding a challenge activity). As a result, the evaluation of the CMT potential of the redesigned unit was significantly higher in most of the topics, as one may see again in Figure 5.2.3 (Section 5.2). Originality is the worst valued in the redesign, but the reasons are the same with those expressed by the French CoI in the original c-book unit: the topics of the unit (calculation of limits) have a sort of natural tendency to be explained from classical exercises. From the comments that the Spanish CoI made on the last evaluation, we may notice that the addition of the four cognitive processes proposed by the French CoI to analyse the CMT potential had an impact in the representations conceived by the Spanish CoI.

Regarding Social Aspects, it seems that they are given a central importance by both CoI’s in their analysis. They agreed in the potentiality of the unit, although it was improved by the addition of some new activities, especially in phases 1 to 3.

Instead, there is a deep change with respect to Affective Aspects. This is mainly triggered by the addition of some new features (aesthetics, narrative, etc) not considered in the first analysis, but also because the Spanish CoI considered that the activities related with the Pythagorean tree could be better exploded, focusing more on properties of fractals, as well as in some other relations that could emerge from the construction. The comments of the French CoI with respect to these changes in the redesign of the unit show that they considered more aspects that promote affection in their representations of CMT potential.

Greek team

S.R.Q4: Did the CoI members’ evaluation of the CMT affordances of a re-designed c-book unit by another CoI (wp7) follow the same line of thought in terms of the focus applied and criteria used as it was the case when they had to evaluate their own c-book units produced in wp6? (special case of CRQ3)

In relation to the Specific Research Question it is interesting to notice how the interaction between different CoI, which actually constitutes an interaction between different contexts-, had an impact on the way each CoI perceives and appreciates the context of its partner. The Greek CoI, in its effort to redesign the ‘not-
algebra’ book, raised mainly two issues closely related to its educational context, i.e., the usage of half-baked activities and the emphasis on the narrative. On the other hand, the partner’s context gives strong emphasis on the alignment of the design of the c-book unit with the curriculum. This latter situation is depicted on the initial comments of the UK Col members in the common workspace in the Colcode. They mentioned the need for “less text”, and suggested that the text “should not divert too much from the maths”. However, after the common discussion and the final redesign of the c-book unit, in their evaluation, they emphasized that it is the narrative that gives meaning to the task which could have been branded ‘boring’ or ‘useless’ otherwise. This is an indication of an influence resulted from the interaction between these two contexts.

The issue of the half-baked activities that are connected mainly (but not exclusively) with Turtleworld seemed to had a twofold impact. The first one concerns this redesigned c-book unit of Alice. The UK partners seem to broaden the notion of half-baked activities and they use this term to talk not only about Logo activities but also about “several questions that the user has to analyze and fix”. The second one concerns Don-Quixote, the Greek c-book unit they adopted and redesigned. In its redesigned version one can see how the UK Col members not only kept the half-baked Turtleworld activities but in some of the cases they adopted a relatively different approach substituting for example the traditional code in Turtleworld with Java-Logo.

Based on the above, it can be said that this experience of cross-case design initially allows each partner to identify the criteria used by the other partner, and occasionally some of these criteria draw the attention of this partner and are used in its own design, crossing thus the boundaries and becoming object of thought for this Col.

**UK team**

At the time of this writing the UK team focused mostly on the following two questions as the rest relate mostly to the use of c-books from students that is work in progress as of M20 of the project.

*S.R.Q1 Are Silver’s 4 indicators "sufficient" vocabulary to describe the potential usage of the c-book designs of c-books in terms of CMT potential? Can we find other indicators or patterns through the process of authoring and/or c-book usage?*

We have found that the extension of Silver’s vocabulary to the grid with the inclusion of affective aspects to be enough to characterise the c-books in terms of their CMT potential. This is mostly thanks to the detailed statements in the grid that served as criteria that helped in the evaluation. In particular, in relation to the redesign the grid acted as a way of prioritising decisions and helped keeping the different CoI on the same page*. 

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6 Analyses of and reflections on Social Creativity in the redesign process

6.1 Common methodology used for the qualitative and quantitative analysis of SC

This section describes and analyses the data obtained from each CoI and CoI-pair in terms of social creativity (SC) processes involved in the redesign processes of the selected c-book units. The theoretical underpinnings of social creativity analysis have been developed in D6.3. As described in this deliverable, the analytical framework to analyse SC can be divided in the five-level process methodology (agreed and used in wp6-cycle 3), which most of them were also used in wp7-cycle 2 (see Figure 6.1.1).

On the one hand, the first two levels, the ‘overall creativity rate’ and ‘creativity score’ (see Figure 1), have been also used in wp7-cycle 2. They provide the quantitative measurement of the SC rate for each c-book unit produced and the creativity score for different creative ideas emerged in the process of redesign. On the other hand, concerning the qualitative analysis, level 3 have been also integrated where each CoI describes the main phases they go through in the redesign process and then a fourth qualitative level was added with the application of an open-ended questionnaire to all CoI members that participated in the redesign, with questions related to the critical episodes appeared and the creative ideas. In the following, we summarized the aims and tools (see D6.3 for more details) of each of the four levels of analysis that will be developed in the following sections.

![Figure 6.1.1. Five-levels methodology to analyse SC in wp6-cycle 3 (D6.3).](image)

**Level 1 - Overall creativity rate**

In this first level, an overall rate of social creativity in the redesign process of each c-book unit selected in wp7-cycle2 has been calculated based on the following 4 components: fluency, flexibility, originality, and social elaboration of the ideas produced by oneCoI or by the interaction of two CoI, that is, a CoI-pair. As proposed in wp6-cycle 3, a final rate is calculated through the combination of the following four scores:

- the **fluency score**: total number of posts generated and uploaded by CoI members in the ColCode workspace within a specific time frame as contributions,
the flexibility score: total number of diverse, unique and distinctive ideas generated and uploaded by CoI members in the CoICode workspace within the same time frame,

the originality score: total number of highly rated creative ideas (in terms of novelty, appropriateness and usability) produced within the same time period,

the social elaboration score: total number of highly creative ideas produced within the same time period, which have received a high degree of CoI members’ involvement in their elaboration (Daskolia et al., 2015, p. 54).

As it occurred in wp6-cycle 3, these definitions of scores for the four SC components have been implemented in two different ways in CoICode linked to two different ways of using CoICode by the four CoI. Consequently, two different formulas were produced and used to obtain the overall SC score. These methods have been presented further in D6.2. Consequently, in wp7-cycle 2, each CoI-pair have been working with one of the two approaches.

Level 2 - Idea creativity score

For the second level, the two CoI pairs have used the same approach and formula to calculate the creative score per idea. As in wp6-cycle 2, each user is asked to vote for contributions in the CoICode (or ideas, as they are defined as a comment in CoICode which is not an off-task node). Users vote yes or no depending on whether they consider that the ideas are novel, appropriate and usable.

- novel if an idea is new, unusual and/or different from any other idea proposed until now in the course of the design process of previous c-book units,
- appropriate as relevant to and aligned with the general design characteristics and CMT affordances of the c-book unit as defined by the CoI members and CoI-pair, and
- usable as ready and available to be used and incorporated in the c-book unit design.

Since the novelty criterion is of the foremost importance in judging the creativity of an idea, the novelty vote will be assigned 0,5 weight, while appropriateness and usability will be assigned 0,25 weight each. The creative score of an idea is thus given by the following formula:

\[
\text{creative score of the idea } i \ (\text{CR}i) = 0.5 \times \text{number of ‘novel’ votes} + 0.25 \times \text{number of ‘appropriate’ votes} + 0.25 \times \text{number of ‘usable’ votes} \text{ if the number of ‘novel’ votes is at least a half of the number of CoI members involved in the c-book unit design, otherwise } \text{CR}i = 0
\]

Level 3 - Main stages of the c-book unit design

This is the first level corresponding to the qualitative approach to describe and evaluate the way the CoI and the CoI-pair work internally in the process of redesigning a c-book unit. This level focuses on the identification of the main phases through which the cross-analysis and cross-redesign go through.

Although each CoI (also each CoI-pair) follow different dynamics of facing the (re)design and evaluation tasks, this level of evaluation allow us to identify some patterns in the flow and phases followed by each CoI and CoI-pair for the redesign of the c-book units.

Level 4 – Open-ended questionnaire about the redesign process

This level refers to the application of an open-ended questionnaire to all CoI members that participated in the redesign. The specific questions were:

1) Describe whether the process of redesign, in which you were involved, has favoured the emergence of new creative ideas. Please, give an example of the emergence of a creative idea, and identify the phase of the redesign (intra or cross-CoI communications) it belongs to.
2) How the use of the socio-technical environment provided by the c-book has facilitated the intra and cross-CoI communication, the design process and the outcome? Please use particular examples within your comments.

3) Identify an episode you have participated (or observed) in which an important decision has been made about any aspect related to the redesign of the c-book unit. Please refer, for example, to a new widget, different contents, other pedagogical approaches, new sequencing, etc. Identify also the phase of the redesign process (the intra or the cross-CoI communications) the episode belongs to.

As can be read in the formulation of questions 1 and 3, in this fourth level, we want to let the CoI-pair members detect and describe some of the main ‘creative ideas’ (level 4 of the methodology followed in wp6-cycle3) and ‘critical episodes’ (level 5) that have occurred in the process of redesigning the c-book units. This level adds an extra qualitative understanding of SC by focusing on the most important ‘creative ideas’, which can then correspond to level 2 of analysis with the creative score per ideas, and then on the ‘critical episodes’ which offers the opportunity to CoI-pair members to better explain and deeply understand the particular manifestations of social creativity in the design process through a selected segment of the redesign process.

6.2 Quantitative analysis of SC

6.2.1 The case of redesigning the c-book unit ‘Musical plane’ by the French CoI

Level 1 - Estimation of the overall ‘creativity rate’ per c-book unit production

In order to analyse Social Creativity, the French CoI introduces the following distinction between the main two stages of the redesign of the c-book unit:

- A first stage (up to February 3rd, 2016), in which only CM and NE from the French CoI participated. Their redesign followed the directions suggested in the initial c-book unit CMT potential evaluation done prior to the redesign. The activity realized during this stage is documented in a first workspace called “Musical plane_v2 - Reconception du c-book par la France”.
- A second stage (from February 4th, 2016), in which members of both CoI (Spanish and French) participated. Their activity was based on the first version of the redesigned c-book unit produced after the first stage. The activity of this process is documented in a second workspace called “WP7 France Spain”. Moreover, because of time constraints (a very short delay for implementing the ideas in the c-book unit), it was decided to mainly propose feasible ideas in such context.

The following table presents the quantitative analysis of each stage (following the French approach of estimating the Fluency-Flexibility-Originality-Social Elaboration values):

<table>
<thead>
<tr>
<th>Stage (or period)</th>
<th>Number of posts</th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Social elaboration</th>
<th>Overall Creativity Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>42</td>
<td>41</td>
<td>1,8</td>
<td>0,67</td>
<td>0,46</td>
<td>63,1</td>
</tr>
<tr>
<td>2nd</td>
<td>89</td>
<td>78</td>
<td>1,71</td>
<td>0,50</td>
<td>0,46</td>
<td>57,5</td>
</tr>
</tbody>
</table>

Table 6.2.1.1

In order to have a general SC score, we have merged data from the workspaces of each of the two stages of redesign to obtain the following data:
The number of active contributors is 2 for the first stage. They are also the only contributors involved in the first stage of the redesign. In the second stage, with the Spanish CoI interaction, the number of active contributors is 5 (see Figure 6.2.2.3). This is why the score for the social elaboration criterion is higher than in the two stages considered separately.

Figure 6.2.2.3 Contributions of the CoI-pair members in the second stage of redesign

Level 2 – Idea creativity score

The common methodology has been applied at this level. One example of ideas with the higher creativity score:

The table below presents the amount of ideas, ideas with positive creative score (with Novel, Appropriate and/or Usable score > 1) and creative ideas generated in the redesign process of the e-book unit ‘Musical Plane’ produced by the French CoI, as well as the ratio of creative ideas:

<table>
<thead>
<tr>
<th>User</th>
<th>Date</th>
<th>ID</th>
<th>Title</th>
<th>Novel</th>
<th>Approp</th>
<th>Usable</th>
<th>SC SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS</td>
<td>01/03/2016</td>
<td>46282</td>
<td>It would be a good idea to save the music plane in mp3</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4,75</td>
</tr>
<tr>
<td>GS</td>
<td>10/02/2016</td>
<td>45847</td>
<td>A musical idea to indicate the resolution of task is right.</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>NM</td>
<td>18/02/2016</td>
<td>46032</td>
<td>Playing with the origin of coordinates</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>MB</td>
<td>02/03/2016</td>
<td>46309</td>
<td>Formula?</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
### 6.2.2 The case of redesigning the c-book unit ‘Limits’ by the Spanish CoI

**Level 1 - Estimation of the overall ‘creativity rate’ per c-book unit production**

In order to analyse Social Creativity, the Spanish CoI introduced the following distinction between the main two stages of the redesign of the c-book unit in order to better analyse data coming from two different workspaces:

- **A first stage** (up to February 4th, 2016), in which only the members from the Spanish CoI participated based on the lines suggested in the CMT potential evaluation previous to the redesign. All the activity of this process is contained in a first workspace called “`Limits_v2_Rediseño de la c-unidad`”.
- **A second stage** (from February 5th, 2016), in which members of both CoI’s (Spanish and French) participated based on the first version of the redesigned produced after the first stage. All the activity of this process is contained in a second workspace called “`WP7 Spain France – Interaction about LIMITS`”.

The following table presents the quantitative analysis of each stage (following the French approach of estimating the Fluency-Flexibility-Originality-Social Elaboration values):

<table>
<thead>
<tr>
<th>Stage (or period)</th>
<th>Number of posts</th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Social elaboration</th>
<th>Overall Creativity Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>64</td>
<td>64</td>
<td>1.74</td>
<td>0.72</td>
<td>0.46</td>
<td><strong>64.22</strong></td>
</tr>
<tr>
<td>2nd</td>
<td>93</td>
<td>87</td>
<td>1.69</td>
<td>0.67</td>
<td>0.63</td>
<td><strong>66.66</strong></td>
</tr>
</tbody>
</table>

*Table 6.2.2.1*

In order to have a general SC score, we have merged data from the workspaces of each of the two stages of redesign to obtain the following data:

<table>
<thead>
<tr>
<th>Number of posts</th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Social elaboration</th>
<th>Overall Creativity Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>157</td>
<td>151</td>
<td>1.71</td>
<td>0.69</td>
<td>0.57</td>
<td><strong>66.35</strong></td>
</tr>
</tbody>
</table>

*Table 6.2.2.2*

The number of active contributors was 3 for the first stage, and 4 for the second stage (see Figure 6.2.2.3). One may observe that the iteration among the CoI members have increased during the second stage of the redesign.
**Level 2 – Idea creativity score**

The common methodology has been applied at this level. One example of ideas with high creativity score:

<table>
<thead>
<tr>
<th>User</th>
<th>Date</th>
<th>ID</th>
<th>Title</th>
<th>Novel</th>
<th>Approp</th>
<th>Usable</th>
<th>SC SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>04/02/20</td>
<td>45675</td>
<td>Variable Pythagorean tree</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>16 11:03:51</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE</td>
<td>12/02/20</td>
<td>45901</td>
<td>EpsilonChat to foster social aspects</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16 11:01:13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NM</td>
<td>18/02/20</td>
<td>46024</td>
<td>About phase 2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>16 14:16:35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 6.2.2.4**

The table below presents the amount of ideas, ideas with positive creative score (with Novel, Appropriate and/or Usable score > 1) and creative ideas generated in the redesign process of the c-book unit ‘LIMITS’ produced by the Spanish CoI, as well as the ratio of creative ideas:

<table>
<thead>
<tr>
<th>c-book unit</th>
<th>Number of ideas</th>
<th>Number of ideas with positive creative score</th>
<th>Number of creatives ideas</th>
<th>Percentage of creative ideas (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIMITS</td>
<td>151</td>
<td>89</td>
<td>49</td>
<td>32.45 %</td>
</tr>
</tbody>
</table>

**Table 6.2.2.5**

Figure 6.2.2.3: Contributions of the CoI members to each stage
6.2.3 The case of redesigning the c-book unit ‘Alice in Patternland’ by the GreekCoI

Level 1 - Estimation of the overall ‘creativity rate’ per c-book unit production

In order to analyse Social Creativity, the Greek CoI introduced the following distinction between the main two stages of the redesign of the c-book unit in order to better analyse data coming from two different workspaces: the Redesign Phase and the Exchange Phase, each one working with separate workspaces.

The following table presents the quantitative analysis of each stage (following the Greek approach of estimating the Fluency-Flexibility-Originality-Social Elaboration values):

<table>
<thead>
<tr>
<th>Stage (or period)</th>
<th>Number of posts</th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Social elaboration</th>
<th>Overall Creativity Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redesign</td>
<td>107</td>
<td>97</td>
<td>46</td>
<td>21</td>
<td>11</td>
<td>6.6</td>
</tr>
<tr>
<td>Exchange</td>
<td>34</td>
<td>30</td>
<td>22</td>
<td>7</td>
<td>0</td>
<td>6.36</td>
</tr>
</tbody>
</table>

Table 6.2.3.1

In order to obtain one score for the whole process, the Greek CoI calculated the average CS weighted by Fluency of each phase (30 & 97). Based on the fact that the workspace of the Redesign Phase has greater size and density when compared to the Exchange one it is reasonable to claim that it is the Redesign Phase rather than the Exchange one that has a greater impact on the design process. In this sense, fluency can be used as measure of the workspace’s size. Therefore, this results to a total score of 6.52.

\[
\frac{97 \times 6.6 + 30 \times 6.36}{97 + 30} = 6.54
\]

Another way –and perhaps more proper one- of measuring the size of the workspace could be the total number of posts. However, in our case, this does not change the Overall Creativity Score for the combined workspaces, since

\[
\frac{107 \times 6.6 + 34 \times 6.36}{107 + 34} = 6.54
\]

Level 2 – Idea creativity score

The common methodology has been applied at this level. The first table, where four members were involved, includes some examples of the higher valued creative ideas from the ‘Redesign Phase’. In the same line, the second table includes ideas from the ‘Exchange Phase’, when six CoI-pair members had the right to vote for each post.

Redesign phase:

<table>
<thead>
<tr>
<th>User</th>
<th>Date</th>
<th>ID</th>
<th>Title</th>
<th>Novel</th>
<th>Approp</th>
<th>Usable</th>
<th>SC SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diamantidis</td>
<td>31/01/2016</td>
<td>45510</td>
<td>2nd page</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Latsi</td>
<td>13/09/2015</td>
<td>41931</td>
<td>Redesigning the frieze</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>2.75</td>
</tr>
</tbody>
</table>
The table below presents the amount of ideas, ideas with positive creative score (with Novel, Appropriate and/or Usable score > 1) and creative ideas generated in the redesign process of the c-book unit ‘Generalisation’ redesigned by the Greek CoI, as well as the ratio of creative ideas.

<table>
<thead>
<tr>
<th>c-book unit</th>
<th>Number of ideas</th>
<th>Number of ideas with positive creative score</th>
<th>Number of creatives ideas</th>
<th>Percentage of creative ideas (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Alice in Patternland’</td>
<td>106</td>
<td>80</td>
<td>21</td>
<td>20%</td>
</tr>
</tbody>
</table>

The table below presents the quantitative analysis of each stage (following the Greek approach of estimating the Fluency-Flexibility-Originality-Social Elaboration values):

<table>
<thead>
<tr>
<th>Stage (or period)</th>
<th>Number of posts</th>
<th>Fluency</th>
<th>Flexibility</th>
<th>Originality</th>
<th>Social elaboration</th>
<th>Overall Creativity Score (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Redesign</td>
<td>6</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>6.37</td>
</tr>
<tr>
<td>Exchange</td>
<td>53</td>
<td>53</td>
<td>19</td>
<td>0</td>
<td>0</td>
<td>4.55</td>
</tr>
</tbody>
</table>

As such the overall creativity score for the whole process is 4.74 (average CS weighted by Fluency)

**6.2.4 The case of redesigning the c-book unit ‘Windmills II’ by the UKCoI**

**Level 1 - Estimation of the overall ‘creativity rate’ per c-book unit production**

The following table presents the quantitative analysis of each stage (following the Greek approach of estimating the Fluency-Flexibility-Originality-Social Elaboration values):
The common methodology has been applied at this level. The first table includes some examples of the ideas emerged in the first stage or ‘Redesign Phase’. As it was stated by the English CoI, “as CoICode was only minimally used, this first table does not show the idea with the most votes but the ones with the most ideas attached and the ones that sparked the key contribution with the integration of the Geogebra page with integrated feedback”.

**Redesign process:**

<table>
<thead>
<tr>
<th>User</th>
<th>Date</th>
<th>ID</th>
<th>Title</th>
<th>Novel</th>
<th>Approp</th>
<th>Usable</th>
<th>SC SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christian Bokhove</td>
<td>7-February</td>
<td>45805</td>
<td>Made many changes some key elements in attachment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotem Abdu</td>
<td>18 February</td>
<td>Skype</td>
<td>Various comments leading to an email attachment and focus on page 6 windmill reconstruction</td>
<td></td>
<td></td>
<td></td>
<td><em>No information about these aspects, due to the fact that the interaction was outside the CoICode</em></td>
</tr>
<tr>
<td>Sokratis Karkalas</td>
<td>10 February</td>
<td>email</td>
<td>Added a Geogebra feedback page from Authelo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 6.2.4.2**

**Exchange phase:**

<table>
<thead>
<tr>
<th>User</th>
<th>Date</th>
<th>ID</th>
<th>Title</th>
<th>Novel</th>
<th>Approp</th>
<th>Usable</th>
<th>SC SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manolis Mavrikis</td>
<td>7-February</td>
<td>46150</td>
<td>Tune in for rebuilt page</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Irini Perissinaki</td>
<td>21-Feb-2016</td>
<td>46138</td>
<td>A missing function</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Irini Perissinaki</td>
<td>21-Feb-2016</td>
<td>46136</td>
<td>Maximum volume</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Irini Perissinaki</td>
<td>21-Feb-2016</td>
<td>46140</td>
<td>Storage 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

**Table 6.2.4.3**

The table below presents the amount of ideas, ideas with positive creative score (with Novel, Appropriate and/or Usable score > 1) and creative ideas generated in the redesign process of the c-book unit ‘Windmills’ produced by the UK CoI, as well as the ratio of creative ideas:

<table>
<thead>
<tr>
<th>c-book unit</th>
<th>Number of ideas</th>
<th>Number of ideas with positive creative score</th>
<th>Number of creatives ideas</th>
<th>Percentage of creative ideas (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Windmills</td>
<td>32</td>
<td>12</td>
<td>8</td>
<td>25%</td>
</tr>
</tbody>
</table>

**Table 6.2.4.4**
6.3 Qualitative analysis of SC

6.3.1 Main stages in the redesign processes

In the Tables below we present an overview of the main stages of the redesign of the four units, as identified by each CoI, describing the key events that occurred in these stages.

**French CoI**

<table>
<thead>
<tr>
<th>Main stages in the redesign process of the c-book unit ‘MUSICAL PLANE’</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Evaluation of the CMT potential of the first version of the c-book unit</td>
</tr>
</tbody>
</table>
| (2) First stage of the re-design based on the CMT evaluation | ▪ This was the longer stage (October 15 to December 2015).  
▪ Two designers were involved in the c-book unit redesign, initiating the redesign work during a face to face meeting, and followed in CoICode.  
▪ Because of the work on straight lines equations and intervals, the designers’ team agreed that the c-book unit could be designed for Grade 10 students. |
| (3) Reification of the second version of the c-book unit | ▪ The two designers worked separately and contributed some ideas in CoICode.  
▪ The introduction of the c-book unit was introduced, and a new structure was added to allow an overview of the whole unit. |
| (4) Cross-communication stage and the final modification of the second version of the c-book unit | ▪ The c-book unit became a boundary object that supported the communication through CoICode.  
▪ These exchanges helped fixing some problems, enhancing the activities already embedded in the unit and fostering the emergence of new creative ideas and the design of a new widget. |
| (5) Cross-evaluation of the CMT potential of the c-book unit last version | Members from both CoIs were involved, two members of the French CoI who had also acted as primary-designers of the original c-book unit (adopted by the Spanish CoI), and three more from the Spanish CoI, who did not participate in the process of redesigning this c-book unit. |

**Spanish CoI**

<table>
<thead>
<tr>
<th>Main stages in the redesign process of the c-book unit ‘LIMITS’</th>
</tr>
</thead>
</table>
| (1) Adoption and evaluation of the CMT potential of the adopted c-book unit | ▪ The process of redesigning the c-book unit of Limits-v2 started with the evaluation of the CMT potential of the original version designed by the French CoI.  
▪ In this stage, the Spanish CoI members involved in the redesign detected and described some elements that could be improved, |
also introducing new criteria for its redesign.

<table>
<thead>
<tr>
<th>(2) Agreeing the ‘protodesign’ of the c-book unit to redesign and main criteria to take into account.</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ The Spanish CoI sub-group of designers follow by discussing about some of the main ideas resulting from the CMT evaluation to agree and draw the ‘protodesign’ of the c-book unit to be redesign.</td>
</tr>
<tr>
<td>▪ Most of the interaction occurred in the first workspace called “Limits v2. Rediseño de la c-unidad”, where designers could debate on which the most interesting aspects are included in the c-book unit, as well as on proposing several creative ideas which guided the following stages of redesign.</td>
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<tr>
<th>(3) Intra-CoI process of redesigning the c-book unit LIMITS</th>
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<tr>
<td>▪ More specific tasks were distributed among each CoI member involved in the redesign.</td>
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<tr>
<td>▪ There was one main moderator who also was responsible of integrating in the redesign all the changes proposed by the designing team.</td>
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<tr>
<td>▪ The team of designers put special attention to the c-book unit narrative, revising the articulation and coherence of all the activities according to the whole story and questions posed, also to its coherence with the main aims and criteria agreed in the first stages.</td>
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<tr>
<th>(4) The cross-CoI communication and cross-CoI redesign</th>
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<tr>
<td>▪ The unit is translated into English and shared with the Frech CoI members, who will join the designers’ team.</td>
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<tr>
<td>▪ A new workspace on CoICodeCoICode was opened to facilitate the cross-communication between both CoIs.</td>
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<tr>
<td>▪ To favour this communication, the workspace was structured according to the four main phases the c-book unit includes and a summary of the main aims and changes introduced in each phase was added to facilitate that the French partners could compare the c-book unit to its original design.</td>
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<tr>
<th>(5) The cross-CoI evaluation of the CMT potential of the new version of the redesigned c-book unit:</th>
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<tr>
<td>Members from both CoIs were involved, two members of the French CoI, who had also acted as primary-designers of the original c-book unit (adopted by the Spanish CoI), and three more from the Spanish CoI, who did not participate in the process of redesigning this c-book unit.</td>
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**GreekCoI**

**Main stages in the redesign process of the c-book unit ‘ALICE IN THE PATTERNLAND’**

<table>
<thead>
<tr>
<th>(1) Evaluation of the CMT potential of the adopted c-book unit</th>
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<tr>
<td>▪ When the Greek CoI adopted the c-book unit “The non-Algebra c-book” designed by the UK CoI, the first stage in the redesign process was to evaluate its CMT affordances.</td>
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<tr>
<td>▪ During this stage a discussion was developed in the CoICode that resulted in identifying the strong and weak points of this</td>
</tr>
<tr>
<td>(6) Talking about the kind of the redesign of the c-book unit</td>
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<td>---------------</td>
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</table>
| (2) Talking about the kind of the redesign of the c-book unit | - One of the first issues raised by the Greek CoI members was the depth of intervention in the English c-book unit. Some CoI members expressed the view that the English c-book unit was not very coherent and that it could be easily modified and extended.  
- The CoI designers’ team preferred focusing on using the available widgets and on trying to develop relevant activities which should be more open-ended and constructionist. |
| (3) Brainstorming - Innovative ideas emerge | - The Greek CoI continued by exchanging ideas and resources as potential suggestions for the c-book unit redesign. The ideas were not fully developed so far but the weak points of the suggested activities were thoroughly discussed.  
- The CoI members try making their ideas more specific and feasible through the development of certain activities exploiting the available widgets. |
| (4) Talking anew about the kind of redesign of the c-book unit | The CoI members were not satisfied by the widget instances developed so far (not focusing adequately on the mathematical concepts or very demanding for the targeted audience, etc.) and they started talking anew about the kind of the c-book unit’s redesign. |
| (5) Brainstorming and emergence of new widget instances | - The CoI members shifted their focus on proposing specific and feasible ideas through the development of certain activities that exploit the available widgets. These activities were posted initially in CoICode and commented by the rest of the CoI-members.  
- The developers of these activities inserted them in the c-book unit and were reviewed by the rest of the team. |
| (6) Focusing on the narrative | The Greek CoI members inspired by the story of ‘Alice’s adventures in Wonderland’, written by Lewis Carol, paraphrased its title and decided to call their redesigned c-book unit ‘Alice in Patternland’. This was the way how they created a relevant story interweaving Alice’s adventures with all the activities in the unit. |
| (7) Reviewing together the redesigned c-book unit | The two CoI groups (the English and the Greek one) spent some time reviewing and discussing on the redesigned c-book unit. The UK CoI members spotted some technical problems, proposed changes in the wording of the activities, also proposed cross-widget communication in some cases, etc. Most of the ideas were implemented in the redesigned c-book unit. |

**UK CoI**

**Main stages in the redesign process of the c-book unit ‘WINDMILLS’**
6.3.2 Social creativity processes: results from the open-ended questionnaire

The key results of the survey are presented in this section. In the next we present a summary of the responses provided by the four designers teams (involving members from the two CoI-pairs) to each of the three questions included in the survey. These responses present some common aspects identified in all, and some other that are only underlined by one CoI or CoI-pair.

1) Describe whether the process of redesign, in which you were involved, has favoured the emergence of new creative ideas. Please, give an example of the emergence of a creative idea, and identify the phase of the redesign (intra or cross-CoI communications) it belongs to.

Emergence of creative ideas in the cross-design process


- From the point of view of all the designers, the redesign process has favoured the emergence of new creative ideas. Each designers quote different ideas. The examples quoted are: “the fact that in order to exchange it was necessary to go through a textual representation of the score which became clear only after discussing about it”, or, “the idea of linking the notion of canon with translations”.
- After the extension of the c-book unit by the French team, introducing new approaches in the musical plane, as e.g symmetries, the Spanish team improved and expanded some ideas such as the one about symmetries. Likewise, in the activity 2 page 4, the exercise became more interesting adding a self-correcting option, and this idea emerged during the cross-CoI phase, otherwise, the contribution that suggested the incorporation of some kind of numerical “axis” to facilitate the counting and provide the coordinates of the points in the musical plane was a new idea of the cross-CoI phase too. Otherwise, we may note that the designers quote new ideas which emerged thanks to their participation.

Redesign of the c-book unit ‘Limits_v2’ by the Spanish-French CoI-pair [Spanish CoI]

- When the Spanish CoI members began with the analysis of the adopted c-book unit, a lot of creative ideas emerged based on this first evaluation. These ideas were mostly related to: (a) improve certain activities (or elements of this activities); (b) create new activities to facilitate the students’ construction of the different meanings or notions of the certain content (for instance, the different approaches and meanings of «limit» in relation of «infinite»); (c) improve the structure of the c-book unit looking for a coherent narrative along the c-book unit. In this moment the Spanish CoI members thought of including new activities and widgets to
provide coherence, articulation and connection among all the pages, and of different phases, in order to enable students flow appropriately.

- When the members from both CoI followed with the cross-evaluation and cross-redesign of the c-book unit in the common workspace (after the first version of the redesigned c-book unit was available and translated into English), it was again a fruitful period of generation of creative ideas. The cross-CoI communication allowed that many creative ideas emerged by proposing new changes or improvements to the c-book unit design. It was in this moment, for instance, when some new widgets to be considered (from Cinderella and from Geogebra) were proposed and resulted very appropriate for the c-book unit.

Redesign of the c-book unit ‘Alice in Patternland’ by the Greek-English CoI-pair [Greek CoI]

- The use of multiple representations while addressing a mathematical concept: The Greek CoI focused on the use of multiple representations while addressing a mathematical concept within a widget instance or across the widget instances that were incorporated in the same page. In particular, the participants referred to the activity titled ‘smiling face’. In this page, the concept of a function was approached through patterns in Cinderella widget (a more spontaneous representation), through an algebra arrows widget instance (a more procedural representation that incorporated at the same time both a table of values and a graphical representation) and finally through a formula (formal).

- The role of narrative: The redesign of the narrative of the c-book unit was considered as a very creative moment by the Greek CoI. Moreover, and according to the discussion in the common workspace, it appeared that the narrative was considered as highly creative by the English CoI too. Most of the English CoI members made an explicit reference to it characterizing the process of redesigning the narrative as being quite inspiring making them thinking quite openly about narrative as valuable resource. This constitutes a typical example of boundary crossing. There was a default reservation about the length and the role of narrative in the c-book unit. Their principle was “less text – not diverting from the math”. And then, narrative crosses the borders, becomes object of thought for the UK-CoI and gains their appreciation.

Redesign of the c-book unit ‘Windmills’ by the English-Greek CoI-pair [UK CoI]

- Types of creativity ideas from re-design: There are at least two different high-level roles of people when they are involved in the re-design process. On one hand, reacting to an existing c-book and be challenged to re-design it to fit a different context and on the other hand a critical evaluation of it or of its redesign. Compared to starting from a specific interest as in the previous c-books, the members involved in redesign commented on the challenge of adopting an already c-book. This helped in the emergence of associative ideas i.e. the c-book made participants think of other related topics or a kind of reframing i.e. different thinking about the same thing, for example different ways to address a similar objective.

- Features and constraints: The process of re-design seems to have challenge members of the CoI to work within both the technical and conceptual constraints of the original c-book but utilising any features known or available to them to augment the design. With a particular interest in feedback, the UK CoI members paid particular attention to the addition of feedback to support students’ interaction in various pages. The novelty of such ideas does not really lie in the actual substantive ideas but more in the process of improving them. Often constraints play a role in this as well. With that is meant that technological tools will not always have all the features necessary (as author/redesigner) to directly implement all the ideas that come to mind. As such, designers/developers (particularly those interacting heavily with the c-book author) have to work with what is available. This is a particular kind of creativity (as analogy, MacGyver and the A team were 80s TV show that epitomised the idea that with a paperclip you could do creative things). The most creative moments were the actual redesign process, and then –following on from other CoI members’ comment-finding (creative) solutions to some of the objections rose. The role of narrative: A particular instantiation of the above aspect is in the role of narrative in c-books. Like in other c-books this issue concerned
members a lot and appeared in their answers to the survey. In parallel with the redesign of this book, the algebra book was also being re-design. A key issue there was the addition of a coherent narrative throughout the book, something that here was being inherited by default. Although there were several discussions about removing the narrative to fit more the UK context, this was not considered appropriate or even made sense --- what would the Don Quixote c-book be about without its narrative? Having to work with this as a constraint (or perhaps an affordance in this case) meant that the UK CoI had to revisit some of its assumptions about the role of narrative. Although some hesitation still remains, a clear shift in thinking had taken place at the end of the redesign process.

2) How the use of the socio-technical environment provided by the c-book has facilitated the intra and cross-CoI communication, the design process and the outcome? Please use particular examples within your comments.

<table>
<thead>
<tr>
<th>Use of the socio-technical environment facilitating the intra- and cross-CoI communication</th>
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<tr>
<td><strong>Redesign of the c-book unit ‘Musical Plane’ by the French-Spanish CoI-pair</strong> [Main Resp.: French CoI]</td>
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<tr>
<td>• The designers agreed on the fact that the organization of the workspace was actually facilitating the communication. The cross-CoI communication was organized by themes, the presentation by a tree actually helped focusing on some aspects rather than trying to go through the revision of a full list of items.</td>
</tr>
<tr>
<td>• The workspace contained the original and new redesigned units, so they could be compared immediately. The progress of the design was also evident, showing the different versions that were easily accessible. So it was easy to comment on, and access the redesigned pages. It was very helpful to know and to see all the scheme of the c-unit redesign to have a complete idea of the work done and the work in process. For instances, the different colours of the background were very useful to distinguish the phases or parts of the c-unit redesign, the comments tree structure was also clarifying, especially in moments where comments proliferating and to follow the thread of the contributions and replies to a one specific idea.</td>
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| **Redesign of the c-book unit ‘Limits_v2’ by the Spanish-French CoI-pair** [Spanish CoI] |
| • The workspaces allow the communication between all the CoI members involved although they don’t be together physically. In this sense the socio-technical environment has been crucial for the cross-CoI communication but also for the intra-CoI communication when the face-to-face meeting didn’t be possible as frequent as they desire. |
| • This environment fostered the communication also in affective way thanks of the opportunity of writing encouraging comments when there were good ideas. |
| • The tree-structure of the CoICode was very helpful in discussing about the different issues. It was very easy to follow the line of different comments about the same idea although there were a lot of comments and a lot of members involved in the line. So, CoICode becomes a tool that facilitates communications in a very constructive manner in order to find several solutions to educational and technical problems too. It provides the members the ability to share links, proto-widgets, etc. and it usually provoked productive discussions, new ideas and interesting changes in the redesign of the c-book unit. |
| • The fact the CoI members have to vote the comments fostered the reflection about all the process of redesign in a holistic view. |

| **Redesign of the c-book unit ‘Alice in Patternland’ by the Greek-English CoI-pair** [Greek CoI] |

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D7.2: Page 63 of 76
The use of CoICode environment for intra and cross-CoI communication

One of the affordances of the socio-technical environment that was mentioned by most of the CoIs’ members was CoI-code. It seems that it catalysed asynchronous communication and interaction within and across CoIs. Although problems were referred, especially with HTML5 version on tablets, it was important that members’ contributions could easily be addressed and commented upon while sequences of response-and-answer could be easily revisited which helped reflection, elaboration and clarification of ideas.

Versioning of the c-book unit: One of the advantages of c-book environment mentioned by the Greek CoI is that it enables easily to make copies of the c-book unit. This was considered important especially during the initial phase of the redesign because the Greek CoI members could easily experiment with successive versions while their constructions could be visible by the other members.

Collaborative modification, extension or deletion of the c-book unit’s content: After initial experimentations, the new widget instances were inserted in the shared version of the c-book unit. During this phase it was important that all members could instantly view any changes and insertions and they were able to modify the c-book unit.

Redesign of the c-book unit ‘Windmills’ by the English-Greek CoI-pair [UK CoI]

Some survey answers demonstrate that the introduction of feedback would not have been possible without the socio-technical environment (of course this is a ‘chicken-and-egg situation’ taking us back to Question 1 as if those features were not available or if the focus of the project was somewhere else this might not have happened). The feedback features made some activities became more straightforward and more importantly some of the assumptions about the role of the c-book in learning were revisited. A typical example is on the role of the Geogebra feedback in that it requires thinking of the particular context of use of the activity, and to which aspects does the learning designer want to draw attention.

3) Identify an episode you have participated (or observed) in which an important decision has been made about any aspect related to the redesign of the c-book unit. Please refer, for example, to a new widget, different contents, other pedagogical approaches, new sequencing, etc. Identify also the phase of the redesign process (the intra or the cross-CoI communications) the episode belongs to.

Identification of ‘critical’ episodes by CoI-pair members


The designers identified different episodes, some examples of the critical episodes detected are:

- How to promote creativity among students: “What struck me as a real step forward was the discussion about promoting creativity among students through organization of social tasks: chatting about music, how to organize that, how to copy-paste easily a subset of a score (something inherent to music), which lead, after some asynchronous discussion, to the text import/export of musical score as a set of points coordinates”.

- Detecting moment of divergent thinking: “The important thing that happened is when some CoI members decided after discussion of the structure of the c-book unit […]. It was the end of the first divergent thinking phase (brainstorming) and the beginning of convergent thinking which enable us to design a first redesign version of the c-book unit.”

- Identifying ideas that could not be finally integrated in the redesign: “In the cross-CoI phase I proposed to think about the possibility of making a change of coordinates in the widget, using square colours to identify
the origin of the system, [...]. Finally it didn't look interesting for the rest of the group, since it was out of the purpose of the c-book unit, and the comments of the other members made me change my mind and agree with them.”

Redesign of the c-book unit ‘Limits_v2’ by the Spanish-French CoI-pair [Spanish CoI]

- **The decision of including a new widget instance to work the infinity concept:** Several of the answers to the survey agreed that a critical episode appeared with the decision of including a new widget about the construction of the Pythagorean tree (Cinderella factory). This widget proposes to experience with some fractal constructions, conjecture about their regularities and patterns and to progressively approach the notion of infinity. **Appearance of new questions to include in the c-book unit and of new widget instances:** Related to this widget with the construction of the Pythagorean tree, there was an important episode when two members of the Spanish CoI proposed to study not only the relation between the sides of the different squares of the fractal structure, but also the relation between the successive areas. This discussion culminated in the design of two new motion-widgets with Geogebra (and two new pages of the c-book unit) to introduce the idea of convergent and divergent series that, in addition, improve the narrative coherence of the first phase.

- **Discussing about the best ways to open the phases and to formulate questions to structure the c-book unit:** Another critical episode detected has been the issue of how to open each phase of the c-book unit, which questions may be included and what freedom may be transferred to students to formulate questions and checking answers. One nice example can be found in phase 2 of the redesigned c-book unit of Limits where it was agreed the integration of a widget with the «nine dots puzzle» problem. This widget and the open-questions related to this, was included to help students to pose new questions about the number of solutions and the possibility of having several solutions depending on the conditions one decides to fix. In the same episode, with the same aim of leaving students the responsibility of facing open questions and formulating new questions, another widget was introduced (the EpsilonChat) to help students sharing, comparing and debating their responses.

Redesign of the c-book unit ‘Alice in Patternland’ by the Greek-English CoI-pair [Greek CoI]

- **The decision to exclude a MaLt2 widget instance:** A member of the Greek CoI proposed a widget instance in MaLt 2 to be incorporated in the second section of the c-book unit in order to offer a different approach to the students’ path towards generalization. However, the other members disagreed and thought that the widget instance was inappropriate regarding the age range and the focus of the activity. Although the widget instance was not finally incorporated, it triggered a very fruitful discussion about the targeted audience and the proposed activity that resulted in ameliorating and extending the activities of the second section of the c—book unit.

- **The kind of the initial c-book unit’s restructuring and redesign:** A main concern in the initial stages of the redesign of the c-book unit by the Greek CoI was the kind and depth of the c-book unit’s restructuring and redesign. The CoI members were wondering whether it would be better to keep the central mathematical concepts and change completely the c-book unit. They were also wondering whether it would be a good idea to add new sections or to merely improve and extend the existing ones. This resulted to proposing some new widget instances such as the ‘sunflower activity’. This was an activity based on Geogebra concerning Fibonacci numbers. These instances were interesting and creative, although there were not finally incorporated in the c—book for certain reasons.

- **Alice and Cheshire cat as central heroes:** Deciding about the plot and the central heroes of the narrative was a critical moment in the redesign process. Initially, it was proposed to use the story of Alice’s adventures in wonderland. The idea was welcome by the CoI members but progressively a new idea emerged: Change the title of the story to ‘Alice in Patternland’. From that time on Alice and Cheshire cat
were the central heroes of the redesigned c-book.

- **Discussing about questions’ formulation and answer checking:** A key point in the cross-Col communication was the issue of formulating questions and checking answers. It was suggested to make the questions that were addressed to the students as explicit as possible. The aim was to avoid questions such as "Can you help Alice?" or "Don't you think Alice needs some help?", since these questions could be potentially answered by a simple ‘Yes or No’. Instead, it was suggested to rephrase the existed questions so as to involve students in producing responses around the mathematical concepts negotiated in the c-book unit. Furthermore, thinking on how making the students’ answers meaningful for them it was decided to provide feedback, a choice pedagogically sound, especially if the c-book is to be used individually.

Redesign of the c-book unit ‘Windmills’ by the English-Greek Col-pair [UK CoI]

- The decision to keep the narrative despite initial reaction to remove it as (among other reasons) it would require a total re-think of the c-book to be without Don Quixote. Additionally, it felt like an opportunity to get the CoI out of its comfort zone and revisit some of its assumptions about the role of narrative. As mentioned in the creative path discussion, this marked a clear shift in thinking for the CoI.

- Extending the amount of scaffolding and being involved in discussions around feedback. This meant exploration of ‘helplines’, feedback-enabled answer boxes and explicit feedback on the Geogebra widget. Drawing on some of the CoICode discussions between the teams, the feedback features made some activities became straightforward and more importantly some of the assumptions about the role of the c-book in learning were revisited. A typical example is on the role of the Geogebra feedback in that it requires thinking of the particular context of use of the activity, and to which aspects the CoI designers wanted students’ attention to be drawn.

6.4 Results on the main research questions related to SC

Each team posed some similar research questions with respect to SC, and some different ones, considering their local contexts and theoretical approaches. These results will feed into D2.4 and Del 2.5.

Here we present the main results for each team.

**French team**

**SRQ1:** *What kinds of relationship between the CoI members, the CoI and the associated CoPs contributes to stimulating social creativity (SC) among the CoI members and to what extent?*

**SRQ1.1:** *What kinds of resources become boundary objects and under what conditions, and how they enable social creativity?*

First, the alien c-book unit and then, its CMT potential evaluation became boundary objects during the first stage of the re-design process. The first one enabled reflection leading to a new and enriched view of the unit and the second one allowed to bring to the fore the weaknesses of the CMT potential of the alien unit and guided the choices of the designers. This is why the first stage of the design has been actually a very good support for the next stages of the design process. The designers used the CMT evaluation of the initial c-book unit to scaffold their re-design work. The organization of the workspace was thought in a way to support the enhancement of the CMT, stressing the affordances the designers wanted to improve.

Second, the review of the c-book unit performed during the stage of cross-communication between the French and Spanish CoIs by the CoI members who were not involved in the design process, which became also a boundary object, showed that this stage fed efficiently social creativity; this was evidenced by the number of new creative ideas expressed. Moreover, the ideas expressed often matched the expertise of each member, but sometimes they were completely unrelated, such as the idea of saving the musical plane music.
SRQ1.2: What are the conditions that enable a person to become a broker, what is his/her role and to what extent does the broker’s role stimulate SC?

One resource that has missed was the participation of somebody who could have helped reify ideas in new widgets with Cinderella. Therefore, shortage in two resources, time and designers with some particular technical skills, hindered the design process. Thus a technical broker missed during the design process.

SRQ1.3: To what extent does the technology foster the social creativity?

The technology helped to foster asynchronous interactions between the designers from a strategic organization of CoI Code workspace.

SRQ2.1: What kinds of social creativity can be brought to the fore drawing on fluency, flexibility, originality and social elaboration measures? What factors fostering each dimension can be identified?

The level 1 of the methodology evidences social creativity during the second stage of the design process through a relatively high originality score combined with a relatively high fluency score and a medium score of social elaboration. One factor fostering the high fluency score was correlated with the number of individuals who interacted in the workspace and their motivation to contribute to the design in the short time planned for this stage.

SRQ2.2: What kinds of social creativity can be brought to the fore drawing on the identification of the stages of the design process?

Divergent thinking was encouraged during the first stage of the redesign process based on CMT and the cross-communication stage. Convergent thinking led to reification of the ideas within the c-book unit and resulted in various versions of the redesigned unit.

Spanish team

SRQ1: How is social creativity stimulated with MC Squared socio-technical environment in a process of cross-case analysis and redesign of a c-book unit? Which gestures, elements, phases, etc. of the socio-technical environment and of the process of redesigning enable a fluent interaction fostering SC?

The socio-technical environment fostered the interaction among members from both CoI at the first stage of intra-CoI redesign work as well as at the second stage of inter-CoI work. Two workspaces were created for each c-book unit to be re-designed (“Limits” originally from the French CoI, and “Musical plane” from the Spanish one), which supported the emergence of many new ideas out of the interactions. The use of CoI Code facilitated very much particular boundary-crossing mechanisms: first, among the members of the Spanish CoI who, although used to work together, now evaluated and redesigned a c-book unit, “Limits”, that was not designed under their ‘shared tradition’; second, members from the French primary-designers contributed to new transformations introduced in the c-book unit. In both cases, most of the CoI members had a very active participation at the time of proposing changes, or new content, to the c-book unit.

In our opinion, some decisions made fostered SC, as e.g. the roles assigned to particular CoI members, the moderation strategies, and particular gestures, which worked very well in enriching the interaction:

- The choice of a main moderator, external to the research team, helped to guide the intra-CoI and inter-CoI work, collecting and prioritizing the main ideas proposed by the team of designers. The moderator was also the key responsible of introducing changes in the c-book unit according to the ideas agreed and
to schedule and prompt the tasks to follow with. The moderator acted as boundary broker, enabling to overcome potential barriers among the different CoI profiles and traditions, facilitating, through collaboration, the progress in the design.

- Compared to WP7-cycle 1, the period of cross-CoI interaction was better planned. This helped us to invest more time and effort to exchange ideas and reach agreements with our CoI-pair. The selection of a second moderator, dedicated to fixing dates for planning the cross-CoI communication, was key, helping to enrich the tasks and fix the periods and deadlines for each kind of interactions.
- The design of the some new widgets (the Geogebra widgets-phase 1 or DME widgets for the 9-points problem) or the integration of some pre-existing widgets (the Cinderella widget of drawing fractals) was an outcome of a negotiation among the CoI-pair members. The construction of these widget instances became also key boundary objects which facilitated that the CoI members’ ideas were discussed, enriched and articulated.

**SRQ2:** How did different re-design periods (for instance the intra-CoI design work, or the cross-CoI re-design period) impact in the social creativity rates and measurements?

In the case of the redesign of the c-book unit of ‘Limits’ there were not big differences between the rates and measurements of SC indicators (Fluency-Flexibility-Originality-Social Elaboration values) if we analyse the first design period (when the Spanish designers team worked alone), and the second period of cross-CoI redesign work (when designers from both CoI were involved). The first period got an overall creativity score of 64.22% and the second one of 66.66%. Although not significant differences between these two rates were found, the three measurements concerning the number of posts (64 for the first period and 93 for the second), the fluency measurement (64 vs 87) and social elaboration (0.46 vs 0.63) are all bigger in the second period of design than in the first one. This could be due to the increase of number of persons involved in the design actively participating in the corresponding workspaces (4 Spanish CoI members in the first, and 6 members of the French-Spanish CoI-pair in the second).

On the contrary, flexibility (1.74 vs 1.69) and originality (0.72 vs 0.67) were rated better in the first period than in the second, when we observe that the time dedicated to the first CMT evaluation of the existing c-book unit in the workspace, allowed for the emergence of many new and original ideas (originality) and new ways and approaches of looking at them (flexibility), allowing for connecting and articulating these ideas.

**Greek team**

**S.R.Q7:** What are the main issues of a c-book unit’s design which structure and advance inter-CoI collaboration and exchange for social creativity?

The two main findings as they emerge from the whole process of the redesign and especially through the exchange were the status of the narrative as a vital component of the c-book unit and the progressive exploitation of the potential strength of the c-book technology. Narrative constitutes a constant point of concern for the Greek CoI and plays central role in the whole series of the produced c-book units. Through the cross-CoI interaction the narrative crosses the borders and starts gaining appreciation from the UK CoI that had reservations about its usage. Actually, it became the motivation for a future collaboration between the two CoI, since the UK CoI proposed to use a similar idea (the movie Donald in Mathmagic Land) as the starting point for a new common c-book unit.

The second finding makes evident that there was a progress in our understanding of what makes c-book technology different from the existing ones. A noticeable example is the co-existence of multiple widgets in the same page that correspond to different (interconnected) representations of the same concept. This affordance of the c-book technology was noticed, discussed, and utilized during the redesign process.

**UK team**

**S.R.Q1:** How can the interactions about the c-book (as improvable boundary object) between CoI members affect the CoI’s performance in terms of social creativity?

We have seen the interactions for the c-books have been crucial in the development of the c-books. Many c-books were sparked by a creative idea, widget or existing artefact (whereby an artefact can also be a
The c-book authoring environment overall and the developments of the book acted as triggers for further discussions around the general design of the c-book (e.g. structure, sequence of pages, widgets) and, at times, innovative uses of widgets or their affordances. The Col did not use CoiCode much for the redesign phase, but did use CoiCode in the exchange phase. It seems that although a lot of creative communication can take place outside of CoiCode, the tool helped when initial ties were less strong, for example geographically different regions. The fact that all communication threads are in one environment was particularly handy. One thing that was, however, a bit unfortunate is that although many Col members (and also people not in the Col but outside of it) interacted about the c-book it often wasn’t
- Actual authoring of the c-book;
- Communicating in a standardized way, like in CoiCode.

If we take these two elements as indicators of performance then there is a lot to want to improve. There is, however, in our opinion a balance to be struck between institutionalizing these two elements and the aforementioned fluidity of the Col.

S.R.Q2: How can the social creativity process elucidate the design of the feedback that c-books or widgets provide and the configuration of data that is useful for Learning Analytics purpose?

One particular focus our Col has was the development of Learning Analytics (LA) and feedback. One of the pages was connected to an authoring tool for LA feedback (Authelo). The SC process informed the development of these (LA) pages. An indication of what this look(s) like is in the Annex.
7 Synthesis of findings on CMT and SC in the redesign phase

In reflecting on the methodology used on CMT and SC, we will first focus on our representations of CMT. After the first cross-case external evaluation in cycle 1 of WP7, and in order to unify the different representations of CMT potential that each CoI had, the four CoI's decided to create a common evaluation tool. As a result, in cycle 3 of WP6, we presented a grid with several features to be considered by the evaluators. One may find a wide description of this grid in D6.3 (page 66), but also a summary in Section 3.1 of this document, as well as the Appendix here with the grid.

Despite that, during this cycle, there are some particularities in the representations of CMT of some CoI's, and moreover, the ulterior analysis of the data collected differs in each team. This respond to the fact that contextual characteristics of the CoI were influencing the co-design process, since the CoI, when reflecting on a specific alien c-book resource, and further creatively redesigned it, was considering their theoretical conceptions, research and pedagogical practices, and national educational context. Let’s now analyse these differences.

For the French CoI, the scale according to which the items are classified is slightly different from the common one: Value 1 means "no affordance" (the corresponding item is present in the c-book unit but it does not foster the given dimension of the CMT); value 2 means "weak affordance" (the item might foster the given dimension of the CMT, but it is rather unlikely); value 3 means "good affordance" (the item might foster the given dimension of the CMT); and value 4 means "strong affordance" (the item is likely to foster the given dimension of the CMT). Actually, this scale is rather similar to the "totally disagree-disagree-agree-totally agree" used by the other CoI, so we think that the results are comparable. With respect to the metrics, the French CoI used the mean (average) of each component evaluated (the four cognitive processes together with social and affective aspects) to have a global conclusion on the CMT potential of the unit. This let them use a radar chart-type graph to represent the CMT potential of the unit (see Figure 5.2.1) as well as a comparison between the CMT potential of the c-book unit before and after the redesign.

The Spanish CoI does the analysis and computes metrics of the four cognitive processes together with social and affective aspects, but keeps a classification they previously used in D7.1 and D6.1-D6.2 in now 5 categories of the different affordances of the grid (see Section 3.2). Nevertheless, this classification is used for a more qualitative analysis. The Spanish CoI use the median to identify the level of agreement in terms of the fostering of each cognitive process (Fluency, Flexibility, Originality and Elaboration, from now on FFOE), as well as Social and Affective Aspects, and the interquartile range to identify the degree of agreement among the reviewers. Moreover, they also give the mean as a measure of symmetry (compared with the median) of each feature, but also to construct a radar graph and, as the French CoI, give a general view on the CMT potential of the c-book unit (see Figure 5.2.3).

The Greek CoI exposes that the proper metrics for this analysis are the median and the interquartile range, representing them in a boxplot for the four cognitive processes (see Figure 5.1.3.3). A visual comparison of this with the previous CMT potential evaluation (see Figure 3.2.12) gives an idea of the improvement of the CMT potential of the unit. In addition, they also analyse each item independently. Regarding Social and Affective Aspects, although the Greek team didn't mention a general metric in the previous analysis (since they analyse each item independently) they give the metrics of them (mean, median, IQR) from the last evaluation.

With respect to the UK CoI, they highlight in their analysis the highest valued items, and give metrics (mean, median, IQR) of the four cognitive processes, as well as of the social and the affective aspects. Regarding Figure 5.2.7 the UK CoI considers that the metric that better describe the CMT potential of the c-book unit are the averages, since they use them to compare the original and the redesigned c-book unit.
All the four c-book units have improved their CMT potential, according to the documented analysis of both CoI pairs. The French CoI asserts that the connections stated between mathematics and music in the c-book unit “Musical plane” (sounds and expressions of functions, symmetries…) make all cognitive processes and aspects evolve from “weak affordance” to “strong affordance”, and especially Originality, Elaboration and Affective Aspects, underlining the role played by the EpsilonChat widget and the careful care on the aesthetics of the c-book unit. Here the initial evaluation of the CMT potential of the c-book unit played a main role in improving the weak points of the unit. The Spanish CoI highlights the main role played also by the initial evaluation, but also by the cooperation process in the redesign, in which the different conceptions of CMT trigger boundary crossing, and become an object of thought for each CoI-pair (designing new activities and widgets to foster Fluency and Flexibility for the Spanish CoI, improving narrative and aesthetics to fostering affective aspects the French CoI). One paradigmatic example is the deepening in the features of the Pythagorean tree proposed by the Spanish CoI, which became a boundary object for the French CoI in the c-book unit “Limits”, and finally brought the design of new contents with new widgets. Hence, all cognitive processes evolve positively in this c-book unit (from "disagree" to "agree" or from "agree" to "totally agree" level), especially Flexibility and Elaboration, as well as Social and, mainly, Affective Aspects.

The positive influence of the different CMT representations of each CoI onto its CoI partner is also commented by the Greek CoI, making the narrative and the used of half-baked activities an object of thought for the UK CoI. According to the Greek CoI, this had an impact on the improvement of both c-book units developed by the Greek-UK CoI-pair, and all cognitive processes go from “not agree” to “agree” level in the c-book unit “Alice in Patternland”. In the case “Windmills II” redesigned by the UK CoI, the evolution of all the cognitive processes and social aspects has been slighter than in the rest of the c-book units, but the affective aspects have evolved deeply (from “totally disagree” to “agree”).

Despite the agreement of the four CoI in the evaluation tool, each of them emphasizes different aspects that condition the meaning of the results obtained from the ulterior analysis of the data. This is due to the fact that each CoI is inclined to still connections with local attitudes and contextual factors. For instance, the importance given by the Greek CoI to the presence of half-baked constructions in the design (identified as a weak point of their design) is not reflected in the analysis of the rest of the CoI. A similar phenomenon happens to the French CoI with the classroom orchestration (reflected in the group activities of their design), the Spanish CoI with the modelling of real life contexts (reflected in the search of a general narrative of their redesign) or the UK CoI with their care of a good match of the c-book unit with the curriculum (reflected continuously in their comments).

We could make a deeper analysis on how the different cognitive processes and Social and Affective Aspects influence the others. To this aim, and following the approach done by the French CoI in D6.3 and also in the CMT potential analysis of the “Musical plane” c-book unit, we present here a computation on the correlations between FFOE and Social and Affective Aspects. Correlations are considered significant when bigger (in absolute values) than 0.7 (the ones marked in colour). If we take the mean value of each component for each of the four c-book units redesigned we get the results below in Table 7.1.1.

<table>
<thead>
<tr>
<th></th>
<th>FLU</th>
<th>FLE</th>
<th>ORI</th>
<th>ELA</th>
<th>SOC</th>
<th>AFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLU</td>
<td>1</td>
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<td>0.94</td>
<td>0.97</td>
<td>0.6</td>
<td>0.52</td>
</tr>
<tr>
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<td>0.8</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
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<td></td>
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<tr>
<td>ELA</td>
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<td>0.78</td>
<td>0.28</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
<td>AFF</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7.1.1. Correlations between the four components in the chart for comparing both CMT potential analyses of the c-book unit “Windmills II”.

According to this, Fluency and Elaboration have a high and positive influence in all the other cognitive processes, and even though the correlation between Originality and Flexibility is not significant, it is very
close to 0.7. The most shocking results may correspond to the low correlation between Affective Aspects (last column) and all the other features but Originality (0.78). Moreover, the correlation with Social Aspects seems to be negative, but we think the data available here are not sufficient to come up with a conclusion. On the other hand, we observe that Flexibility and Elaboration affects positively Social Aspects. This may be due to the fact that many activities in the c-book units that are proposed to be done in groups promote Flexibility (different strategies) and Elaboration (setting new conditions for the problems, creating new ones), according to the comments of the reviewers.

As with respect to Social Creativity, we use the common theoretical and methodological approach to SC that has been exposed in Section 6.1. Focusing on the first level of this approach, in order to define a possible metric for measuring SC, there are two different approaches that the four Col have used, namely the French approach (used in this cycle by the French and the Spanish teams) and the Greek approach (used in this cycle by the Greek and the UK teams). A detailed explanation of the first one may be found in pages 29-32 of D6.3, and of the second one in pages 41-43 of D6.3.

During this process of cross-Col collaboration, each c-book unit has been redesigned in two different stages, with a different workspace, and then a different SC score, for each of them. The final overall creativity rate (final SC score) may be computed in two different ways: the first one is obtained by merging both workspaces into a new one and then make the corresponding analysis (French or Greek) of the merged space. The second way is as the average of both workspaces, weighted by Fluency (Fluency is the total number of post minus off-task comments). We present in Table 7.1.2 below both options. Here FLU1 and FLU2 are the "Fluency" of the workspace of phases 1 and 2, respectively; similarly, SC1 and SC2 represent the SC score of each phase. Hence, SC_M is the total SC score when merging both workspaces and SC_W is the total SC score when averaging weighted by Fluency.

<table>
<thead>
<tr>
<th></th>
<th>FRENCH APPROACH (0-100)</th>
<th>GREEK APPROACH (0-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FLU1</td>
<td>FLU2</td>
</tr>
<tr>
<td>FRANCE</td>
<td>41</td>
<td>78</td>
</tr>
<tr>
<td>SPAIN</td>
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<td>30</td>
</tr>
<tr>
<td>UK</td>
<td>6</td>
<td>53</td>
</tr>
</tbody>
</table>

Table 7.1.2. Total SC scores of all c-book units.

First, we note that, in the French approach, both total SC scores are very similar, but not when using the Greek approach, in which both total SC scores may vary around 1 point (over 10). Attending to the definition of the formulas applied in each approach, it turns out that the Greek one is more sensitive to the number of commentators. Instead, in the French approach the number of commentators just plays a role when defining "Social Elaboration" and, moreover, only "active contributors" (the ones with more than the 5% of the total comments. Hence, using the French approach one may use any of the two total scores, but in the case of the Greek approach, choosing a weighted average seems more convenient.

The differences between both approaches with respect to the total SC score may make one conclude that both methodologies are not compatible. However, a careful read of the statements of each of them (D6.3, Section 3.2) shows that both methodologies share the same theoretical frame and their fundamentals, so they are just two different ways of measuring SC. The French approach deals closer with the tree structure of the CoI Code when associating a metric to Flexibility and Social Elaboration, and the number of contributors (active contributors, actually) affects only in the definition of the metric of Social Elaboration. Furthermore, the effect of the number of active contributors in the overall SC score is reduced when this is number is much smaller than Fluency. On the other hand, the Greek approach deals deeper with the system of votes (and so the opinions of contributors), and the total number of contributors appears in the metrics defined for Originality and Social Elaboration. Hence, the Greek approach, especially if we give a high weight to Originality and Social Elaboration with respect to Flexibility (which is the case here) is more sensitive to the
number of contributors (and their participation in each tree of the workspace). Hence, merging workspaces with different contributors is not a proper way for defining an overall SC score. We think that both approaches are valid and compatible, but the Col should state some rules of participating in the CoICode before starting the design of a c-book unit in order to make the final formula reflect in a proper way the SC processes that emerge during the design. Nevertheless, in terms of obtaining reliable conclusions when comparing different processes of designing a c-book unit, we should then follow always one of the methods.

In this line, we may only compare each score with the ones obtained for the units designed for each Col during cycle 3 of WP6 (see Section 3 of D6.3). Hence, in the cases of the French Col (mean 58.42, standard deviation 8.19) and the Spanish Col (mean 57.95, standard deviation 10.04) following the French approach, and the case of the Greek Col (mean 6.15, standard deviation 0.67) following the Greek approach, the three c-book units have an overall creativity score slightly higher than the average, which drive us to think that the participation of several CoI affects positively in the enrichment of Social Creativity, evidencing the boundary crossing among communities with different contextual conditions and theoretical approaches (we should remark that in D6.3 there is some information missing on the units designed by the UK team, then we cannot consider their data in this analysis).

If we focus on the qualitative analysis of SC, first of all the four Col have presented the main stages of redesign of their corresponding units. Although there are some commonalities, we may underline a main difference, which has to do with the cross-Col design process. In the case of the French-Spanish Col pair the cross-Col stage covered a longer period of the redesign than in the case of the Greek-UK Col-pair. This may be reflected in the analysis done by the c-book designers and the reviewers, since the French and the Spanish Col admit a better synthesis of the views of both Col, and hence, both c-book units contain approaches from both Col adapted to the contextual features of each local partner. A careful read of the analysis done by the Greek-UK Col pair reveals that this phenomenon just happened in one direction (the UK Col adopts the Greek approach, for example, with respect to the importance of the narrative).

Regarding the emergence of creative ideas all the four Col teams recognise that the cross-design process has triggered the emergence of creative ideas. In the case of the French-Spanish Col-pair they refer ideas from both stages (intra-Col and cross-Col). Regarding the Greek-UK Col-pair, the main creative ideas proposed in the redesign emerged during the Greek intra-Col stage, however the UK Col considered them as a highly creative idea, adopting them in the redesign. Then we can consider the emergence of creative ideas at these three levels: adoption of an alien idea, redesign of an idea, and collaborative design of an idea. These SC instances, although different, are equally valid, and can be considered in different cross-design processes.

With respect to the use of the socio-technical environment, the four Col appreciate the use of the workspace (CoICode) as an important tool for the development of the redesign of the unit, especially in the cross-Col stage, when f2f meetings are not possible. Hence, the socio-technical environment is an important affordance to trigger SC. For example, it has been a tool that helped the designers to produce collaboratively creative ideas; for the moderator it was a tool that facilitated Col’s orchestration and helped to keep the whole work well organised and functional. Furthermore, it is a very useful tool for researchers when identifying SC processes, since they track the path of creative ideas as well as reflect critical episodes.

Finally, regarding ‘critical’ episodes:, the ones identified by the four Col have some common features that could be presented in two different groups: a) Some of them refer to the technology (necessity of new widgets or changes in existing ones), and have emerged from ideas and contributions of members of both Col pairs (for example, intra-Col stage in the redesign of the c-book unit “Alice in Patternland” or cross-Col stage in the redesign of the c-book unit “Limits”); b) Some others refer directly to confronting different CMT representations of the Col-pair. For example, the narrative in the redesign of both c-book units of the Greek-UK Col pair becomes a boundary object for the UK Col. Another example is the reformulation of some questions and ways of giving answers (with the intention of giving the chance of making the c-book unit more open, so users can propose their own questions and also give answers with enough freedom) for the French-Spanish Col.
To sum up, according to the answers given by the CoI in the research questions in Section 6.4, the cross-CoI communication has definitely fostered SC. The socio-technical environment is highlighted by all CoI as essential for this purpose. The French CoI underlines the first CMT potential evaluation as a central boundary object for the first stage of the redesign (intra-CoI stage), but also the first version given by the French CoI to the Spanish CoI when starting the cross-CoI stage. The Spanish CoI stresses the better organization of the process during this cycle and the role played by the main moderator, external to both research teams, who became a boundary broker and facilitated the integration and acquisition of alien ideas and made each CoI team leave its conformability area to adopt the other CoI representations. The Greek CoI outlines the discussions on the narrative (a vital component of the c-book unit) and the progressive exploitation of the potential strength of the c-book technology as the main features that has fostered SC. The UK CoI underlines the use of the CoICode during the cross-CoI stage as a proof of the increase of SC during the process.

Finally, we reflect on an approach for measuring CMT potential. We consider that it would be interesting to study the relation between SC processes and the final outcome of these processes, that is, the c-book units in terms of their CMT potential. Having defined a metric for SC, the next step should be defining also a metric for CMT to make a comparison.

The Spanish CoI proposed (page 67 of D6.3) a metric to describe the CMT potential of the unit, based on the radar graph in Figure 5.1.2.4. This metric is the percentage of the big hexagon filled by the hexagon corresponding to the unit, which is obtained by giving the mean of each component (FFOE, Social Aspects and Affective Aspects) to each vertex of the hexagon. We have computed these metrics for each c-book unit in Figure 7.1.3.

![Radar graphs and CMT metric of all the c-book units.](image)

Musical Plane: 73.01%  
Limits: 56%  
Alice in Patternland: 45,13%  
Windmills II: 52.59%

Figure 7.1.3. Radar graphs and CMT metric of all the c-book units.

In D6.3, Section 4, page 85 this metric was used to study the relation between SC and CMT. There a positive correlation of 0.74 between SC (following the French approach) and this metric for CMT was found. Hence, making these calculations for the cross-experimentation done using the four redesigned c-book units (choosing the French approach, for the sake of consistency, and the SC_M as the overall creativity score), we
get a correlation of 0.56, smaller than the one in D6.3, but still positive. This fact agrees with the idea that a higher social iteration and exchange of new ideas will affect positively to CMT affordances.

Nevertheless, we think the data available here are not sufficient to come up with a conclusion. Furthermore, we must underline here the influence that the local contextual characteristics have in the evaluation of the CMT affordances, which limits the definition of an objective metric of CMT. Hence, we cannot assure that a c-book unit with lower CMT score is less creative than another c-book unit with a higher one, since this metric depends strongly on the CMT representation of the corresponding CoI.
8 References


