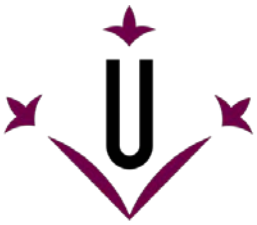

**PRE-PRINT VERSION OF THE PAPER:**

Pifarré, M. (2019). Using interactive technologies to promote a dialogic space for creating collaboratively: a study in secondary education. *Thinking Skills and Creativity, Volume 32, 1-16*. **https://doi.org/10.1016/j.tsc.2019.01.004**

# Using interactive technologies to promote a dialogic space for creating collaboratively: a study in secondary education

Manoli Pifarré

**Manoli Pifarré,** Psychology Department, Universitat de Lleida, Spain. Address: Avinguda Estudi General, 4. E25001, Lleida (Spain)

e-mail: pifarre@pip.udl.cat

**Summary**

This research expands our understanding on the role of interactive technologies to draw learners into a dialogic space capable to promote ways of thinking creatively together. Grounded on dialogic theory, the research examines and characterizes the emergence of co-creative processes in an interactive technology framework. To this end, this paper reports on an empirical study with secondary-school students who followed a technology-enhanced dialogic pedagogy that promotes co-creativity in real secondary-education classrooms. Qualitative methodology was used to document real-life multimodal interaction. The video data was processed in different phases to develop an analytical framework capable of identifying strings of episodes indicating typical facets of technology-enhanced co-creative processes. Results provided seven typical co-creative facets: 1) collective framing of the task; 2) overcoming technological challenges; 3) engagement in generating a shared pool of ideas; 4) developing intersubjectivity; 5) fusing ideas for a new perspective; 6) evaluation of ideas and 7) making ideas a reality. Furthermore, the findings show that each co-creative facet covers specific objectives in the co-creativity cycle and presents distinct features along three key dimensions: a) co-creative processes involved, b) typical discourse features and, c) dialogic use of specific technology affordances (e.g. visibility, interactivity, responsiveness, multimodal representation, provisional, stability, re-usability) for co-creating. Future educational implications to design a more

effective technology-enhanced dialogic pedagogy that can connect learners to their creative potential are also discussed.

**Key Words**

Collaborative Creativity; Interactive Technology; Dialogic Education; Multimodality, Interthinking; Secondary Education.

## 1. Introduction

The term "Homo Connectus" (as an evolution of "Homo Sapiens") was first coined by some creative and innovative brands as a metaphor to visualize the power of the impact of interactive technology on humans' behaviour (e.g. consumption, leisure…) and creative thinking. This metaphor encapsulates the idea of humans connected with others, sharing and externalising their ideas in open spaces, interplaying with others' voices expressed through different and multiple multimodal channels. As a result of this active on-line dialogue, new, dynamic and co-created knowledge emerges.

Although many qualified voices have stressed the potential benefits of interactive technologies in engaging people in co-creative settings (Wegerif & de Laat, 2011), little is known about what collaborative creative processes are triggered when interacting with digital technologies and what mechanisms elicit the students' engagement in co-creative actions in technological environments (Davidsen & Vanderlinde, 2016; Hennessy, 2001; Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010). The research in this paper aims to fill in those gaps in our knowledge and discusses the potential of interactive technology as a means of promoting a dialogic space for co-creation because it has affordances that can open up, widen and deepen the learners' opportunities to generate, modify and reflect on new ideas through multimodal interaction along with talk.

To focus this discussion and examine the emergence of collaborative creativity processes supported by technology in real-classroom settings, this research describes an empirical study with secondary-age students who followed a technology-enhanced dialogic pedagogy for finding, in small groups, creative solutions to one real-life and social challenge. This paper focusses on small-group work around and through technology to capture the emergence of co-creative processes in a multimodal interaction supported by technology and understood as "multimodal ensemble" of communication

(Goodwin, 2000) which can include different modes such as gaze, movement, gesture or talk. The data obtained have made it possible to develop a characterization of co-creative processes as a psychological inter-mental phenomenon (Glăveanu, 2010; Palmgren-Neuvonen, Korkeamäki, & Littleton, 2017).

Additionally, the paper highlights the importance of the dialogical use of technologies in supporting the emergence of a dialogic space for creating collaboratively which implies mutual attunement and mutual understanding. Finally, the paper presents the educational implications of designing a more effective technology-enhanced dialogic pedagogy to connect learners with their creative potential.

## 2. A dialogic account of collaborative creativity

There is growing interest in creativity as a social and situated phenomenon (Glăveanu, 2010; Glăveanu, Gilliespie, & Karwowski, 2018; Plucker, Beghetto, & Dow 2004). Creativity is conceived in those fields a part of a joint activity to generate new ways of solving a collective problem (Hämäläinen & Vähäsantanen, 2011). Research concludes then that creativity entails a communicative experience, intersubjectivity and interactive dialogue (Negus & Pickering, 2004) and there is a need to investigate how to better orchestrate the joint creative activity (Sawyer, 2012).

Collaborative creativity based on dialogic theory has been defined as the emergence in the group of new perspectives from the interplay of voices (Wegerif et al., 2010). From this perspective, creative thinking is learnt in the context of a dialogic space characterised by joint interactions, intersubjective orientations and rich and reflective dialogues. One main concern of dialogic theory is the need to investigate more about ways to promote powerful and rich dialogues among teenagers in which constructive tension between different perspectives could be established and become the seed that would grow into fruitful group creative-thinking mechanisms.

The acknowledgment of the social nature of creativity charted the interest in identifying the characteristics of the dialogue and the dialogic space of joint activity and relationship that promotes seeing and feeling things from a new perspective. I will discuss this piece of research with the aim of developing a theoretical framework for understanding and learning the characteristics of co-creative dialogues. This discussion focuses on the following five characteristics: 1) open-ended situated "living" dialogues; 2) open-mindedness; 3) holding different perspectives; 4) a multi-voiced

dialogue and 5) togetherness.

Firstly, Wegerif et al., ( 2010) claims that the dialogic approach of creativity begins with open-ended situated "living" dialogues with no forehand direction in which the meaning that flows in the dialogue depends on a tension between different perspectives. The concept of *Middle c* creativity (Moran, 2010) can contribute to promote real and open-ended creative dialogues because it enhances the "situated-ness" (Plucker et al., 2004) of creative activities which are located along the middle of the continuum between the idiosyncratic end (or little-c creativity, Craft, 2000) and the universal end (or Big-C creativity). Middle-c creative activities are developed in participation and in collaboration with others in a small-community of people to solve wider social group challenges. In such peer-group communities, creativity emerges within dynamic processes of collaboration and co-construction that lead to new solutions for the issues to take.

Secondly, open-mindedness is another characteristic of co-creative dialogues. In an attempt to develop the concept of dialogic open-mindedness, Wegerif et al., (2017) claim that this concept includes cognitive openness to new information and active processing of this information in a coherent identity and the ability to partially inhabit the positions and feelings of others. In this vein, recent experimental studies claim that the perspective taken is one of the key indicators to explain the emergence of original ideas in dyads when solving a divergent task (Glăveanu et al., 2018; Harvey, 2013).

Thirdly, another key component of the dialogic learning theory is the gap between voices in the dialogue in which various voices are in relationship and able to inter-animate and inter-illuminate each other (Wegerif, 2007). The capacity of holding different perspectives together in tension is viewed as a resource for the emergence of new positions. Therefore, bringing more voices into the dialogue and learning from the creative tension between them is a key aspect for understanding the emergence of co-creativity processes.

Fourthly, creative dialogue has also been characterised as a multi-voiced dialogue. Different strategies have been identified that help group members play and incorporate other's group members' ideas in the dialogue and, consequently, facilitate the emergence of a new perspective or a new way of conceiving the issue under discussion. In this line,

numerous researchers (Harvey, 2013; Howes, Healey, Hills, & Howes, 2015; Kohn, Paulus, & Choi, 2011) conclude that different perspectives emerge in a group when participants display the following three strategies: a) building on ideas; b) combining ideas and c) reflecting and evaluating ideas in a cycle that creativity researchers have named as the balloon cycle -an expanding stage of divergent inter-thinking, followed by a convergent inter-thinking stage (Sawyer, 2012).

Regarding the first strategy of building on another group member's idea, it involves recognizing his/her idea as promising and selecting it for further elaboration. Research has identified that building up on others' ideas is supported by a co-constructive talk typically referring to chaining, integrating, elaborating or reformulating each other's contributions to create meaning (Palmgren-Neuvonen et al., 2017; Rojas-Drummond, Albarrán, & Littleton, 2008). As regards the second strategy of combining ideas, it consists in recognizing the similarity between different ideas, abstracting a broader concept and integrating the ideas into a new conceptualization; all these actions create something new. This is confirmed in Thagard & Stewart (2011) study that highlights creativity insights come from novel combination of representations. In the Findings section of this paper the readers can find different examples of this strategy like the one in which students, after a thorough examination and discussion of two painted walls that were found near the school (a "painted" tetris and a "mosaic" landscape), combined some characteristics of both pictures to create their own design (sea landscape formed with squares of a tetris). Finally, social reflection and evaluation of some ideas is the third strategy that characterises multi-voiced and creative dialogue. Social evaluation of an idea demands the originator to give further justification and exemplification about its value and these new arguments enrich the dialogue among the members of the group (Glăveanu et al., 2018). In this vein, Hao et al., (2016) claim that generation and evaluation of ideas alternate during creative processes, and idea evaluation has positive effects on the group creative outcome. Exploratory talk (Mercer & Littleton, 2007) supports the combination and evaluation of ideas in which explicit reasoning in the form of arguments and counter-arguments is made visible (Harvey, 2013; Palmgren-Neuvonen et al., 2017; Vass, Littleton, Jones, & Miell, 2014).

To finish with, togetherness, physical and affective dimensions are also important in dialogic co-creation (Sakr, 2018; Thagard & Stewart, 2011; Vass & Deszpot, 2017;

Vass et al., 2014). The development of trust in each other at emotional, social and cognitive level is crucial in co-creation. In this vein, Wegerif (2005) points out that playful talk is important to foster cohesion and joint meaning-making in co-creative situations because playful talk involves making verbal puns and imaginative associations with words (Wegerif, 2005). Shared embodied responses among peers can enhance the development of trust, emotional creative attunement (Vass et al., 2014), group flow (Sawyer, 2012) or multimodal interaction and communication (Sakr, 2018). Therefore, it is argued that, when studying co-creativity, one should focus on students engagement by monitoring a wide range of modes of interaction including gaze, facial expressions, body orientation, movement, gesture and touch (Sakr, 2018; Vass et al., 2014).

## 3. Interactive technologies and collaborative creativity

The medium is an essential part of the social creativity process, and creators often get ideas while working with their materials and symbolic resources (Zittoum, 2007). Understanding the potential of interactive technology for resourcing and promoting creative dialogue and learning is a key strand of educative research (Major, Warwick, Rasmussen, Ludvigsen, & Cook, 2018; Mercer, Hennessy, & Warwick, 2017). Technology can play an important role in mediating students' actions and dialogue as well as engaging them into meaning-making and knowledge-creation (Säljö, 1999). We think with and through artefacts that constitute mediational means that have both certain affordances and constrains (Mercer et al., 2017). Previous research has characterised ten distinct features of interactive technology that can play a role in promoting and shaping co-creative dialogues (Hennessy, 2011; Loveless; 2002; Rogers & Lindley, 2004; Sakr, 2018). These ten features of interactive technologies potentially offer strong support for cumulative, collaborative and recursive learning (Hennessy, 2011; Major et al, 2018).

*1) Accessibility* to others ideas: new open access software enables easy creation and access to multi-user shared-spaces; 2) *Connectivity:* via internet or Wi-Fi connection; 3) *Visibility* for all the members of the group which helps maintain simultaneous focus on shared ideas and artefacts; 4) *interactivity and immediate responsiveness* to others' ideas and contributions which widen the communication among peers; 5) *Direct manipulation* of shared artefacts to aid the development of joint meaning-making and joint insights; 6) *Multimodal representation* of ideas can be thought-provoking because

it can lead to deepening and widening understanding of shared ideas; 7) *Tangibility* of information such as explicit inferences and reasoning can widen and enrich; 8) *Provisional*, refers to the fact that all actions done in the digital shared-space can be modified and expanded by building on and evolving shared-artefact. This feature can stimulate "if-thinking" (Craft, 2000) because students can interplay with their ideas and voices leading to many different possible paths that can be analysed at different points in time; 9) *Stability*, all the actions and ideas using technology can be maintained and saved; and 10) re-used (*re-usability)* and re-visited across time.

These features enable the creation of a tangible dialogic space fostering co-creativity that can embody physical actions (through direct and visible manipulations), cognitive representations (through the construction of shared-digital artefacts) and emotional relationships (through multimodal shared experiences). This multifaced dialogic space opens up, widens and deepens learner's opportunities to be engaged in a co-creative dialogue by generating, sharing, expanding, explaining, justifying and reformulating ideas -using language and/or other symbolic representations (Mercer et al., 2017; Wegerif, 2013).

A significant proportion of research on the role of technology in supporting dialogue and learning has been conducted using interactive white boards technology, in whole class dialogue conducted by the teacher (Coyle, Yanez, & Verdu, 2010; Mercer, et al., 2017). Other research has focused on investigating the development of dialogue supported by technology in primary-education small group work (e.g. Kazak, Wegerif, & Fujita, 2015). In contrast to previous research conducted mainly in primary education and in whole-class setting context (Engin & Donanci, 2015; Higham, Brindley, & Van de Pol; 2013), this study will contribute with further research in the use of a whole collection of interactive technologies in promoting or inhibiting rich dialogues during small group interaction for co-creation in a secondary education.

## 4. The study

This study is part of a larger design-based research project involving secondary schools teachers and students with the aim of promoting co-creative learning through technology and active involvement in research from teachers. Specifically, the study aims to answer the following two research questions:

1. What kind of co-creativity processes emerge when students use interactive

technology dialogically?

2. How does interactive technology support the emergence of a dialogic space for co-creation among peers?

### 4.1. Context and participants

This empirical study was conducted in a Spanish secondary real-classroom within a science, technology, arts and maths curriculum. Twenty-five, secondary education students, aged between 12 and 13, and three teachers participated in this study. Students worked in small groups of 4/5 students and, whenever technology was used, students worked together in a shared-digital space; every student worked and was connected to the shared-space with his/her own laptop. Throughout the project, each group of students was seated forming a square to ensure that students could interact verbally and visually with each other. The students took part in a STEAM (Science, Technology, Arts and Mathematics) creative project, spanning 12 two-hour lessons (24 hours in total) and divided into six different phases with distinctive creative learning objectives. In turn, each phase was divided into different tasks with tangible learning goals. Find bellow a detailed description of the project and its pedagogical underpinnings.

The research complied with the ethical code by requiring the school authorities and parental consent to allow participation of their children to the study. The research team guaranteed confidentiality and data protection of the children by assigning pseudonyms to each student.

#### *4.1.1. The educational intervention: The STEAM technology-enhanced co-creative project*

In this study, the paramount role of pedagogy when using technology in education (Hennessy, Deaney, Ruthven, & Winterbottom, 2007; Mercer et al., 2017) was addressed by designing a joint project between researchers and teachers in which the following seven pedagogical axes were included.

*1) Promotion of "middle c" creativity.* Both classroom and school were considered a small community capable of engaging students in "middle c" co-creativity to solve a social, real open-ended challenge significant to the school community. More specifically, the challenge came from the environmental school committee and consisted in outlining a mock-design for a new decoration for a wall of the school playground. The mock-design included a written explanation about the rationale behind

each decision, materials used and budget required. The proposed design had to raise awareness into the importance of being environmentally friendly. Eventually, the mock-design should be presented orally to a wider audience: the school's environmental committee formed by a representation of teachers and students.

*2) Significant and contextual learning of STEAM contents.* The 2015 report of the European Commission on Science Education (Hazelkorn et al., 2015) highlights the relevance of the STEAM skills for solving current social challenges in creative and innovative ways. Grounded on this report, the educational intervention was nurtured with STEAM contents of Science, which explains the knowledge about the concept of environmentally-friendly; Technology, which describes the existence of different type of materials to decorate the play-ground wall; Engineering, which applies the techniques used by students during the completion of the project; Arts, which elicits the students' creativity in project design, and Mathematics, which includes the measurement of the playground wall and the preparation of a real budget for the implementation of the small-group mock-design.

*3) Enrichment and orchestration of collaborative creativity processes.* Teachers designed different learning phases and tasks with tangible goals to orchestrate each group's creativity flow. The design of these phases and tasks followed Sawyer's (2012, 2013) creativity model. The different phases and activities revolved around three main creativity processes: a) *Divergent process,* in which students should generate and be open to new ideas and others' points of view; b) *Exploration process,* it refers to the co-working on the ideas emerged and on new relevant information and c) *Convergence process* in which students focus on searching a group consensus on decision, action or conclusion. Figure 1 represents a description of the different phases and tasks developed during the STEAM project. This representation takes the form of a diamond because it visualizes these three main creative processes: openness (divergence) – exploration – closure (convergence).

*4) Promotion of multi-levels of dialogue.* The designed pedagogy combined the promotion of small-group dialogue focused on outlining a group wall-design along with whole-class discussion focused on sharing and reflecting about the small-group work-in-progress designs. These two levels of dialogues aimed to reinforce the sense of a dialogic community working together to find the best solutions to the proposed

challenge instead of establishing a competition between groups trying to find the best solution.

*5) Creation of a dialogic space for thinking and creating together.* The dialogic space set in this study was influenced by dialogic theory (Wegerif, 2013) and Thinking-Together approach (Dawes & Sams, 2004; Mercer & Littleton, 2007). Students were encouraged to actively create, reflect and evaluate ideas by using effective communication skills and ground-rules. In Figure 1, these activities are spread in four different moments within the project labelled as Thinking Together (TT).

*6) Holding different perspectives and ideas.* All the activities of the project enhanced discussion among peers and negotiation of agreements. It was suggested to the students to provide more than one idea as consensus to widen the discussion within small groups.

*7) Dialogic use of interactive technology.* The creative STEAM project used two interactive technologies, namely, caccoo.com and sketcheboard.com. These technologies allowed the next actions: a) setting up a synchronic shared-space to which all users could contribute, play and speculate with each other's ideas; b) using different tools to manipulate and fashion all the information in the shared-space (e.g. group ideas, sketching…); and c) displaying visual representation of the group ideas by using different types of information, both linguistic and graphical.

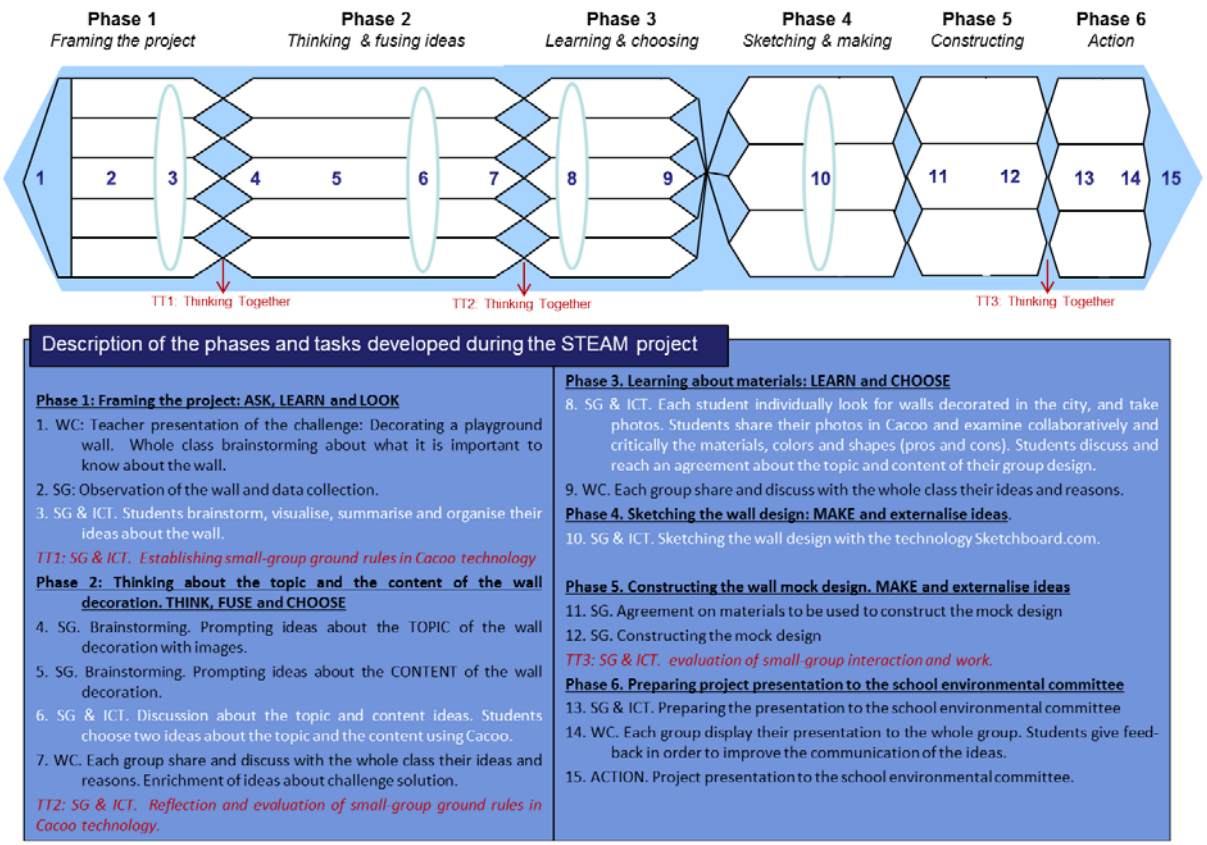


Figure 1: Representation and description of the learning phases and tasks developed during the STEAM project.

Legend: SG – task performed in small group; WC – whole; ICT - Computer is used (tagged as ICT); TT – Thinking Together activities.
Tasks rounded (i.e. tasks 3, 6, 8 and 10) are investigated in this paper.
In phases 1, 2 and 3, students worked in five small-groups, the five rows of the Figure represent these five small-groups. In phases 4, 5 and 6, students worked in three groups. Students decided to reorganise the groups attending to the topic and characteristics of the wall design.

## 4.2. Data collection

The data collected in this study consisted on video-recorded small-group discussion around and through technology in a real-life setting, and downloads of the students' shared work in the interactive technologies. Two cameras were used: one recorded the whole class while the other camera recorded one small group interaction randomly chosen. To help capture the interactions between digital technology and productive dialogue for creative learning, one of the students' laptop was screen recorded. For the purposes of this study, only data related to solving the four tasks of the STEAM project devoted to co-design the wall decoration (i. e. tasks 3, 6, 8 and 10, Figure 1) were considered.

### 4.3. Methodological process

Limited research has been conducted that authentically captures both oral and on-line interaction in technology-rich learning environments of the type that this paper is grounded on (Solli, Mäkitalo, & Hillman, 2018; Yang, van Aalst, Chan, & Tian, 2016). Considering the situational and contextual nature of the study of co-creativity (Craft, 2008; Glâveanu, 2010), the research reported here adopted a naturalistic approach (Corsaro, 1998) and applied qualitative research methodology (Sherman & Webb, 1988) using a dialogic approach (Sullivan, 2011) to document real-life classroom interaction through and around technology. A total of 5 hours of small group interaction supported by interactive technologies was considered. The adopted qualitative data analysis procedure consisted in the following five steps:

1. General written descriptions of small group snapshots.

2. Small group interactions both orally and digitally were accurately transcribed. Since students often used multimodal communication, the transcriptions were organised in two columns: one column shows the transcripts of verbal and non-verbal interaction among students. The other column shows the simultaneously recorded students' actions in the computer (in the Findings section some examples are further explained).

3. Based on the preliminary viewing of the video data, an identification of co-creative facets was done following a thematic analysis approach using principles from the Grounded Theory (Glaser & Strauss, 1967). The themes of this analysis were inspired by a thorough examination of the video data, the eight creative stages by Sawyer (2012; 2013) and the five inter-creating facets of Palmgren-Neuvonen et al., (2017). For the purposes of this study as many as seven facets were operationalized and used as the analytic framework to explore the characteristics of collaborative creative processes that emerged when students used interactive technology dialogically. Table 1 shows a definition of the seven co-creative facets. The appearance of these facets does not declare their temporal linearity. On the contrary, students' transit from one to the other in a zig-zag movement (Sawyer, 2013).

| Co-creative Facets with technology | Definition |
|---|---|
| Collective framing of the task | Participants' contributions focussing on building a shared understanding on the (sub)task. This includes the initial ideas, the initial procedures for solving the task and how to use the technology to solve it co-creatively. |
| Learning together from technological challenges | Participants' contributions aiming to overcome the technological difficulties in using the shared technology for co-creation. |
| Engagement and generation of a shared pool of ideas | Participants' contributions which result in opening-up a tangible and content-orientated shared-space in the computer screen and to be engaged in the generation of shared, new and creative ideas to solve the (sub)task |
| Developing intersubjectivity | Other-orientation interaction which result in turning point from individual ideas to collective ideas. This facet involves participants' contributions aiming to play with, to elaborate, to extend and co-create with each other's ideas in the digital shared-space. |
| Fusing ideas for a new perspective | Participants' contributions leading to a specific course of action or decision which result in a further elaboration of each other's ideas, or in a collective re-organisation of shared-ideas or in a transformation of shared-ideas in the computer screen. |
| Evaluating and Choosing ideas | Participants' contributions that actively develop criteria to reflect, criticize, judge, choose or discard common ideas. |
| Making ideas a reality | Participants' contributions which result in a final collective representation or organisation of shared ideas. |

Table 1: Definitions of co-creative facets used as the analytical framework of this study

4. Following Mercer's (2004) sociocultural discourse analysis, it is considered both verbal and non-verbal interaction together with computer actions as a whole in order to fully analyse the emergence of a specific co-creative facet. Longer sequences rather than the individual turns were established as the unit of analysis. Thus, the data were divided into interactive episodes (Linell, 1998), each one formed by several students' turns grouped together as a thematically meaningful unit of interactional exchange (Kumpulainen & Rajala; 2017). Moreover, researchers claim that the count approach by counting turns or ideas miss the way that conversation can influence the creative process (Glăveanu et al., 2018; Howes et al., 2015). To avoid that, a string of episodes was identified, each of which was linked to a particular co-creative facet.

5. The author and a researcher of our research group checked, discussed and agreed on the following: firstly, the process of dividing the data into interactive episodes with a clear focus based on the content of the data. Secondly, the analysis of the meaning of each interactive episode and its assignment to a particular co-creative facet. Thirdly, discrepancies were solved using a consensus-based approach.

6. Key typical and powerful interactive episodes were selected for each co-creative facet.

## 5. Findings

After conducting the data analysis presented in the previous section, the seven co-creative facets were actually found in the empirical data (see Table 1). In addition, the findings show that each co-creative facet covers specific objectives in the co-creativity cycle and presents distinct features. The analyses have identified three key dimensions that characterise each co-creative facet: a) distinct co-creative processes involved, b) typical discourse features and, c) the dialogic use of specific technology affordances. As shown in Figure 2, the distinctive features of these three dimensions established a dialogic space for co-creating with technology.

Based on the analytical framework and informed by features of creative collaboration (Vass et al., 2014; Eteläpelto & Lahti, 2008), by creative collaboration with technology (Hennessy, 2011; Kennewell & Beauchamp, 2007; Sakr, 2018; Wegerif et al., 2010) and by the different types of talk suggested by Mercer et al. (Rojas-Drummond, Littleton, Hernández, & Zúñiga, M.; 2010; Mercer & Littleton, 2007; Mercer, 1995); a description of emerging technology-enhanced co-creative processes for each co-creative facet was developed. Table 2 summarises this description and below follows an argumentative description of the technology-enhanced co-creative processes that emerge in each facet.

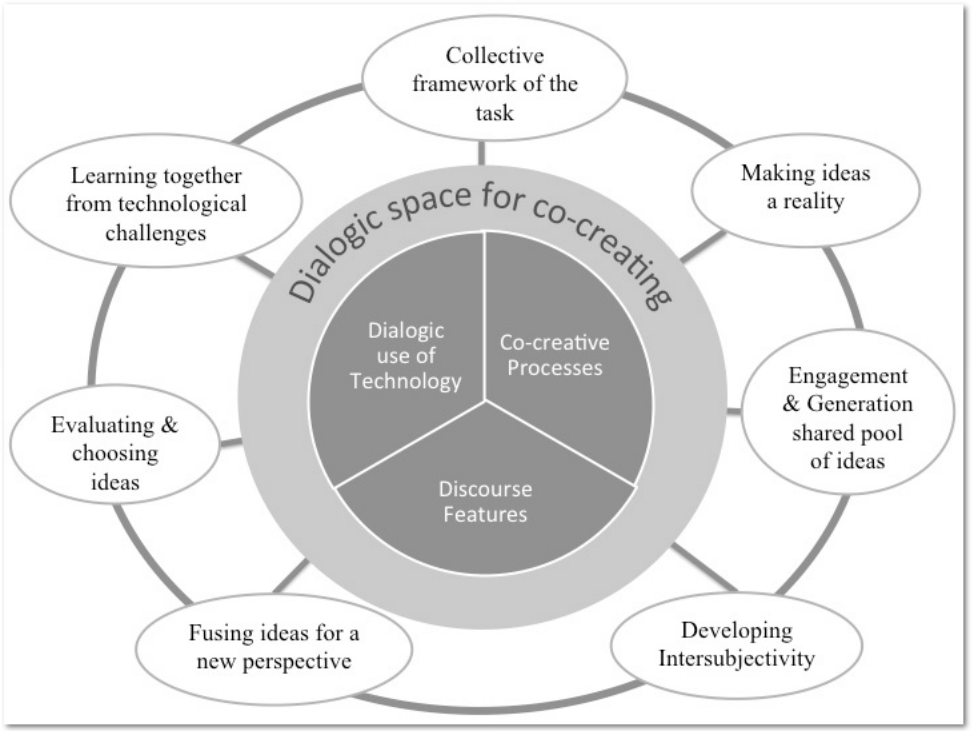


Figure 2. Facets and dimensions that characterize the technology-supported dialogic space for co-creating

*5.1. Collective framing of the task*

Research in collaborative creativity processes states that participants have relatively little shared understanding of the ill-defined task and its outcome (Middup, Coughlan, & Johnson, 2010). Consequently, it is crucial that students develop a shared understanding of the objectives and outcome of the task, as well as a definition of steps to make progress in the joint task. Data in this project reflects that students displayed shared understanding of the task when faced with an empty computer screen. In this situation, students performed actions addressed to pursue the following co-creative processes: a) Defining the task goals and expected outcomes; b) Acknowledging the topic and contents to discuss; c) Outlining the structure of shared-space in the computer screen or d) planning the first collective steps in the shared-space that could enable progress towards the task solution (Table 2).

In this facet, students performed dialogic features routed to open-up a common shared space and presented features of co-constructive talk. These dialogic features were characterised by open-ended questions about the task such as: *what shall we do? How should we start? Shall I insert a table in the middle?* The open questions caused a short-lived conversation in which students seek each other's opinions on how to proceed. Often, students expressed their individual opinions and understanding of the task along with the possible strategies to solve it without providing much reasoning behind each strategy.

Additionally, in this conversation, students presented high intersubjective orientation characterized by asking open questions; by looking and listening to each other showing interest in relation to the others' views; by using frequently the word "we" in the language of this facet; giving possible actions and suggestions using words such as "*if we", "I think we could…"*

Interestingly, during this facet students used the interactive technology affordances to re-visit and visualize previous work with an eye on maintaining continuity with previous group-work and finding clues or inspiration about how to start the common work or anchor new connections and ideas. Besides, finding an empty-shared space in the computer screen prompted joint discussions to set up the task.

*5.2. Learning together from technological challenges*

During the early stages of the project, students had to overcome technological challenges such as: difficulties to enter the shared-space; non-visualization of others' contributions in the shared-space; unfamiliarity with specific software options or no internet connection.

The technological challenges stimulated mutual emotional resonance which triggered students' openness to help the other group members. These efforts resulted in an enrichment of their common knowledge about software possibilities for better articulation and organisation of creative ideas. Participants showed togetherness in overcoming the various technological challenges posed by displaying the following actions: a) moving closer to the student showing signs of difficulty handling technological resources and offering help to solve his/her problems; b) giving concrete explanations on how to solve those technological issues; c) modelling how to solve the problem by giving explanations or showing his/her computer screen and d) working and learning together on how to better exploit the software possibilities.

*5.3. Engagement and generation of shared pool of ideas: hands-on*

In relation with the co-creative processes involved in this facet, they were characterised by collective brainstorming. A strong hands-on orientation was observed, whereby each student wrote cumulatively new ideas in the shared-space. The fact that individual ideas were visible and accessible by all the group members created a lively and dynamic brainstorming, in which all the members were engaged and contributed with new ideas and new content. Although students in this facet typically did not communicate much orally, students communicated through technology and showed high levels of engagement by shared gaze, facial expressions indicating acceptance of each other's contribution in the computer. In this facet, the interactivity of the technology used and the visibility of the other's thoughts in the computer screen as tangible objects allowed all the group members to join in the shared space, be engaged and contribute in the collective space with idea/content generation. By means of actions in the digital shared-space that resemble cumulative talk (Mercer, 1995), students proposed and added new ideas or they confirmed each other's ideas.

As an example of this facet, in task 3 of the STEAM project (Figure 1), students agreed to write the main characteristics of the wall collected during the wall observation.

One of the students took the lead by writing "*cement and brick porous*" (see Figure 5, framed in grey) right away, all other members of the group followed suit and started writing too. Each student wrote and added his/her new ideas cumulatively on the shared-space in the computer. Figure 3 presents this facet in the centre of the image.

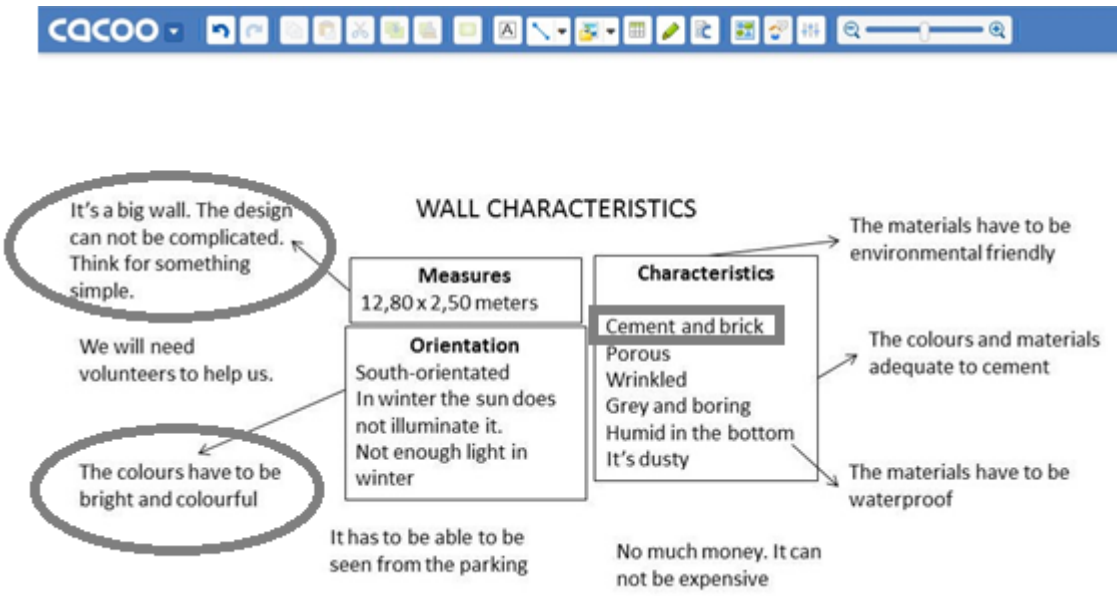


Figure 3: Example of students' engagement and generation of shared pool of ideas

Data analysis revealed non-verbal cues between students, e.g. nodding, smiling or glances, which showed clear engagement to the activity. In some instances, interactivity and responsiveness of technology elicited confusion among students who externalized their frustration or disappointment by saying things like: '*Who is writing this now?*', '*Who deleted my sentence?*', '*What is going on now*". These technological challenges resulted in an unexpected positive impact because groups worked in collaboration among its members to find solutions to the problem, hence, promoting shared meaning-making."

*5.4. Developing intersubjectivity: Opening-up of a co-creative dialogic space*

As the group learned to express its ideas in the technological shared-space, other-orientation emerged and students' dialogue and actions become more reciprocal. Students were able to open up a common dialogic space that was materialised physically in the shared-digital space and could interact by adding and editing each other's contributions. Students responded to each other intertwining verbal, non-verbal interaction and performing actions in the computer which generated "sparks of insights"

(Sawyer, 2006). In this facet, students' co-creation processes typically focused on joint idea generation and make ideas more complex, therefore, processes such as building-up on each other's ideas, developing and extending ideas were the most frequent. The following excerpt presents an example of how students generated ideas and contents collectively in the shared-digital space. Specifically, it shows the generation of the following ideas: *it's a big wall, it cannot be expensive and colours have to be bright and colourful* (note these ideas encircled in Figure 3).

| *Verbal/non-verbal interaction* | *Interaction through interactive technology* |
|---|---|
| *1. Girl 1: It's a big wall! It will be difficult to draw on it. We will need some help, painters?* | |
| *2. Girl 2: No, that would be too expensive* | |
| *3. Boy 1: I can draw ((smiling)) I have already drawn a graffiti with my cousin in my village* | *Girl 2: Writes: No much money, It can't be expensive* |
| *4. Girl 1. I don't believe you ((and laughs))* | |
| *5. Boy 1. Seriously, It's true! I am good at it ((showing pride).* | *Girl 1. Starts writing: It's a big wall* |
| *6. Boy 2. ((looking at the computer)) But we can do something simple and do it by ourselves ((gaze at boy 1))* | *Boy 2. Continues writing: the design can't be complicated. Look for something simple* |
| *7. Boy 1. (nods)* | |
| *8. Boy 2.((Reads and nods. Girl 2 and Boy 2 looked at each other))* | *Girl 2. Writes: colours have to be bright*<br>*Boy 2. Girl 2 continues writing and adds "and colourful".* |

*Excerpt 1: Intertwining different modes of communication*

Excerpt 1 reflects the intertwining of different modes of communication among students –i.e. verbal, non-verbal and online–, which promoted rich dialogues leading to co-creation and high level of emotional connectivity, mutual trust and collective affection (e.g. Boy 1, line 3, shares his ability and previous experience in painting graffiti).

Furthermore, the intertwining of different modes of communication and the manipulation of a shared-digital object favours collective thinking and joint idea generation. For example, in this episode, students build on (lines 1 & 2), develop, extend and elaborate each other's ideas (line 6). In addition, excerpt 1 displays the support of technology in establishing a smooth, interactive and tangible flow of the shared-work on the computer screen. This lively construction on each other's ideas also enabled that the new ideas were dialogically generated in a multi-voiced dialogue. For example the written idea in Figure 3: *It's a big wall. The design cannot be complicated. Think for something simple*; introduces the voices of all the group-members manifested either verbally or written in the shared-digital space.

*5.5. Fusing ideas for a new perspective*

In this co-creative facet, students had converging objectives. Students widened and deepened their understanding of the shared-ideas by recognizing similarities and fusing ideas in a new perspective. These co-creative processes demanded reaching consensus among peers and generating reasons, justifications and arguments in order to create a new and shared conceptualization. Therefore, exploratory talk features were displayed in this facet. Three different co-creative processes were developed in this facet: a) labelling; b) grouping the ideas and, c) widening the shared ideas using multimodal representation in the digital-shared space.

*a)* Labelling the ideas: Deepening their common understanding

In Figure 3, students label and group the ideas about the characteristics of the wall as: *Measures, Orientation and Wall Characteristics.* One of the students started labelling *"Measures" and "Characteristics"*. This contribution initialized others' group members' actions toward re-mapping some other ideas spatially and introducing other labels in order to build deeper understanding about which wall characteristics were more important to take into account for the mock-design. For example, Girl 2 positioned the idea "*The colours have to be bright and colourful"* next to "*Orientation"*. Boy 2 agreed: *that's cool*, and he moved the idea "*we will need volunteers to help*" down to the idea "*it's a big wall*". In this example, the technology affordance of direct manipulation of the spatial representation of group ideas served as a resource to visualize the *intermental creativity zone* (ICZ) (Littleton & Mercer, 2013) in which students could build up a continuing and dynamic referential framework about their joint endeavour and develop collectively creative processes (in this case: labelling the group ideas) that resourced the co-construction of shared ideas to accomplish the common task.

*b)* Grouping and deepening the ideas in a superior account

Students accommodate to others' ideas by jointly and gradually transforming the ideas shared in the computer screen in a superior account. Using drag-and-drop affordance, students group together their ideas and communicate their reasoning. Doing so sequentially, students interpret peer's thinking and jointly abstract and integrate the ideas into a new perspective.

In the development of activity 6 (Figure 1), students brainstormed in the shared space the topics and contents they would like to include in the wall design. They had a pool of ideas and had to discuss and agree on two ideas. This activity engaged students in a lively discussion in which they displayed exploratory talk while explaining the actions they took in the computer. Hennessy (2011) named this talk as talk-in-action (line 4, excerpt 2).

| *Verbal/non-verbal interaction* | *Interaction through the computer* |
|---|---|
| *1. Girl 1. Let's choose. Everybody has mentioned "nature", isn't it?* | |
| *2. Boy 1: No, I don't* | |
| *3. Girl 1: Yes, You have landscapes, and that is similar to nature, don't you think?* | *Girl 1. Highlights in yellow the word landscape, written by Boy 1* |
| *4. Boy 2. OK and… animals is nature (dragging the word animals next to the category NATURE))* | *Boy 2. Writes in the word NATURE and drag bellow the words written by the other's that he feels have relation with nature* |
| *5. Boy 1(( Nodding)) I see!* | |
| *6. Girl 2. Yes, We have to make groups and then we could decide.* | |
| *….* | |
| *7. Girl 2. Another label could be "friendship" because Boy 1 have cooperation, Boy 2 has "being friendly" I have friendship* | *Boy 2. Starts writing "friendship"* |
| *8. Boy 2. I like the idea of drawing a mosaic* | |
| *9. Girl 1. But nobody else has written it, and we already have two ideas.* | |

Excerpt 2: Example of students' grouping ideas

Students looked for similarities in their ideas (lines 3 and 4); differences (line 9) and gave reasons for selecting an idea (line 7). This type of talk was accompanied by actions in the computer which consisted in successively annotating, linking and grouping the shared ideas in the computer screen. The fact of annotating and linking ideas helped students to better interpret and understand the ideas of others and, subsequently, develop a collective understanding about the possible shared ideas for selecting the best wall design topic. Despite the convergent focus of this task, students were allowed to finish the discussion holding two different ideas. This pedagogical instruction encouraged students in a process of developing arguments for each idea rather than competing about the best idea.

At the end of the process, students elaborated and externalized a solid narrative about two main topics for the wall design: Tetris and sunset landscape. The multi-faced arguments for each idea maintained the two possible topics for the wall design of this group till the end of the project. This is an example of the high degree of dialogical

embedding of the students' dialogues.

c) Widening the shared ideas by multimodal representation

In activity 8 of the project (Figure 1) students took photos about real-life painted walls with an eye on starting to think how to put into practice their ideas, especially in thinking about the feasibility of their ideas, the best materials to use and colours to employ. The small-group students brought and shared three photos from real-life decorated walls (see Figure 4): one Tetris, one tiling landscape and one coloured graffiti.

As can be seen, students' photo search and selection was led by the common knowledge built during the previous small-group creative discussions because all the photos met the criteria discussed during their previous joint work: colourful, Tetris, graffiti, coloured landscape and simple designs. Therefore, the photos showed the progression in students' discourse developed during the creative activities of the project and how technology affords two interrelated features of dialogue: cumulative and recursive (Alexander, 2008).

Besides, each photo meets each student's individual interest and preferences. Thus, Boy 2 claimed for Tetris (photo 1), Girl 1 argued for a landscape (photo 2) and Boy 1 showed experience in painting graphite (photo 3). This shows that the discussions had so far helped students to hold different perspectives that are progressively expanded with well-grounded reasons and preferences. While sharing the photos, students were engaged in a communication characterised by explicit and tangible reasons that refer to specific characteristics of the shared photos rather than purely oral forms without concrete examples. For example, Boy 1 when talking about the graphite of photo 3 said *"I think we could make graphite with our faces on it, like in this photo, but instead of these faces draw students' faces smiling, being happy"*

Besides, students showed high emotional connection, because each student gave situational and emotional information related with the photo (e. g. *"it's close to my house"*) which raised other students' interest shown by verbal interaction (e.g. *"I have already seen it, it is awesome"*) and non-verbal interaction such as: surprise, admiration, happiness. Otherness orientation was displayed in students' dialogue.

Furthermore, students' explanations communicate meaning less abstractly than oral communication. Interaction with the photos mediated by gaze, pointing gestures to

specific aspects of the photo offered opportunities to check understanding. In this facet, students displayed an exploratory talk characterised by reasons, comparisons, tangible examples and explicit links. Multimodal representation of students' ideas about how to design the wall decoration gave each student the opportunity to better visualize his/her ideas and give more concrete explanations that could, in turn, be evaluated and criticized by the others.

The visual representations (in this case in the form of photos) widened the possibilities to build new arguments and make new concrete connections. For example when arguing about the pros of the photo of a landscape, Girl 1 introduced a new argument: *… but the landscape is more environmental-friendly that a Tetris. I do not like the Tetris, it means nothing to me.* This leads students to fashion new insights about how to design the wall and even more so the limitations that each representation could have. For example, boy 2 fused the photo of Tetris and landscape in a new idea: *why don't we do a landscape with the squares of Tetris? This landscape (referring to photo 2) is made of small tiles, we could make them bigger and it would be easier to build it.* This new idea had the positive feed back on all the group members and agreed that the topic for the wall decoration would be sunset landscape designed with Tetris squares. In sum, this is a typical example about how technology affordances of multimodal representation of ideas, visibility and interactivity supported rich, new and multimodal forms of dialogue that triggered novel and multi-voiced ideas about the topic under discussion.

*5.6. Evaluating and choosing the best ideas: holding different perspectives*

The pedagogy of promoting multi-levels of interaction, i.e. small group and whole class discussion (as a wider audience), about the ideas and decision emerged in each group favoured critical and reflective analysis of pros and cons of each idea that allowed students to elaborate deeper arguments in favour or against ideas.

On many occasions, the small-group decided to organise their arguments in favour and against the different ideas in a table allocated in the shared-digital space. Figure 4 presents an example of this type of organisation and analysis of group ideas. This representation allowed students to group together and visualizes all members' ideas, organise them as "in favour" or "against" and estimate the weight and added value of each argument. In these episodes, students present rich, multimodal and reflective dialogues in which students consider multiple variables of the topic under reflection,

among these variables are worth mentioning: a) external constrains such as time to solve the task (e.g., in Figure 4: *quickly to paint*), budget (e.g., in Figure 4: *easy to get and buy*) or the link of the design to an environmentally-friendly rationale (e.g., in Fig. 4: *the smell is toxic*); b) individual constrains such as: students' expertise in designing, level of difficulty to develop the ideas (e.g., in Fig. 4: *difficult to do*) and c) individual preferences such as: *I like or I don't like, I love the sea and the beach.*

This facet resulted in a strong intersubjective orientation as students showed considerable concern for others' contributions, hold different perspectives at a time, evaluating cons and pros. Students display exploratory talk features characterised by logical reasoning and explicit argumentation. It is important in co-creativity to provide feedback and to argue for their positions in order to push the collective task forward.

| Photo | Technique + | Technique - | Material + | Material - |
|---|---|---|---|---|
| Photo 1. Paint brush  | Quickly to paint. Possible to do different forms. | None. | Easy to use | The paint can be spread and colours can mixed up |
| Photo 2: Mosaic (tiling)  | It looks pretty. It's hard and durable. Original texture. | It can take long type to build. Easy to undo. Difficult to do | Easy to get and buy. Lively colours It looks realistic. We would need bigger pieces. | Difficult to manage. Easy to break when you manage them. |
| Photo 3: Graphite  | It is funny. Teenagers love them. Easy to paint. Everybody can do it. | Expensive | Quickly to paint. Easy to use it. | The smell is toxic. It is dirty when you use it. After time wears down. |

Figure 4: Example of students' representation for the evaluation of group ideas

### *5.7. Making ideas a reality*

This facet covers the collective externalization of the shared ideas. Students converge in a collective multimodal representation of group ideas which articulates and refines the discussion and the agreements arrived in previous stages. As students have a common ground of reference, high collective engagement is observed with a strong hands-on orientation. Usually, all the students are co-working in the computer. The interaction patter of this facet resembles the "working together" defined by Sakr (2018) in which

shared gaze, facial expressions indicating high levels of engagement, simultaneous movements in the computer in response to others that extends the joint activity.

This facet is characterised by a high intersubjective orientation in which students try to synthesize in one common outcome the different perspectives and idea displayed in previous stages. In doing so, co-constructive talk features are exhibited.

During the project, students used mainly two co-creative processes to externalize the common ideas: sketching and writing a summary of the agreements reached during the group work. For example, students sketched collaboratively their idea of designing a landscape with squares of Tetris (Figure 5). These externalisations had the function of intermediate products to be used as generators of new ideas or as anchored references of the group work. Re-usability affordance of technology allowed students to revisit these intermediate products during the different stages of the group work.

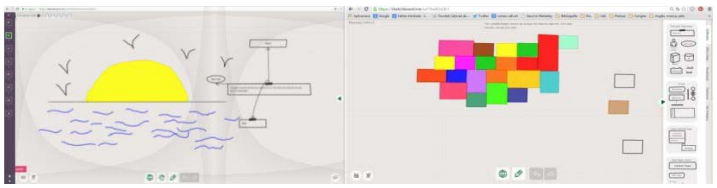

Figure 5: Example of students' sketching the agreed ideas

## 5. Discussion and conclusions

The aim of the study was to characterise the emergence of a dialogic space for co-creating with interactive technology in a real-life classroom project. The first result of this study is evidence-based understanding of seven typical co-creative facets involved when secondary students co-create by means of interactive technology in the framework of a STEAM project. Each facet focuses on an overarching co-creative objective to solve the (sub)task. The seven typical co-creative facets are named: 1) collective framing of the task; 2) learning together from technological challenges; 3) engagement and generation of a shared pool of ideas; 4) development of intersubjectivity for opening up a shared co-creative dialogic space; 5) merge ideas to obtain a new perspective; 6) evaluation of ideas and 7) making ideas into reality. These facets coincide with the ones found in previous studies on collaborative creativity (Palmgren-Neuvonen et al., 2017; Sakr, 2018; Vass et al., 2014; Sawyer, 2012). In the present study, these typically co-creative facets were used intermittently in solving the different subtasks throughout the project until the small group of students achieved their common goal –i.e. to jointly negotiate the mock-design for

decorating one playground- wall following environmentally-friendly principles.

A second significant result of this study is that students pursued the co-creative objective of each facet by establishing a dialogic space that had specific features in relation to the next three dimensions: a) distinctive co-creative processes involved, b) typical discourse features and, c) dialogic use of specific technology affordances. The description provided contributes to our understanding about how co-creativity looks like when solving a real challenge and it extends previous research on this area.

A third finding of this study is the prominent role of interactive technologies in supporting the emergence of salient co-creative processes in each facet. The findings show some of the benefits to co-creation that interactive technologies provide that lead to new ways of thinking creatively together (i.e. creative mindset). Students have the opportunity to enrich their co-creative processes repertoire (Sawyer, 2013) by watching, joining-in, sharing, applying and imitating other members' creative processes. In relation to the support of the interactive technology for co-creating, the study provides data-based evidence about the next five applications:

*1) Developing cumulative dialogue for co-creation.* Revisiting and re-using the records of previous work and information have been outlined as key affordances of interactive technology for sustaining and progressing cumulative dialogue. These technological affordances enable the learners to visualize previous work and re-use it as updating source of reference for new connections and development of new ideas (Hennesy, 2011; Kennewell & Beauchmp, 2007).

*2) Establishing a dialogic, multimodal and multi-voiced shared-digital space.* Interactivity and visibility of each other's thoughts as tangible objects in the shared-space promoted active engagement and hands-on contribution from each group member during the different co-creative facets of the project. This space successfully facilitated expressing ideas in a digital-shared space which, in turn, opened up an "external space" (Kazak et al., 2015, pp. 107) in which dialogue and dialogic relationships between ideas could occur. The results confirmed that students developed an intersubjective orientation (Wegerif, 2005) by relating dialogically with other's ideas and unfolding the commitment to negotiate their perspective. As a result of this negotiation, multi-voiced and new ideas were developed during the project.

*3) Developing a dialogic space of new ideas and understanding.* Direct manipulation of

each other's ideas in a provisional and easily-editable manner helped students explore shared-ideas and explicitly represent new connections. Theory of Creativity claims creativity occurs during work (Sawyer, 2012). Similarly, results in this study showed that creative insights happened during manipulation of ideas in the shared-space.

*4) Holding different perspectives and switching perspectives.* This was reflected in the study when any action that students took in the shared space was short- lived, provisional and editable by the other members, which helped students explore and understanding each other's ideas. In these exploratory actions, students manipulated, explored and experienced the gap between voices of small group members (i.e. contributions through technology) and inter-related and inter-animated each other's voice (Wegerif et al., 2017). Indeed, students created a physical and cognitive dialogic space on the computer screen (Hennessy, 2011), in which, like in utterances, the actions in the shared space are never final or fixed but exist transiently within the dialogic space (Bakhtin, 1986). In concordance to Hay (2008), representations allow learners to oscillate dialogically between their own exploratory explanations and criticism their externalised representations from another's perspective.

*5) Promoting of reflective dialogues that widen and deepen students' understanding and co-creation*. Multimodal representation of ideas encouraged dialogue with explicit and tangible reasons for their ideas. Furthermore, by converting thoughts into external objects, students widened and deepened their understanding of each other's ideas, which in turn resulted in a better negotiation and the best choice to solve the task (Wegerif, 2010).

In this study, pedagogical design brings out the paramount role of pedagogy in creating a technology-enhanced dialogic space for co-creation To this end, five pedagogical instruments were implemented: a) promotion of middle-c creativity by involving students in solving a challenge related with the school community, activated students' previous learning experiences, ideas and motivations and afforded students to move through different learning spaces. Indeed, the results show that students' previous experiences had been dialogically incorporated into small group discussions as a source for co-creative inspiration. In this pedagogical approach, the classroom walls have become more permeable to students' outside experiences and the classroom has become a node, or "an intersection" (Leander, Phillips & Taylor, 2010 p.336) within a trajectory of different learning experiences. These learning trajectories, as they were grounded on wider social

groups and on students' participation in life-long learning practices, can afford to effectively deal with societal challenges (Daskolia, Kynigos, & Makri; 2015); b) Design of phases and subtasks with tangible creative sub-goals facilitated and paced creative group flow and acted as an external orchestration of group creative processes (Mudaly, Morgan, van Lare, Singh & Mitchell, 2015; Seitamaa-Hakkarainen et al., 2010); c) embedding activities for "thinking together" raised students' awareness for co-creativity (Sullivan, 2011) and developed co-constructive (Rojas-Drummond et al., 2008) as well as exploratory (Mercer & Littleton, 2007) talk features; d) agreement on two different ideas and perspectives across time and activities helped students to develop different dialogic features as: opening up to the others, holding two perspectives together in tension and maintaining a multi-voiced dialogue and, e) intertwining of multimodal (face-to-face and computer) and multilevel (whole class and small group discussion) dialogic interaction create opportunities to enrich students dialogue by considering a wider audience when explaining their ideas (Lipponen, 2000) and by developing a common idea through non-verbal interaction in which participants mirrored each other in their gaze, as if "looking inwards" (Sakr, 2018).

Furthermore, this study extends our understanding of interactions between digital technology and co-creative dialogue. The analytical approach of this study identifies the origin of co-creativity processes during technology-enhanced students' interaction and specific discourse features. Previous research had already noted that when students interact around computers, they display communicative features that some researchers have denominated as "talk-in-action" (Hennessy, 2011) and as "thinking through writing" (Pifarré & Li, 2018). This type of communication combines verbal and written communication. The analytical approach developed in this paper captures this multi-modal communication to better understand the multi-modality and different layers of the dialogic co-creative processes emerged in a technology-enhanced learning context.

*Difficulties, limitations and future research*

Although students helped each other to overcome technological difficulties, in some instances, technological resources presented issues that could not be solved which delayed the process of co-creation. If the latter happened, teachers encouraged students to share laptops to solve the issue. However, such practice caused emotional disengagement

as students found it difficult to work collaboratively in pairs with a small laptop, and so collaboration "came loose" (Sakr, 2018). That is, the focus of task attention was interrupted, the participant rested his/her gaze elsewhere and his/her oral contributions were reduced. As in other researches (Al-Samarraie & Hurmuzan, 2018; Davidsen & Vanderlinde, 2016), technological difficulties became one of the main obstacles to co-creativity because they disrupted group flow. In future research, such difficulty should be corrected by providing previous training to students or allowing a computer assistant during the computer sessions.

Another remarkable limitation of this study is that the activities selected and analysed were those dedicated to thinking the co-creative design of the play-ground wall decoration. This study has revealed that students were active-in-thinking (Wang &Wegerif, in press) creatively and presented features of exploratory talk that prior research claimed to have a positive impact on STEAM learning outcomes (van der Veen & Van Oers, 2017; van der Veen, de Mey, van Kruistum, & Van Oers, 2017). However, this study did not collect data or analysed whether students improved their STEAM knowledge and performance. Future research should study how the features of the dialogic space for co-creating reported in the present work supported meaning-making, joint co-construction of knowledge and the internalization of disciplinary strategies of thinking (Wang, Peng, Cheng, Zhou, & Liu, 2011). Actually, such research is underway in a separate paper (Author citation 2, in preparation).

There is also need to design a larger-scale empirical study to implement the dialogic technology-enhanced co-creative pedagogy to solve other challenges in other educational contexts and examine whether the emergence of co-creative processes have similar features to those found in this paper or whether other co-creative processes arise.

The empirical study reported in this article is grounded on qualitative research methodology which allowed the analysis of the nature and functions of dialogue in promoting co-creativity over a period of time. However, the development of a mixed-method approach which integrates quantitative analysis could provide different insights into the characteristics of co-creativity processes that emerged along the project.

As a final conclusion, our globalized and technological society requires from citizens to engage themselves in creative dialogues through and around digital platforms, in which it is crucial to create a dialogic space to cultivate new ways of thinking creatively. This paper

describes a case study of how this dialogic learning can be promoted in real-life classrooms.

**Acknowledgment**

This research was funded by the Ministerio de Economía y Competitividad of the Spanish Government (project number: EDU2016-80258-R). The author would especially like to thank the teachers: Ester Isern, Alba Huix & M. Carme Roures, which participated in the design, implementation and evaluation of the STEAM project in the classroom.

**References**

Alexander, R.J. (2008). Pedagogy, curriculum and culture. In Hall, K., McCormick, R., Murphy, P., Soler, (Ed). *Pedagogy and Practice: culture and identities* (pp. 3.27). London: Sage.

Al-Samarraie, H., & Hurmuzan, S. (2018). A review of brainstorming techniques in higher education. *Thinking Skills and Creativity, 27*, 78–91. http://doi.org/10.1016/j.tsc.2017.12.002

Bakhtin, M.N. (1986) The problem of speech genres. In C. Emerson & M. Holquist (Eds.). *Speech Genres and Other Late Essays* (pp. 60–102). University of Texas Press, Austin, TX.

Corsaro, W. A. (1998). Preadolescent peer cultures. In M. Woodhead, D. Faulkner & k. Litleton (Eds.). Making sense of social development (pp 27-50). London: Routlege.

Coyle, Y., Yanez, L., & Verdu, M. (2010). The impact of the interactive whiteboard on the teacher and children's language use in an ESL immersion classroom. *System, 38(4),* 614-625.

Craft, A. (2000). *Teaching creativity: Philosophy and practice*. London and New York: Routledge.

Craft, A. (2008). Studying collaborative creativity: Implications for education. *Thinking skills and creativity, 3(3),* 241-245.

Daskolia, M., Kynigos, C., & Makri, K. (2015). Learning about urban sustainability with digital stories. *Constructivist Foundations, 10(3),* 388-396.

Davidsen, J., & Vanderlinde, R. (2016). You should collaborate, children: A study of teachers' design and facilitation of children's collaboration around touchscreens. *Technology, Pedagogy and Education, 25(5),* 573–593.

Dawes, L., & Sams, C. (2004). Developing the capacity to collaborate. In K. L. D. M. & D. Faulkner. (Ed.), *Learning to Collaborate: Collaborating to Learn* (pp. 1–21). Nova Science Pub. Inv.

Engin, M., & Donanci, S. (2015). Dialogic teaching and iPads in the EAP classroom. *Computers & Education, 88,* 268-279.

Eteläpelto, A., & Lahti, J. (2008). The resources and obstacles of creative collaboration in a long-term learning community. *Thinking Skills and Creativity*, *3*(3), 226–240. http://doi.org/10.1016/j.tsc.2008.09.003

Glaser, B., & Strauss, A. (1967). Grounded theory: The discovery of grounded theory. *Sociology the journal of the British sociological association, 12,* 27-49.

Glăveanu, V. P. (2010). Paradigms in the study of creativity: Introducing the perspective of cultural psychology. *New Ideas in Psychology*, *28*(1), 79–93. http://doi.org/10.1016/j.newideapsych.2009.07.007

Glăveanu, V. P., Gillespie, A., & Karwowski, M. (2018). Are People Working Together Inclined Towards Practicality? A Process Analysis of Creative Ideation in Individuals and Dyads. *Psychology of Aesthetics, Creativity, and the Arts*. http://doi.org/10.1037/aca0000171

Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of pragmatics, 32(10),* 1489-1522.

Hämäläinen, R., & Vähäsantanen, K. (2011). Theoretical and pedagogical perspectives on orchestrating creativity and collaborative learning. *Educational Research Review*. http://doi.org/10.1016/j.edurev.2011.08.001

Hao, N., Ku, Y., Liu, M., Hu, Y., Bodner, M., Grabner, R. H., & Fink, A. (2016). Reflection enhances creativity: Beneficial effects of idea evaluation on idea generation. *Brain and Cognition, 103*, 30–37. http://doi.org/10.1016/j.bandc.2016.01.005

Harvey, S. (2013). A different perspective: The multiple effects of deep level diversity on group creativity. *Journal of Experimental Social Psychology*, *49*(5), 822–

832. http://doi.org/10.1016/j.jesp.2013.04.004

Hazelkorn, E. (Chair) (2015). Science Education for responsible citizenship. European Commission. Retrieved from http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf.

Hennessy, S. (2011). The role of digital artefacts on the interactive whiteboard in supporting classroom dialogue. *Journal of Computer Assisted Learning*, *27*(6), 463–489. http://doi.org/10.1111/j.1365-2729.2011.00416.x

Hennessy, S.; Deaney, R.; Ruthven, K.; Winterbottom, M. (2007). Pedagogical strategies for using the interactive whiteboard to foster learner participation in school science. *Learning, Media and Technology*, *32*(3), 283–301.

Higham, R. J. E., Brindley, S., & Van de Pol, J. (2014). Shifting the primary focus: Assessing the case for dialogic education in secondary classrooms. *Language and Education*, *28*(1), 86-99.

Howes, C., Healey, P. G. T., Hills, T. T., & Howes, C. (2015). Ideas in Dialogue : The Effects of Interaction on Creative Problem Solving Ideas in Dialogue : The Effects of Interaction on Creative Problem Solving, (September). http://doi.org/10.1016/j.compedu.2009.10.015

Kazak, S., Wegerif, R., & Fujita, T. (2015). The importance of dialogic processes to conceptual development in mathematics. *Educational Studies in Mathematics*, *90*(2), 105-120.

Kennewell, S., & Beauchamp, G. (2007). The features of interactive whiteboards and their influence on learning. *Learning, Media and Technology*, *32*(3), 227–241. http://doi.org/10.1080/17439880701511073

Kumpulainen, K., & Rajala, A. (2017). Dialogic teaching and students' discursive identity negotiation in the learning of science. *Learning and Instruction*, *48*, 23-31.

Kohn, N. W., Paulus, P. B., & Choi, Y. H. (2011). Building on the ideas of others: An examination of the idea combination process. *Journal of Experimental Social Psychology*, *47*(3), 554–561. http://doi.org/10.1016/j.jesp.2011.01.004

Leander, K. M., Phillips, N. C., & Taylor, K. H. (2010). The changing social spaces

of learning: Mapping new mobilities. *Review of research in education, 34(1),* 329-394.

Linell, P. (1998). *Approaching dialogue: Talk, interaction and contexts in dialogical perspectives* (Vol. 3). John Benjamins Publishing.

Lipponen, L. (2000). Towards knowledge building: From facts to explanations in primary students' computer mediated discourse. *Learning Environ- ments Research, 3(2),* 179–199.

Littleton, K., & Mercer, N. (2013). *Interthinking: Putting talk to work.* Abingdon: Routledge.

Loveless, A. M. (2002). *Literature Review in Creativity*, New Technologies and Learning.

Major, L., Warwick, P., Rasmussen, I., Ludvigsen, S., & Cook, V. (2018). Classroom dialogue and digital technologies: A scoping review. *Education and Information Technologies*, (March), 1–34. http://doi.org/10.1007/s10639-018-9701-y

Mercer, N. (1995). *The guided construction of knowledge: talk amongst teachers and learners.* Clevedon: Multilingual matters.

Mercer, N. (2004). Sociocultural discourse analysis: analysing classroom talk as a social mode of thinking. *Journal of Applied Linguistics*, *1*(2), 137–168. http://doi.org/10.1558/japl.2004.1.2.137

Mercer, N., & Littleton, K. (2007). *Dialogue and the development of children'sthinking: A sociocultural approach.* London: Routledge.

Mercer, N., Hennessy, S., & Warwick, P. (2017). Dialogue, thinking together and digital technology in the classroom: Some educational implications of a continuing line of inquiry. *International Journal of Educational Research*, (August), 0–1. http://doi.org/10.1016/j.ijer.2017.08.007

Middup, C. P., Coughlan, T., & Johnson, P. (2010). Proceedings of COOP 2010, 203– 222. http://doi.org/10.1007/978-1-84996-211-7

Moran, S. (2010). Creativity in school. In K. Littleton, C. Wood & J. Kleine-Staarman (Eds.) *International handbook of Psychology in Education* (pp. 319-359). Bingley: Emerald.

Mudaly, R., Morgan, K. P., Van Laren, L., Singh, S., & Mitchell, C. (2015). Connecting with pre-service teachers' perspectives on the use of digital technologies and social media to teach socially relevant science. *Perspectives in Education, 33(4),* 23-41.

Negus, K., & Pickering, M. J. (2004). *Creativity, communication and cultural value*. Sage.

Palmgren-Neuvonen, L., Korkeamäki, R. L., & Littleton, K. (2017). Intercreating in the context of learner-generated DV production. *Thinking Skills and Creativity*, *26*(April), 13–23. http://doi.org/10.1016/j.tsc.2017.04.005

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why isn't creativity more important to educational psychologists? Potentials, pitfalls, and future directions in creativity research. *Educational psychologist, 39(2),* 83-96.

Pifarré, M., & Li, L. (2018). Characterizing and unpacking learning to learn together skills in a wiki project in primary education. *Thinking Skills and Creativity*, *29*, 45–58. http://doi.org/https://doi.org/10.1016/j.tsc.2018.06.004

Rogers, Y., & Lindley, S. (2004). Collaborating around vertical and horizontal large interactive displays: Which way is best? *Interacting with Computers*, *16*(6), 1133–1152. http://doi.org/10.1016/j.intcom.2004.07.008

Rojas-Drummond, S. M., Albarrán, C. D., & Littleton, K. S. (2008). Collaboration, creativity and the co-construction of oral and written texts. *Thinking Skills and Creativity*, *3*(3), 177–191. http://doi.org/10.1016/j.tsc.2008.09.008

Rojas-Drummond, S., Littleton, K., Hernández, F., & Zúñiga, M. (2010). Dialogical interactions among peers in collaborative writing contexts. K. Littleton & C. Howe. *Educational dialogues: Understanding and promoting productive interaction*, 128-148. London: Routledge.

Sakr, M. (2018). Multimodal participation frameworks during young children's collaborative drawing on paper and on the iPad. *Thinking Skills and Creativity, 29,* 1–11. http://doi.org/10.1016/j.tsc.2018.05.004

Säljö, R. 1999. Learning as the use of tools: A sociocultural perspective on the human technology link. In K. Littleton and P. Light (Eds.) *Learning with computers: Analysing productive interaction* (pp. 144–61). London: Routledge.

Sawyer, R. K. (2006). Educating for innovation. *Thinking skills and creativity, 1(1),* 41-48.

Sawyer, R. K. (2012). *The science of human innovation: Explaining creativity*. New York, NY.

Sawyer, K. (2013). *Zig zag: The surprising path to greater creativity*. John Wiley & Sons.

Seitamaa-Hakkarainen, P., Viilo, M., & Hakkarainen, K. (2010). Learning by collaborative designing: Technology-enhanced knowledge practices. *International Journal of Technology and Design Education*, *20*(2), 109–136. http://doi.org/10.1007/s10798-008-9066-4

Sherman, R. R., & Webb, R. B. (2004*). Qualitative research in education*. Routledge.

Solli, A., Mäkitalo, Å., & Hillman, T. (2018). Rendering controversial socioscientific issues legible through digital mapping tools. *International Journal of Computer-Supported Collaborative Learning, 1-28*. https://doi.org/10.1007/s11412-018-9286-x

Sullivan, F. R. (2011). Serious and Playful Inquiry : Epistemological Aspects of Collaborative Creativity Dialogism. *Journal of Educational Technology & Society, 14,* 55–65.

Sullivan, P. (2011). *Qualitative data analysis using a dialogical approach*. Sage.

Thagard, P., & Stewart, T. C. (2011). The AHA! experience: Creativity through emergent binding in neural networks. *Cognitive Science*, *35*(1), 1–33. http://doi.org/10.1111/j.1551-6709.2010.01142.x

van der Veen, C. & van Oers, B. (2017). Advances in research on classroom dialogue: learning outcomes and assessments. *Learning and instruction, 48,* 1-4.

van der Veen, C., de Mey, L., van Kruistum, C., & van Oers, B. (2017). The effect of productive classroom talk and metacommunication on young children's oral communicative competence and subject matter knowledge: An intervention study in early childhood education. *Learning and instruction, 48,* 14-22.

Vass, E., & Deszpot, G. (2017). Introducing experience-centred approaches in music teacher education—Opportunities for pedagogic metamorphosis. *Thinking Skills and Creativity, 23,* 1–16. http://doi.org/10.1016/j.tsc.2016.11.003

Vass, E., Littleton, K., Jones, A., & Miell, D. (2014). The affectively constituted dimensions of creative interthinking. *International Journal of Educational Research*, *66*, 63–77. http://doi.org/10.1016/j.ijer.2014.02.004

Wang, M., Peng, J., Cheng, B., Zhou, H., & Liu, J. (2011). Knowledge visualization for self-regulated learning. *Journal of Educational Technology & Society*, *14*(3).

Wegerif, R. (2005). Reason and creativity in classroom dialogues. *Language and Education, 19 (3),* 223-238.

Wegerif, R. (2007). *Dialogic education and technology: Expanding the space of learning.* London: Springer.

Wegerif, R. (2013). Dialogic. Education for the Internet Age. London: Rodopi.

Wegerif, R., McLaren, B. M., Chamrada, M., Scheuer, O., Mansour, N., Mikšátko, J., & Williams, M. (2010). Exploring creative thinking in graphically mediated synchronous dialogues. *Computers and Education*, *54*(3), 613–621.

Wegerif, R., & de Laat, M. F. (2011). Reframing the teaching of higher order thinking for the network society. In S.Ludvigsen, A.Lund & R.Saljo (Eds). *Learning in social practices: ICT and new artefacts– transformation of social and cultural practices*. London: Routledge

Wegerif, R., Doney, J., Richards, A., Mansour, N., Larkin, S., & Jamison, I. (2017). Exploring the ontological dimension of dialogic education through an evaluation of the impact of Internet mediated dialogue across cultural difference. *Learning, Culture and Social Interaction*, (September), 0–1. http://doi.org/10.1016/j.lcsi.2017.10.003

Yang, Y., van Aalst, J., Chan, C. K., & Tian, W. (2016). Reflective assessment in knowledge building by students with low academic achievement. *International Journal of Computer-Supported Collaborative Learning, 11(3),* 281-311.

Zittoun, T. (2007b). Symbolic resources and responsibility in transitions. *Young, 15(2),*