Journal of Universal Computer Science, vol. 22, no. 10 (2016), 1360-1379
submitted: 24/3/16, accepted: 23/9/16, appeared: 1/10/16 © J.UCS

Introducing a Collaborative Tool Supporting a Learning Activity Involving Creativity with Rotation of Group Members

Gustavo Zurita
(Management Control and Information Systems, Faculty of Economics and Business
Universidad de Chile, Santiago, Chile
gzurita@fen.uchile.cl)

Nelson Baloian, José A. Pino
(Department of Computer Science, Universidad de Chile, Santiago, Chile
{nbaloian@dcc.uchile.cl, jpino@dcc.uchile.cl)

Mary Boghosian
(American University of Armenia, Yerevan, Armenia
mboghosian@aua.am)

Abstract: There is consensus among curriculum developers of Business Schools that along with technical knowledge students should also be trained to acquire soft skills. Communication, collaboration, creativity, critical thinking and problem solving are mentioned by some authors as the most important skills for professionals of the 21st century to be successful. Students must perform learning activities applying these skills in order to develop them. In this work we present a learning activity intended for Business students which requires creativity in order to be performed. We developed a collaborative tool to support this activity, called Sketchpad. The students who used the system evaluated the contribution of the designed activity to creativity and the ability of the tool to support it through an open questionnaire based on the Creativity Factor Evaluation (CSI). A second evaluation was done concerning Sketchpad's collaborative support. Both studies showed a positive students' perception of the activity and tool value according to these evaluation dimensions.

Keywords: Creativity, Collaboration, Business Schools, Mobile Devices, Brain Sketching.
Categories: L.2, L.2.3, L.6.2

1 Introduction

There is currently an increasing need that students develop not only technical competences but also the so called "soft skills" in order to perform professional activities in an effective and efficient way in a globalized world. This is especially valid for professionals of the business and economics field, who need to perform tasks in a highly competitive, changing and demanding environment, in order to adapt themselves to the constant changes and generate strategies which provide added value to business practice. In order to achieve this goal it is necessary to include relevant pedagogical activities, methods and tools in their university curricula.

[Griffin 11] presented the KSAVE (Knowledge, Skills, Attitudes, Values, Ethics) model which defines ten key competences professionals of the 21st century should

have in order to be successful. This model categorizes creativity as part of the Ways of Thinking competences, besides critical thinking, problem solving, decision making, learn to learn, and meta-cognition. The operational definition of creativity provided by the KSAVE model includes knowledge, skills, and attitudes related to thinking and working creatively, individually and collaboratively. In the same way, KSAVE highlights the importance of collaboration and communication skills, which are named as Ways of Working skills.

According to [Schlee 14], creativity and the ability of working in teams are the most relevant and required skills for professionals of the business area in order to be successful. Moreover, the Association to Advance Collegiate Schools of Business mentioned the importance of considering various competences, among these creativity and the ability of working in teams, when designing curricula for business schools students [AACSB 13] which is in line with the KSAVE model. In 2015, the AACSB held various seminars on Curriculum Development Series. One of them was called Teaching Design for Creativity and Innovation [AACSB15], which again highlights the importance of creativity as the way to cope with the requirements of the modern business environment. The Harvard Business Review also gives importance to creativity, publishing many articles on this subject [Harvard 15].

The literature reports about several works on how to encourage creativity in university students, presenting learning activities introduced in courses in business schools [Weisberg 93], [Mihai 12], [Yar 08], [Fairbank 01]. However, no one makes use of modern technology to support it. Our research strategy was to develop a learning activity requiring creativity and then a collaborative tool to support it.

This paper thus presents a pedagogical activity designed to help the development and application of skills and attitudes related to collaborative work and creativity in undergraduate students of a business school. The activity, which is performed inside the classroom, was designed according to previous research work on this subject reported by the literature. It is supported by a collaborative application called Sketchpad, running on wirelessly interconnected tablet PCs. Sketchpad was designed based on the principles of collaboration and externalization using brainsketching. The activity also incorporates rotation of students working in various groups on the same task, so they can enrich their ideas looking at the others'.

In this scenario, the research work has been guided by the following questions: (1) According to the students' perception, to what extent the activity supported by the provided tool (Sketchpad) contributes to the development of creativity?; (2) which is the perception the students get about the contribution of Sketchpad to promote collaboration?; and 3) is there a difference in this perception when students work in groups where members have to rotate among the groups and when they not?

The activity and the tool were evaluated using two questionnaires. The students who used the system evaluated the contribution of the activity to creativity through an open questionnaire based on the Creativity Factor Evaluation (CSI) [Carroll 09]. A second evaluation was done concerning Sketchpad collaborative support. Both studies showed a positive students' perception of the activity and tool value according to these evaluation dimensions. The results also show that students consider that rotation enhances creativity when compared to working without rotation. There was also positive evidence on the perception students had about the ability of Sketchpad supporting collaboration and externalization.

The rest of the article is organized as follows. Chapter 2 examines creativity in general. Chapter 3 explores ways of stimulating creativity in learning activities. Chapter 4 deals with Sketchpad development. Chapter 5 contains the evaluation methodology, while Chapter 6 presents a discussion and the conclusions.

This paper shows an extension of the work presented in [Zurita 15].

2 What is Creativity and which is the Role of Collaboration?

Several authors and experts in the field of Creativity have attempted to define it within the context of their studies. [Seeling 12] defines it as "*provocative. Just one word ... provocative*". [Gryskiewics 87] defined creativity as "*novel associations that are useful*". [Noller 79] developed a symbolic equation for creativity as a function of Knowledge, Imagination, and Evaluation, reflecting an interpersonal attitude towards the beneficial and positive use of creativity. [Rhodes 61] compiled 56 definitions of Creativity all intertwined and overlapped, from which [Isaksen 11] described a six step process for Creative Problem Solving (CPS) based on the concept of creativity as being a whole system model based on the four overlapping themes identified by [Rhodes 61], namely *Persons*- the characteristics of creative people, *Process*- the operations within the creative process, *Product*- the creative results and outcomes, and *Press*- the context or place for creativity [Iseksen 84]. A comprehensive study and analysis on 91 exceptional individuals was conducted by [Csikszentmihalyi 96] to define and analyze the flow of creativity and the psychology of discovery and invention. This research observed creativity as interrelations within a system model made up of three parts: *domain (cultures), field, and person*.

[Weisberg 93] challenged the common belief that product novelty requires creativity to come from *extraordinary* and unconscious thinking, sudden leap of insight, or possession of extraordinary, genius, flexibility, and sensitivity. Using examples from general daily life activities, he proved that creativity can also be an outcome of *ordinary* thinking, since ordinary thinking processes, which are based on continuity with the past, can also bring about *novel work of value to the future*, especially when they are subjected to a radical shift or discontinuity in thoughts, whether those are internal or external discontinuity thoughts.

Creativity within the context of organization and work environment is best described by [Harvard 99] as that intertwined and complex system that exists within an organization, based on strong internal desire (internal motivation) to solve problems leading to solutions, due to interests (expertise: technical, procedural and intellectual knowledge that the person possesses), and environment stimulating imagination and creative problem solving. --In conclusion, creativity can be explained as an outcome of a complex dynamic process that include several elements for generating unique and valuable outcomes by transformation of existing ones .

2.1 Creative Thinking and Critical Thinking

From above, it becomes clear that *creative thinking* is the generation of new knowledge and ideas within or across domains, intentionally breaking the established rules and processes. It includes behaviors such as preparation, incubation, insight, evaluation, elaboration, and communication. Creative thinking can be stimulated by

both unstructured process using *brainstorming*, and structured process using *Lateral Thinking*. The concept of lateral thinking was developed by [De Bobo 90] to describe the process of using information to bring about creativity and insight. It can be learned, practiced and used. Unlike *Vertical Thinking*, Lateral Thinking is not analytical, does not seek clarity or a likely path, it involves restructuring, explores the least likely path to move in order to generate directions, new ideas, and new thinking leading to creative results. Like brainstorming, the Lateral Thinking is used to generate new ideas, developing new properties, and new configurations from existing ones. Brainstorming processes combine the Lateral Thinking and the Vertical Thinking for generation of new unstructured ideas.

Creative Thinking, also known as *generating (divergent) thinking*, is a process requiring starting from a single point, from a single question, asking as-many questions and seeking as-many answers as possible to extend the search in many different directions, generating wide variety of new ideas. Questions need to be open-ended, effective, poking, and generative looking for gaps, paradoxes, opportunities, challenges, concerns, and searching for meaningful new connections, new possibilities from different viewpoints or perspective, and seeking unusual, non-standard possibilities and details to expand or enrich the existing ones. Critical Thinking, on the other hand, also known as *focusing (convergent) thinking*, is a process that attempts to identify many different ideas and challenging assumptions, draws them together towards a single goal or result through recognizing the importance of the context, exploring alternatives, and developing a concluding action plan. It involves examining the different ideas and possibilities carefully, fairly, and constructively, then focusing all thoughts and actions by organizing and analyzing possibilities, refining and developing promising solutions, choosing, ranking or prioritizing and deciding on final options.

2.2 Creative Problem Solving

Creativity and creative thinking are closely linked to Creative Problem Solving (CPS) [Isaksen 85], as both seek new unstructured, open ended outcomes and opportunities, overcome challenges, encouraging innovation, closing gaps and clearing uncertainties, and meeting new solutions and opportunities. Creative Problem Solving is also linked closely to the critical thinking as they both need to reach to a novel, workable, satisfying close ended solution and opportunity, recognizing and exploring alternatives, then focusing constructively on a workable solution. Therefore, the successful CPS process is dependent on both generating and focusing parts - divergent and convergent thinking - drawing from the entire system of people, method, and content and context approach of both parts. [Rhodes 61; Isaksen 85] describe the CPS as a six stage process of continuously generating and focusing ideas to understand the challenge, generate ideas, and prepare for action from constructing opportunities, exploring data, framing problems, to generating ideas, developing solutions and building acceptance. One can draw similarities between this process and the Global Sharing Pedagogy (GSP), which constitute the basis for learning in digital storytelling [Niemi 14] and brainsketching [Van der Lugt 02], thus basing both on the same principles namely, interpretation and validation of ideas and knowledge, collaboration, exchange of information, and networking: the same skills called for 21st Century teaching and assessment for business leaders, politicians, and educators.

2.3 Creativity and Collaboration

Some authors have already touched the topic of collaboration in creativity and tools supporting it [Mamikaya 02]. For training students in developing creative skills is necessary to introduce collaborative activities [Fairbank 01]. Technology should help according to the complexity of them, including emotional, motivational, cognitive and metacognitive, individual and social aspects of the process of learning. Technology allows students to learn at any time, to participate when they want to, without feeling intimidated by others, and go at their own pace [O'Donell 2013], in addition, it may provide evidence for the teachers and students of the student's progress and allow teachers to give a precise feedback according to the necessities of students. Incorporating technology in education has been quite successful, even within off-line courses there have been experiences in carrying out paperless courses in which the whole material has been electronically distributed through Tablet PCs [Fons 2010].

For communicating with others and solving problems, sketching may be used successfully. First because there is a process in which individuals can externalize their ideas through a sketch and watch the problem from an "outside" perspective allowing them to analyse their own thoughts from outside; and second, because sketches can be used to explain one's ideas and to build shared understanding [Fischer 2004].

Therefore, research should be conducted and technologies should be developed for creatively solving highly complex problems with highly effective collaborative networks and teams, in large diverse and internationally dispersed as well as small local coherent groups. Detailed investigation into the process of CPS, and the collaboration and networking process is required. The kind of approach to sharing and exchanging information at every step of the CPS also needs to be studied.

In this work we focus only on the relation between collaboration and creativity by presenting and evaluating a collaborative learning activity and a tool supporting it, which allows students to train their creativity by developing ideas (like new business proposals or ways to use technology to improve life in their communities) within a group, sharing them with other groups, and improving their initial proposal with the help of the ideas of their classmates.

3 Supporting Creativity Development

The complexity of teaching students to be creative lies in the fact we cannot teach that skill but to foster its development through educational activities that include specific design principles, pedagogical practices that generated positive previous experiences based on theories explaining how to generate creativity [Rotherham 09].

The design principles of the pedagogical activity, and consequently of the tool supporting it, presented in this work are based on a pedagogical frame that incorporates mainly two elements: collaboration and externalization. Regarding collaboration, [Fischer 04] proposes that creativity emerges from the interactions between individuals and the world, and between the individual and others; in the same way, [Csikszentmihalyi 96] emphasizes human interaction as the place where creativity emerges. [Fischer 04] adopts a similar approach when proposing that creativity lies in interactions between persons' thoughts and their socio cultural context. [Sawyer 11] proposes that creativity breakthroughs occur during the dialog

among persons when they answer to each other; this contrasts with the myth of individual inspiration, which represents the idea that creative inspiration comes from the individual. Likewise, [Hennessy 11] identify that the base of creativity lies in the tension between different perspectives. Therefore, interactions among people having different points of view, which are in opposition (tension), can be the base for a suitable activity where creative ideas may arise. From the importance of collaboration we can derive the convenience of designing activities that include intensive and varied interaction with other persons, allowing the sharing and discussion of ideas, and observing new points of view. The second element of creativity we consider, externalization, refers to "taking out of her/himself" the ideas and thoughts in order to translate them in concrete artefacts representing them, in order to make them accessible for working and reflect about them [Bruner 96]. This attribute of externalization is based on what [Schön 83] calls the "back-talk". The meaning is that the process of externalizing ideas can unveil questions about them which were initially ignored, facilitate the emergence of new perspectives, show new possibilities or obstacles, as well as new relationships to other ideas. Sketching, drawing and diagramming are good examples of externalization processes [Antunes 13], which can facilitate creative work and foster the development of this competence. From the advantages of externalization we can derive the usefulness of designing activities which include the elaboration of sketches or other forms of graphic expression [Zurita 08].

The literature reports on a number of pedagogical practices that make no use of technology which are aimed at fostering expressiveness and externalization in order to stimulate creativity. Some of them make use of various methods which combine the collaborative exchange of ideas [Guzdial 01] based on drawing and sketching [Van der Lugt 02; Lane 10]. The simplest case is the brainsketching technique [Pickens 80], in which students first draw their ideas individually and then exchange them, so that other participant can complement or modify them, either silently or explaining them at the moment they pass them to other participants [Linsey 11]. A more elaborated version is C-sketch, which was conceived to foster collaboration in industrial design. Five persons work individually on a problem simultaneously proposing a solution by drawing a sketch. After this, they pass their sketches to the following person who complements, modifies or deletes parts of the original design. Sketches are passed among the members of the group until each participant has worked on each proposal once, thus incorporating the aspect of rotation of the ideas to implement collaborative work [Shah 01].

There is positive evidence about the use of technology for supporting brainstorming processes using sketches and drawings, although not precisely focused on creativity support: Inkboard [Beavers 04], Collboard [Alvarez 13], Magic Paper [Beavers 04], and Co-lab [Van Joolingen 05] are some examples.

Inkboard was designed to be used along with videoconferencing, where participants synchronously can draw sketches over a shared workspace (a virtual board) [Beavers 04]. Collboard, incorporates collaborative elements and freehand sketches using digital pens and interactive boards with private and public spaces; sketches first drawn on private workspaces can be then shared in public ones in order to continue working collaboratively [Alvarez 13]. Magic paper was developed by the

MIT and allows teacher and students to draw physical models on a virtual board working collaboratively [Beavers 04].

All mentioned applications use technology to support creativity. A common aspect to all of them is that participants first develop ideas individually and then share them, in order to converge to a single idea collaboratively; therefore we incorporate this aspect in the design of Sketchpad. Another common aspect of all mentioned applications is that working groups remain static during the whole activity.

Regarding pedagogical practices in business schools' curricula for developing creativity skills in students, the literature reports some research works made on pedagogical methodologies introduced in the courses of their curricula. For example in the year 2007, the *Creative Marketing Breakthrough* (CMB) presents a reference frame for the development of creativity in lectures through specific activities related to Marketing [Titus 07]. The CMB model defines creativity as the process through which disruptive ideas are generated, and considers five theoretical concepts as its key elements: (1) *task motivation*, (2) *cognitive flexibility,* (3) *disciplinary knowledge,* (4) *serendipity* and (5) *uncertainty* [Titus 07]. [Aylesworth 08] proposed to develop creativity in the business classroom through the *improve-mindset* based on the use of techniques of theater improvisation applied to discussion of case analysis. For this purpose, students must follow five steps of theater improvisation: (1) "*Yes, and…*" they have to accept what their classmates say and add something to it. They cannot deny or reject what others previously said. (2) "*Deny, order, repeat and question*", none of these actions is permitted. (3) "*Driving in the rearview mirror"*, they have to build on the context proposed at the beginning. (4) "*Take Care of yourself … by Taking Care of Everyone Else"*, collaboration instead of competition is promoted. (5) "*Mistakes are good offers in disguise",* there are no mistakes during the discussion since all ideas can lead to new perspectives and better understanding of the case [Aylesworth 08]. The *improve-mindset* is meant to generate a collaborative and highly participative atmosphere in the classroom, which leads to spontaneity and creativity.

We think it is worthwhile to explore which is the role technology can play for developing creativity in students of a business school, like for example, using tablets for supporting externalization through brainsketching.

4 Sketchpad Design

Sketchpad is a collaborative tool running on tablets (specifically iPads) which was designed and developed to support pedagogical activities aimed at developing creativity in fourth year undergraduate students at the Business School of the University of Chile. It has been implemented using HTML5 and the Coupled Object technology (described in [Frez 12; Baloian 13]) so it can be run using web browsers Chrome, Mozilla, or Safari regardless from the operative system of the computational device. Its main interface, shown in Figure 1, consists of a workspace, which can be private or shared, where the user creates sketches by freehand drawing and text typewriting, including basic edition functionalities like deleting, copy and paste, undo, redo, changing colors, zooming in and out, etc.

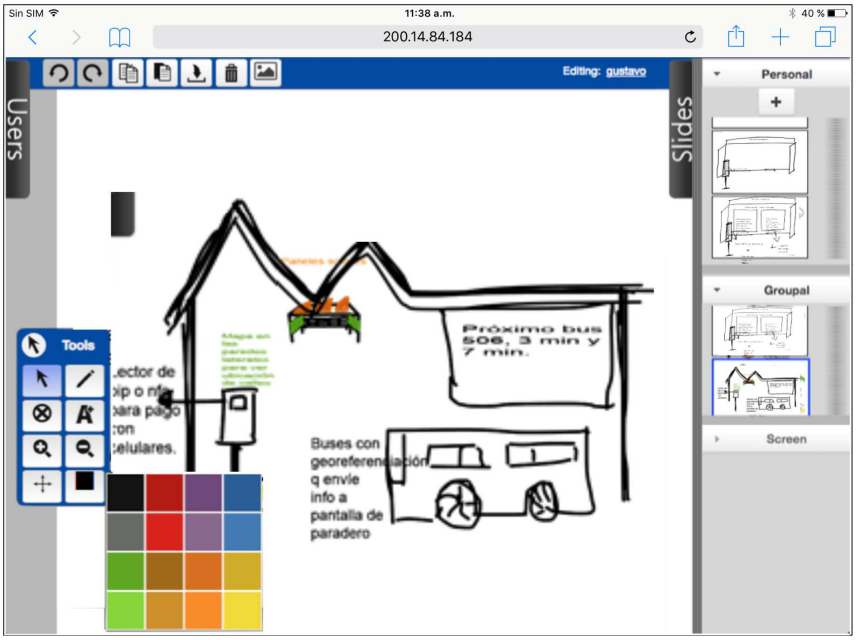

Figure 1: Main interface of Sketchpad showing in the main workspace a proposal for the design of "technological bus stop"; that is being edited collaboratively. The selected page (highlighted with a blue frame) is in the public ("Groupal") area.

Students can make their contributions through brainsketching to several individual and/or shared pages but they can work on one at a time only. Icons with a small view of the page content are shown at the right hand side of the interface, separated in two areas: private ("Personal") and public ("Groupal"). The page that is currently edited is highlighted with a blue frame (Figure 1). In order to share a private page the user has simply to drag and drop its icon from the private to the public area. A copy of the page will appear in the public area, keeping the original page in the private one. After this, all users participating in the session will see this page as a new icon in the public area. They can start working collaboratively by selecting it, clicking on the icon. Figure 1 shows that the user has created two private pages; one of them has been copied to the shared area and has received another icon of someone else who shared a page. The second public page is highlighted with a blue frame indicating that the user is currently working on it, thus it is shown in the main workspace at the center of the interface. By sketching, students can externalize ideas and proposals, thus promoting creativity [Bruner 96; Zurita 08]. [Bruner 96] and [Schön 83] mention the advantages of translating ideas into sketches. Collaborative work using Sketchpad is aimed at promoting creativity as stated by [Csikszentmihalyi 96; Fischer 04] and [Sawyer 11], who say that the base for creativity lies in the interaction with others. The easy way that students can access the working pages in the collaborative area contributes to the *tool transparency* (section 3.2). Sketchpad implements some functionalities in order to easily include participants in a group and also to exclude

them. This, and the fact that Sketchpad can be used on tablets make it easy to perform rotations of students among the groups. The rotation strategy is a way to get students involved in the others‘ proposals and create positive interdependencies [Guerrero 03]. We think the more students can contribute to one idea or proposal, the better will be the *exploration* factor described in section 3.2, since various points of view can defy the thinking and knowledge structures previously built.

5 Evaluation of the Sketchpad´s Contribution to Creativity and Collaborative Support

Sketchpad was tested in a real classroom in order to formally evaluate how students perceived its contribution to two strongly related aspects. The first aspect is related to the support level Sketchpad is able to provide for performing the learning activity requiring creativity and the second, the support level Sketchpad is sable to provide for performing a collaborative activity. This second aspect will be tested under two working modality: one without reconfiguration of groups and the other with reconfiguration. In the second modality students will have to work with different groups at different stages of the activity, leaving a group and joining another several times. The reason for introducing reconfiguration of groups can be found in other works which have presented learning activities which also include this aspect [Chang 09], [Jonassen 99], [Zurita 05]. This is a way to allow students get inspired by looking into others' ideas and at the same time contribute with the ideas seen in one group to another.

The first aspect of the evaluation answers the research question (1) According to the students' perception, to what extent the activity supported by Sketchpad contributes to the development of creativity?; and the second to the following two: (2) which is the perception the students get about the contribution of Sketchpad to promote collaboration?; and (3) is there a difference in this perception when students work in groups where members have to rotate among the various groups and when they do not?

The current study employs mainly a quantitative design in order to evaluate both mentioned aspects [Creswell 09]. First, quantitative students' perception data were analyzed to evaluate the support level Sketchpad provides for developing a learning activity requiring creativity through an open questionnaire based on the Creativity Factor Index (CSI) [Carroll 09]; in addition to qualitative data, open answer questions and observation records were used as complementary data to support quantitative findings. Second, quantitative students' perception data were analyzed to measure Sketchpad's contribution to collaboration for each of the two mentioned modalities, with and without group reconfiguration. Based on these results we could evaluate if there was a difference between the students' perception when working on one or another modality, for which a quasi-experimental design was conducted.

Participants were students of a fourth-year "Technology Information" undergraduate course with students of the Business and Economics Faculty, from the Universidad of Chile. Nineteen students (13 men and 6 women, average age = 22.7 years) were randomly assigned to six groups consisting of three students each and one of four students; three of these groups were part of the experimental group (EG) –

students working with rotation, and the other three were a control group (CG) – students working without rotation. The group with four students was part of the control group.

A week before the experiment, all students were instructed in the use of Sketchpad, and how to propose a creative idea. The actual learning activity was done during a regular class during 90 minutes, where all students from the EG and the CG were asked to work collaboratively to identify requirements that people have in a common bus stop, in Santiago de Chile, and together make a single creative technological proposal to fulfill those requirements. For performing the learning activity each student received an iPad where they could run Sketchpad by invoking the URL of the server where it was deployed. Students were asked to jointly propose an idea per group using Sketchpad working collaboratively face-to-face, generating first various ideas (divergent phase of creation), share them among the group members and then come up with an one they consider the most creative (convergent phase of creation). In this way, the learning activity and the use of Sketchpad address "collaboration" and "communication" (to externalize ideas) aspects mentioned as part of the 21st century skills, when searching for a creative idea proposal.

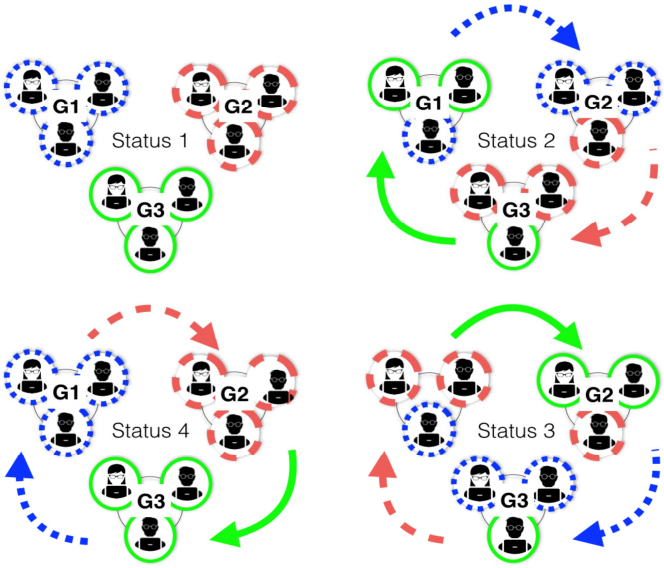

Figure 2: The figure shows a descriptive schema of the collaborative activity during rotations among group members. The four statuses show the composition of the groups after the rotations indicated by the arrows.

As already mentioned, rotation in the EG was included in order to observe if this aspect allows them to benefit from a wider range of possibilities and viewpoints. We focused on supporting collaboration as much as possible and giving students the possibility to evaluate and approach the problem from different perspectives. Therefore, two students of each experimental group had to rotate to the group next to

them, in order to see the other group's solution and share their own. They did this until they rotated among all the other groups and viewed all other proposed solutions. After finishing the rotation, they joined their original group and helped modifying their original solution, inspired from ideas seen in other groups. The control groups performed the activity without rotation, i.e., only sharing ideas among their own groups.

Figure 2 shows schematically how rotations were performed. There were three working groups G1, G2 and G3, each one with three students. The first sketch (upper right) shows status 1, where participants are in the original arrangement. The second sketch (upper right, status 2) shows the groups after two students have moved to the next group. The third sketch (bottom right, status 3) shows the groups after the second rotation. The fourth sketch (bottom left, status 4) shows the groups after the final rotation where students return to their original groups. It is important to highlight that sketches do not rotate, but only the students. So when students arrive to a new group they have to join the new group by joining the public session in which the sketch corresponding to that group is being worked out. This activity shares some similarities with brainsketching, Gallery method and C-sketch, because it involves sketching and the possibility of having various perspectives on them. The main difference lies on the interaction with other group members before producing the final proposal of the group. Figure 3 shows a picture taken during the learning activity.

Figure 3: The picture shows a room layout where students performed the collaborative activity with Sketchpad. Note that the furniture eases the rotation of the team members.

The next subsections describe the evaluations and results of this activity, by using a questionnaire applied to the students 45 minutes after completing it.

5.1 Evaluating the Level of Creativity Support Provided by Sketchpad

[Carroll, 09] proposed a new and revised tool based on a questionnaire called Creativity Support Index (CSI), which was designed to help researchers and designers evaluate the level of creativity support provided by any technological application used in situations where there is participant collaboration. The CSI encompasses six factors related to creativity, which are presented bellow along with the assertions used to measure it, which were included in the questionnaire applied to the students:

(1) *Collaboration*: "The system/tool allowed other people to work with me easily". Authors justify this question due to that collaboration is a very important aspect of creativity support that must be measured individually
(2) *Exploration*: "It was easy for me to explore many different ideas, options, designs, or outcomes".
(3) *Expressiveness*, (or *externalization*): "I was able to be very expressive and creative while doing the activity".
(4) *Results worth effort*: "What I was able to produce was worth the effort I had to exert to produce it".
(5) *Immersion*: "My attention was fully tuned to the activity, and I forgot about the system I was using".
(6) *Enjoyment*: "I was very engaged in this activity - I enjoyed this activity and would do it again".

Students had to express their agreement to each assertion using a Likert scale. Additionally, there was a questionnaire with open answers aimed at evaluating the interaction among participants and their opinion about the possibility the activity gives them to approach the problem from different points of views, which is important for boosting the creativity process. We also included an external viewer who registered aspects about collaboration and externalization.

The CSI tool was applied in two steps. In the first step, students answered the questionnaire presented above by using a six points Likert scale, assigning values from "totally disagree" to "totally agree" to five assertions, each one expressing that according to their opinion, Sketchpad was able to support one of the six factors (collaboration, exploration and expressiveness - externalization, results worth effort, immersion, and enjoyment). In the second step, students were presented with a list of all six possible factor pairs. Since there are six factors, the list consisted of 15 pairs. From each pair they had to select which factor they considered more important than the other one for performing the activity.

Therefore, the obtained data was also analyzed in two steps. First, the data collected with the CSI questionnaire were processed according to what the authors propose in [Carroll 09] in order to generate values from 0 to 100 for each factor. Second, the data was processed for obtaining descriptive statistical information using a standard software application (SPSS). One assertion of the CSI questionnaire was slightly changed for the collaboration factor from "The system/tool allowed other people to work with me easily", with "Sketchpad allowed other people to work with me easily". On another hand, the data obtained by the observations were analyzed manually. As we mention before, the activity was performed during a normal class, after which the questionnaire was applied.

5.2 Results of the Sketchpad Contribution to Creativity

Results associated to the CSI questionnaire are shown in Table 1. According to them, Sketchpad favors creativity on a 67.85 level, from 0 to 100. Students who participated in the activity with rotation evaluated better the support of the technological tool with a CSI of 75.07, compared with a CSI of 58.96 from the students who participated in the activity without rotation. Yet, this difference is not statistically significant and cannot be generalized. Now we will analyze the CSI factors applied to Sketchpad, this is the pairwise comparison of the factors: a) *collaboration* was the factor which was perceived as the most relevant by the students who worked with rotation as well as by the students who worked without rotation; b) *exploration* and *expressiveness (externalization)* are the factors which come next, and are within the 53.2% of the total relevance of the factors, therefore, we can consider that Sketchpad supports the expression and exploration of the proposed ideas; c) although *results worth effort* factor received a good evaluation (VP = 6.97), it was seldom selected as the most relevant factor for performing the activity d) Also the *immersion* was well evaluated but was seldom regarded as important for the activity; e) *enjoyment* was the factor with the lowest evaluation and the least important for performing the activity.

	Total			Group without Rotation - CG			Group with Rotation - EG		
FACTOR	**ANF**	**VP**	**Rate**	**ANF**	**VP**	**Rate**	**ANF**	**VP**	**Rate**
Collaboration	5	6.40	21.33	5	5.32	17.73	5	7.60	25.33
Exploration	4	6.68	17.82	4	5.86	15.63	3	7.60	15.20
Expressiveness (Externalization)	3	7.16	14.32	3	6.58	13.16	3	7.80	15.60
Results worth effort	2	6.97	9.29	1.5	6.58	6.58	3	7.40	14.80
Immersion	1	6.21	4.14	1	6.22	4.15	1	6.20	4.13
Enjoyment	0	5.64	0.94	0.5	5.14	1.71	0	6.20	0.00
	Rate:		67.85	**Rate:**		58.96	**Rate:**		75.07

ANF = mean number of times this factor was selected as the more important in the pair wise comparison; VP = Average score assigned by the students to each factor computed as (number of times the factor was selected *ANF)/1.5. Rate= the rate of the factor according to the answers to the Likert scale evaluation, modified according to the CSI to obtain values between 0 and 100.

Table 1: Results of the first part of the questionnaire

From the analysis of the answers given to the open answers questionnaire related to the aspects of interaction among participants, approaching the problem from various points of view and having them included in the final proposal, the possibility to approach the solution we can conclude the following remarks: a) regarding the ability of the activity and the tool to support interaction among participants, students in general responded with totally agree, or strongly agree; they said they could discuss with their classmates various ways to approach the problem and the ideas that were proposed. Only 5% of the answers were negative. b) Regarding the ability for approaching the solution through various points of view the perception of the students was also positive and most answers were totally agree, strongly agree or agree. Again only 5% were negative. c) Regarding the ability to contribute from various points of view to the final result, students said they could know ideas from other participants

and this helped to refine the final proposal. Most answers to this assertion were totally agreed, strongly agree or agree. Only 7.9% of the answers was negative.

The analysis of the observation guideline has shown that students actively interacted with their classmates, sharing their ideas and explaining them to the rest. Then students proceeded to merge the individual proposals. In this way, new solutions emerged from the elements of the initially proposed ideas and the discussion. Sketchpad obtained a good rate (67.85) thus we can consider that according to students' opinion, it contributes to the development of a learning activity requiring creativity. Moreover, when having various points of views, which was the case for the students working with rotations, the rate was even better than for students working without (75.07 for the EG against 58.96 for the CG). During the discussion the individual ideas complemented each other and disagreements were part of the merging process. New ideas emerged when individual proposals were challenged transforming the original ones in new contributions. Sketches made individually helped students to explain their proposals promoting discussion among them. We observed that the number of ideas proposed by the groups which worked with rotation was higher than the number of ideas generated by the groups without rotation.

		Assertions
Collaboration support (D1)	**SD1.1**	(1) The activity promotes interaction among students. (2) We were able to discuss each other's ideas. (3) We could discuss how to approach the solution.
	SD1.2	(1) The interaction with other participants allowed me to learn different points of view. (2) The interaction with other participants allowed me to see the problem from various perspectives. (3) The interaction with other participants allowed me to think about various solutions to the problem.
	SD1.3	(1) The interaction with other participants was very important for the final solution proposal. (2) Knowing other groups' solutions influenced the final solution proposed by my group (for experimental group only). (3) Knowing the ideas of my group members was of great help for proposing the final solution.
Sketchpad contribution to collaboration (D2)	**SD2.1**	(1) Sketchpad facilitated the Exchange of ideas between participants. (2) Sketchpad was useful for sharing sketches with other members of the group. (3) Sketchpad helped me to better explain my own ideas to other participants. (4) Sketchpad helped me to better understand other participants' ideas. (5) Sketchpad helped me to better explain the ideas of my group to the members of the other groups (for control group only).
	SD2.2	(1) Sketching helped me gain new perspectives of my own idea. (2) Sketching helped me to better understand the problem addressed. (3) Sketching helped me think about solutions I did not considered first. (4) Sketching helped me to communicate my ideas in a better way.
	SD2.3	(1) The activity could not have been carried out in the same way without Sketchpad.

Table 2: Student assertions regarding Collaboration and Sketchpad contribution.

5.3 Evaluating the Sketchpad Support to Collaboration

After completing the activity, students answered a questionnaire related to it and the Sketchpad tool to evaluate the contribution to collaboration. The questionnaire was

designed to measure two dimensions: *Collaboration support* (D1) and *Sketchpad contribution to collaboration* (D2) during the activity in the classroom.

Each dimension was divided into three sub dimensions each: SD1.1 = interaction, SD1.2 = approaching through various viewpoints, SD1.3 = integration of various points of view in the final solution, SD2.1 = contribution to collaboration, SD2.2 = contribution to sketching, SD2.3 = contribution of technology. The sub dimensions of D1 were extracted from [O'Donnell 13]. The questionnaire also included a box of comments.

The questionnaire contained a set of assertions to which the students had to express their agreement or disagreement using a 6-point Likert scale (1= totally disagree 2= strongly disagree 3= disagree 4= agree 5= strongly agree 6= totally agree). For the analysis, a majority of responses from 1 to 3 represents a negative result and majority from 4 to 6 is a positive result. The questionnaire also included a box of comments. Table 2 shows in detail the assertions presented to the students associated with the two dimensions and the six sub dimensions evaluated.

5.4 Result of the Sketchpad Contribution to Collaboration

Figure 4 shows percentages of the Likert-type answers showing the students' perception regarding the assertions for Collaboration support (D1) and for Sketchpad contribution to collaboration (D2) to the learning activity. Numbers are given for the CG and EG. The data shows that students of both EG and CG tend to positively agree with the assertions of the Collaboration support dimension. Agree, strongly agree and totally agree numbers add up to 90.1%. An interesting result is the much higher percentage of students of the EG who "totally agree" with the assertions compared with the CG on all sub-dimensions. These results indicate that the activity supported by Sketchpad including rotation increases the possibility of interacting and discussing with peers, as well as obtaining and developing different perspectives.

We also observe that for the assertions related to *Sketchpad contribution to collaboration* dimension the answers from the students were positive in both, the control and experimental group. In fact, percentage of all positive answers ("totally agree", "strongly agree" and "agree") is 66.31%. This indicates that the perception the students have about the contribution of Sketchpad is overall positive. Moreover, its facility of using sketches allows for a better expression of ideas, obtaining new perspectives, and supporting the activity. Once again responses tend to be much more positive among students from the experimental groups, indicating that students' perceive Sketchpad to be useful for supporting a collaborative activity with rotation.

Regarding the students' comments, there were four aspects which were frequently mentioned: a) Sketchpad presented some problems that should be corrected (mentioned 17 times). The problems mentioned were mainly technical problems and a few about design and usability: "I had problems when I wanted to move my personal slide to the group space. Some images appeared in different places of the slide and the application sometimes got stuck when working collaboratively. The application is a little bit slow loading and performing some instructions". "The tool must be improved with more functions, for example, something to erase parts of the sketch". b) There is a positive perception of the activity and the utility of the tool (mentioned 10 times): "If the problems of this prototype are solved this tool would be very useful to support better group work". "The activity was very good, no complaints". c) The technical

problems the tool has are an obstacle for an optimal performance of the activity (mentioned 3 times): “Moreover, it is necessary that the tool works in an optimal way. It is critical that the users know how to use it; otherwise it will block creativity while sketching solutions. It also hinders the individual and collaboration. I did not know how to edit something or when I did not know which button I should use to create a rectangle, etc.” d) Sketching helps them express and understand ideas (mentioned 2 times): “Sketching ideas is much better than explaining them with a text”.

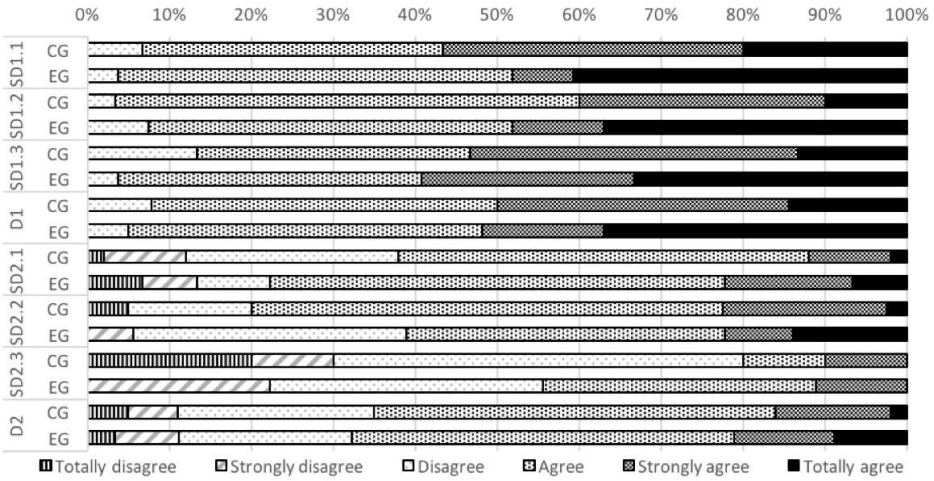

Figure 4: Percentages of questionnaire answers for CG=Control Group, EG=Experimental Group

6 Discussion

The obtained results allow us to answer positively to the research question about the perception students get regarding the contribution of Sketchpad to the collaborative activity. They expressed they could interact with the rest of the participants during the activity and that this interaction was fruitful. This assertion is backed by the 67.85 over 100 score they assigned to the creativity factor of the tool. In the same way, we can conclude that students had a positive perception about working with rotations, since students who worked this way evaluated all factors better than those working without rotations. Performing the activity with rotations gave students the opportunity to get acquainted with various points of view, often different from their own ones, in a short period of time and considering them when preparing the final proposal. In this way, we wanted to shape a pedagogical activity with a strong collaborative component. This has been backed by the observations of a collaborative activity performed by students, where we identified that new ideas emerged from discussions among participants. Another key element considered for shaping the activity was externalization, proposed by [Bruner 13] and [Schön 83], which was achieved by incorporating sketches which students had to elaborate and share; this gave students

the opportunity to know new perspectives, thus promoting creativity. During the activity sketches were used to explain ideas, being a central element for discussion.

Although there are sketching tools already in the market or developed for certain research projects, as seen in section 3, there are features that sketchpad supports which are not implemented by other tools. These are those which enable a student to leave a group and join another, while keeping a personal copy of the workspace of the first group. This was easy the rotation of the students among groups. It is important that this process proceed swiftly without taking too much time or having to perform complicated steps, in order not to disturb the normal flow of the activity.

Results obtained about collaboration during the activity let us believe that the proposed tool, Sketchpad, can be successfully used to support pedagogical activities in classrooms that promote creativity skills. The difference between the results obtained with participants who worked with rotations and without them let us think that Sketchpad could be most effective when used for supporting collaborative activities, as well as in activities requiring a tool for sharing ideas.

Other students who worked in both types of group, with and without rotation, mentioned collaboration as the factor which Sketchpad supports most, which indicates this is perhaps the most relevant factor of the tool. Although the expressiveness (externalization) was the third one selected by the students as the most important factor, it was the one with the best evaluation. This let us consider that Sketchpad is successful for supporting an activity based on collaboration and externalization for promoting creativity through brainsketching.

We could find some evidence supporting the hypotheses stated at the beginning of this paper regarding the differences in the perceived collaboration between the control and experimental groups and the contribution of Sketchpad to the collaboration during the activity. The positive results for the collaboration dimension mean that the proposed activity does promote the interaction necessary for collaborative learning and developing collaboration skills. Although we cannot assure that it will produce collaborative learning, we can say that it provides students with the necessary environment for this kind of learning. The predominantly positive results regarding the students' perception of the tool's ability to support collaboration confirm the ideas previously expressed. The use of sketches has also shown to be a good vehicle to express ideas and approach a solution to the problem including various points of view. Therefore, we think that despite the technical problems of the tool (which have been mostly solved in a new version already developed) we consider the activity successful for both, the control and experimental groups. Negative comments from the students mostly addressed technical problems with the tool and the positive ones were related to the activity itself and the contribution of the tool.

Several activities are envisioned as future work concerning this project. One of them is to make experiments with various types of problems to be presented to the students to check if they make any difference in the results. A second activity is to get external assessment of experts concerning creativity, according to the criteria presented in Section 1.

References

[AACSB 13] AACSB: Standard 9. "Curriculum content is appropriate to general expectations for the degree program type and learning goals*";* (2013) [cited 20-04-2015]; Available from: http://www.aacsb.edu/accreditation/standards/2013-business/learning-and-teaching/standard9.aspx

[AACSB 15] AACSB: "Teaching Design for Creativity and Innovation*";* (2015) [cited 2015 20-04-2015]; Available from: http://www.aacsb.edu/en/events/Seminars/curriculum-development-series/design-thinking.aspx

[Alvarez 13] Alvarez, C., Salavati, S., Nussbaum, M. Milrad, M.: "Collboard: Fostering new media literacies in the classroom through collaborative problem solving supported by digital pens and interactive whiteboards"; Computers & Education, 63 (2013), 368-379.

[Amabile 96] Amabile, T.: "Creativity in context"; Westview Press (1996)

[Antunes 13] Antunes, P., Simoes, D., Carrico, L, Pino, J. A.: "An end-user approach to business process modeling"; Journal of Network and Computer Applications, 36, 6 (2013), 1466-1479.

[Aylesworth 08] Aylesworth, A.: "Improving case discussion with an improv mind-set"; Journal of Marketing Education, 30, 2 (2008), 106-115.

[Baloian 13] Baloian, N., Gutierrez, F., and Zurita, G.: "An architecture for developing distributed collaborative applications using HTML5"; IEEE 17th International Conference on Computer Supported Cooperative Work in Design (CSCWD), IEEE (2013), 213-220.

[Beavers 04] Beavers, J., Chou, T., Hinrichs, R., Moffatt, C., Pahud, M.,and Eaton, J. V.: "The learning experience project: Enabling collaborative learning with ConferenceXP"; Microsoft Research Technical Report MSR-TR-2004-42, April 2004.

[Bruner 96] Bruner, J.S.: "The culture of education"; H.U. Press (1996)

[Carroll 09] Carroll, E.A., Latulipe, C., Fung, R., and Terry, M.: "Creativity factor evaluation: Towards a Standardized survey metric for creativity support"; 7th ACM conference on Creativity and cognition, Berkeley, California, USA, October 26-30, (2009), 127-136.

[Chang 09] Chang, C. C.: "Using Jigsaw Collaborative Learning Strategy in online discussion to foster a project-based learning community on the web"; International Journal of Instructional Media, 36, 2 (2009), 221-234.

[Creswell 09] Creswell, J.W.: "Research design. Qualitative, quantitative and mixed method approaches"; Sage Publications (2009)

[Csikszentmihalyi 96] Csikszentmihalyi, M.: "Creativity: flow and the psychology of discovery and invention"; HarperCollins Pub., 1st Ed. (1996)

[De Bobo 90] De Bobo, E.: "Lateral Thinking: a textbook for Creativity"; Penguin Books Pub., 2nd Ed. (1990)

[Fairbank 01] Fairbank, J. F., & Williams, S. D.: "Motivating creativity and enhancing innovation through employee suggestion system technology"; Creativity and Innovation Management, 10, 2 (2001), 68-74.

[Fischer 04] Fischer, G.: "Social creativity: turning barriers into opportunities for collaborative design"; Proceedings of the eighth conference on Participatory design: Artful integration: interweaving media, materials and practices, ACM Press, New York (2004), 152-162.

[Fons 2010] Fons, John: "A year without paper: Tablet computers in the classroom"; The Physics Teacher, 48, 7 (2010), 481-483.

[Frez 12] Frez, J., Baloian, N. and Zurita, G.: "Software Platform to build geo-collaborative Systems supporting design and planning"; IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD. IEEE Press (2012), 350-357.

[Griffin 11] Griffin, P., McGaw, B., and Care, E.: "Assessment and Teaching of 21st Century Skills"; Springer, Dordrecht (2011).

[Gryskiewics 87] Gryskiewics, S. S.: "Predictable creativity"; in S. G. Isaksen (Ed.): "*Frontiers of creativity research: Beyond the basics"*; Bearly, Buffalo, NY (1987), 305-313.

[Guerrero 03] Guerrero, L., Mejias, B., Collazos, C., Pino, J. A., Ochoa, S.: "Collaborative learning and creative writing"; First Latin American Web Congress, IEEE (2003), 180-186..

[Guzdial 01] Guzdial, M., Rick, J., and Kehoe, C.: "Beyond adoption to invention: Teacher-created collaborative activities in higher education"; J. of the Learning Sc., 10, 3 (2001), 265-279.

[Harvard 15] Harvard Business Review: "Harvard Business Review Search: Creativity" (2015) [cited 22-04-2015]; Available from: https://hbr.org/search?term=creativity

[Harvard 99] Amabile, T. et al.: "Harvard Business Review *on Breakthrough Thinking"*; HBS Press (1999)

[Hennessy 11] Hennessy, S.: "The role of digital artefacts on the interactive whiteboard in supporting classroom dialogue"; Journal of Computer Assisted Learning, 27, 6 (2011), 463-489.

[Isaksen 11] Isaksen, S. G., Dorval, K. B., and Treffinger, D. J.: "Creativity, Approaches to Problem Solving- A Framework for Innovation and Change"; Sage Pub., 3rd Ed. (2011)

[Isaksen 84] Isaksen, S. G.: "Organizational and industrial innovation: Using critical and creative thinking"; Paper presented at the Conference on Critical Thinking: An Interdisciplinary Appraisal, sponsored by Kingsborough Community College, NY (1984).

[Isaksen 85] Isaksen, S. G. and Treffinger, D. J.: "Creative Problem Solving; The Basic Course"; Bearly Ltd. Pub. (1985)

[Jonassen 98] Jonassen, D. H., Pfeiffer, W. S.,, & Wilson, B. G.: "Learning with technology: A constructivist perspective"; Prentice Hall (1998)

[Lane 10] Lane, D., Seery, N., and Gordon, S.: "Promoting Creative Discovery and Mental Synthesis through Freehand Sketching"; in "Visualizing Change: Graphics on the Horizon"; ASEE Engineering Design Graphics Division 65th Mid-Year Conference (October 2010), Houghton, Michigan (2010).

[Linsey 11] Linsey, J.S., E.F. Clauss, E. F., Kurtoglu, T., Murphy, J. T., Wood, K. L., Markman, A. B.: "An experimental study of group idea generation techniques: understanding the roles of idea representation and viewing methods"; Journal of Mechanical Design, 133, 3 (2011), 1-15.

[Mamykaya 2002] Mamykina, L., Candy, L., & Edmonds, E.: "Collaborative creativity"; Communications of the ACM, 45, 10 (2002), 96-99.

[Mihai 12] Mihai-Yiannaki, S., & Savvides, S.: "Creativity in business schools-post financial crisis implications"; International Journal of Organizational Analysis, 20, 2 (2012), 187-202.

[Niemi 14] Niemi, H., Harju, V., Vivitsou, M., Viitanen, K., Multisilta, J., & Kuokkanen, A.: "Digital Storytelling for 21st -Century Skills in Virtual Learning Environments"; Creative Education, 5 (2014), 657-671.

[Noller 79] Noller R. B.: "Scratching the surface of creative problem solving: A bird's eye view of CPS"; DOK, Buffalo, NY (1979)

[O'Donnell 13] O'Donnell, A. M., Hmelo-Silver, C. E., & Erkens, G. (Eds.). "Collaborative learning, reasoning, and technology"; Routledge (2013)

[Pickens 80] Pickens, J.: "Brainsketching"; Norman, OK: University of Oklahoma (1980)

[Rotherham 09] Rotherham, A.J. and Willingham, D.: "21st Century skills: The challenges ahead"; Educational Leadership, 67, 1 (2009), 16-21.

[Rhodes 61] Rhodes, M.: "An analysis of creativity"; Phi Delta Kappan, 42 (1961), 205-310.

[Sawyer 11] Sawyer, R. K.: "Explaining creativity: The science of human innovation"; Oxford University Press (2011)

[Schlee 14] Schlee, R.P. and Harich, K. R.: "Teaching Creativity to Business Students: How Well Are We Doing?"; Journal of Education for Business, 89, 3 (2014), 133-141.

[Schön 83] Schön, D.A.: "The reflective practitioner: How professionals think in action"; vol. 5126, Basic Books (1983)

[Seeling 12] Seeling, T. L.: "inGenius- A Crash Course on Creativity"; HarperCollins Pub., 1st Ed. (2012)

[Shah 01] Shah, J.J., Vargas-Hernandez, N.O.E., Summers, J.D., Kulkarni, S.: "Collaborative sketching (C-sketch): an idea generation technique for engineering design"; J. Creative Behav., 35**,** 3 (2001), 168-198.

[Titus 07] Titus, P.A.: "Applied creativity: The creative marketing breakthrough model"; Journal of Marketing Education, 29, 3 (2007), 262-272.

[Van der Lugt 02] Van der Lugt, R.: "Brainsketching and how it differs from brainstorming"; Creativity and Innovation Management, 11, 1 (2002), 43-54.

[Van Joolingen 05] van Joolingen, W. de Jong T., Lazonder, A. Savelsbergh, E. Manlove S.: "Co-Lab: research and development of an online learning environment for collaborative scientific discovery learning"; Computers in human behavior, 21, 4 (2005), 671-688.

[Weisberg 93] Weisberg, R. W.: "Creativity: beyond the myth of genius"; W. H. Freeman & Co., NY (1993).

[Yar 08] Yar Hamidi, D., Wennberg, K., & Berglund, H. (2008). Creativity in entrepreneurship education. Journal of Small Business and Enterprise Development, 15(2), 304-320.

[Zurita 05] Zurita, G., Nussbaum, M., & Salinas, R.: "Dynamic grouping in collaborative learning supported by wireless handhelds"; Educational Technology & Society, 8, 3 (2005), 149-161.

[Zurita 08] Zurita, G., Baloian, N., and Baytelman, F.: "A collaborative face-to-face design support system based on sketching and gesturing"; Advanced Engineering Informatics, 22, 3 (2008), 340-349.

[Zurita 15] Zurita, G., Cárdenas, C., & Baloian, N.: "Sketchpad: A Learning Tool Supporting Creativity in Collaborative Learning Activities", CYTED-RITOS International Workshop on Groupware 2015, Springer (2015), 198-209.