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Evaluation of computer tools for idea generation and team formation in project-based learning

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ABSTRACT

The main objective of this research was to validate the effectiveness of Wikideas and Creativity Connector tools to stimulate the generation of ideas and originality by university students organized into groups according to their indexes of creativity and affinity. Another goal of the study was to evaluate the classroom climate created by these tools and the method "Think Actively in a Social Context" (TASC) proposed by Wallace and Adams (1993) and framed within project-based learning (PBL). The research was conducted with a sample of 34 students in the third year of a Computer Engineering degree, which, during a period of 15 weeks, required them to design and implement an innovative distributed application project. The procedure consisted of the implementation of the eight phases of the TASC method integrated to the Wikideas and Creativity Connector tools. The information provided by the tools, interviews and questionnaires administered to students were used to analyze our hypothesis. The results show that the tools helped the students to generate, evaluate and select the most relevant ideas and to form teams for project execution. They also revealed that teams with high indexes of creativity and affinity (type α) achieved the best grades in academic performance and project originality. Furthermore, research data show that Wikideas and Creativity Connector along with the TASC approach created a positive classroom climate for students. Based on this work, several suggestions can be extracted on the use of the tools and the TASC method for project-based learning.

1. Introduction

Creativity, referred to by some authors as divergent thinking, is the ability of humans to produce something new and useful and to solve problems in an original way. It can manifest itself many forms, but even in an educational context, it often refers to ideational creativity (Feist, 1999; Mumford, Mobley, Uhlman, Reiter-Oaknib, & Doares, 1991; Sternberg & Lubart, 1995; Torrance, 1988; Weisberg & Hass, 2007). Creativity is modifiable, teachable and can be enhanced by exercising the three essential skills that determine it: flexibility, that is, the ability to generate many ideas; fluidity, specifically, of different categories; and originality, i.e., producing something new or unique (Cubukcu & Dündar, 2007; George, 2007). Creativity has become an area of interest to researchers in many scientific disciplines because of the great influence creative skills have over solving the problems of the modern world (Runco, 2004).

Four directions can be identified in the current literature on creativity research: (a) to find the association of creativity with personal factors such as cognitive ability and/or with personality traits (Piirto, 1999); (b) to examine the cognitive and social processes that are involved in creativity (Paulus & Brown, 2003); (c) to foster ideational creativity by means of computer tools (Neo & Neo, 2009; Shneiderman et al., 2006; Yang & Cheng, 2010); and (d) to determine the environmental factors that nurture or inhibit creativity (Amabile, 1996; Amabile, Barsade, Mueller, & Staw, 2005; Sanz de Acedo Lizarraga, Sanz de Acedo Baquedano, Goicoa Mangado, & Cardelle-Elawar, 2009). The present study was conceived to investigate the effectiveness of two computer tools incorporated into a project-based learning (PBL) method in ideational creativity, which applies to directions (c) and (d).

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Diverse sets of technological tools have been used to support individual and group creativity, mainly in a work context with different team sizes (Lazzeretti, Boix, & Capone, 2008). They can substantially contribute to organization creativity and innovation and can play a relevant role in competitiveness. Such tools facilitate the control of production by making use of simultaneous communication, reducing user apprehensions of being evaluated negatively by others by maintaining anonymity, and supporting many kinds of interactions (Baer, 2010; Dawson, 2008). A well-known example is the Electronic Brainstorming System, or EBS (Nunamakar, Dennis, Valacich, & Vogel, 1991; Pinsonneault, Barki, Gallupe, & Hoppen, 1999), which was designed to change the behavior of groups and to help employees relate easily in their meetings. Members sit in front of their computers and type their ideas anonymously. The ideas are then passed on to other members electronically and synchronously. Recent studies continue to evaluate the pros and the cons of using EBS in organizations. This system seems to have more positive effects on the efficiency of the groups than both nominal brainstorming and face-to-face brainstorming (Chidambaram & Tung, 2005; Dornburg, Stevens, Hendrickson, & Davidson, 2009).

Researchers work to improve the performance of new technologies and to identify their potential applications for enhancing or even transforming the way people learn, work, think, interact, and communicate with each other (Fleming, Mingo, & Chen, 2007; Johnson, Suriya, Yoon, Berret, & Fleur, 2002; McLoughlin & Lee, 2009). There has been a groundswell of interest in how computers and the Internet can best be used to increase the efficiency and effectiveness of education at all levels and in both formal and non-formal settings. It is known that online teaching and learning enable students to become interactive learners and to construct their knowledge through exploration. Computer tools can help more students learn reflectively and stimulate their intrinsic motivation. Although the educational potential of information and communication technologies (ICT) is stressed in a variety of ways (Becker, 2000; Cooper & Brna, 2002), their impact on some competences of learning, particularly on creativity skills, requires further study (Cennamo & Vernon, 2008; Florida, 2002, 2005; Jang, 2009). According to Shneiderman (2007), while there has been extensive research on creativity in many disciplines, the topic is a relatively new one in computer and information science. More data about the impact of ICT applications on creative thinking are necessary to answer whether and how the use of ICT can enable idea generation and originality.

PBL is considered as very important learning strategy because students grow when they are actively involved in tasks that give them choices in product, process and evaluation (Adams, 2006; Laffey, Tupper, Musser, & Wedman, 1998; Nagel, 1996). PBL encourages students to "learn how to learn" via "real-life" problem solving. The PBL method has many elements of the constructivist learning model because it requires that the students become active participants in their learning. In this model, learning is regarded as a process whereby learners construct new ideas and concepts based on their previous knowledge, experiences, and social environments. Social interactions enable students to learn with and from one another, and this activity can lead to increased development of cognitive skills, knowledge and understanding. In other words, students learn best when placed in an environment where they can work collaboratively with their peers and interact socially to discuss and exchange ideas to solve a realistic problem (Neo & Neo, 2009). Yang and Cheng (2010) concluded after working with 60 project groups that PBL influences the development of creativity and innovation in students. Several studies have provided evidence for the idea that creative potential is improved in social environments where groups work with freedom and autonomy or in settings that encourage positive attitudes toward creative behavior (Hunder, Bedell, & Mumford, 2007; Niu & Sternberg, 2003).

The development of a project involves the implementation of a number of phases. In this study, we follow the eight phases proposed by Wallace and Adams (1993) in their method called "Think Actively in a Social Context" (TASC), which consists of the following phases: (1) seeking information about the project, (2) defining the learning goals, (3) generating new ideas about the goals, (4) deciding which ideas are more relevant, (5) verifying the learning, (6) assessing the way the skills were practiced and the project performance, (7) presenting the achievements attained and the difficulties encountered by the group, and (8) learning from the experience.

This method claims to stimulate thinking skills and self-concept so that students will perceive themselves as being capable of achieving realistic goals through their own effort, to facilitate the teachers' effective organization of the instruction, and the students' learning, mainly through group activities, to provide meaningful learning experiences that will help them acquire the syllabus content, and to promote creativity, not only in the third stage of the method, which is idea generation, but also in all of the others, which develop students' expectations of self-efficacy (Sanz de Acedo Lizarraga & Sanz de Acedo Baquedano, 2007). As stated by Wallace and Adams, the method is based on a holistic theoretical perspective. In this sense, it proposes social interaction through intentional mediation, going step-by-step in the learning process so that the current level of performance can change dynamically to a higher one; it suggests activities that demand reflection, creativity, and common sense from students and teachers; it assumes that learning is the result of the interaction of context, behavior, and thinking processes; it obliges students to be capable of regulating and judging their own behavior and making decisions to change it, and it necessitates students to transfer the learning acquired in one context or with certain materials to their performance in another context or with other related materials. As described in the section on procedure, the phases of the method were performed with special support from the Wikideas and Creativity Connector tools.

2. Computer tools

Most of the tools that try to support groups of users in generating creative ideas do not limit the number of ideas that can be observed and discussed by each of the participants nor do they offer the possibility of forming working groups bearing in mind indexes of creativity and affinities among users. Therefore, considering these two limitations, we designed the Wikideas and Creativity Connector tools to assist idea generation and team formation.

The first limitation is overcome in our tools by introducing some mechanisms, such as allowing that every participant could only access ideas generated on a limited number of subjects and connecting to subjects that have similar indexes of creativity, for example, productive subjects with other productive subjects and unproductive subjects with other unproductive subjects. The incorporation of these characteristics was for the following reasons: (a) the frequent loss of concentration of the participants due to the excess of ideas received, which interferes the generation of their own ideas (Pinsonneault et al., 1999), and (b) the negative comparisons that can take place between contributors that can cause productive members to reduce their contribution to match the group's poor standards (Paulus, Dugosh, Dzindolet, Putman, & Coskun, 2002).

The second limitation, which is related to the possibility of creating project teams, is overcome by allowing the tools to form teams with similar indexes of creativity and affinity and with indexes opposite to these two features. The pedagogy of project-based learning maintains that to achieve the goals of this methodology it is better that groups are composed of students who have similar ability and interest in the topics being learned (Lin, Huang, & Cheng, 2010). However, the debate on the effectiveness of homogeneous and heterogeneous groups is still open and needs further investigation (Bowers, Pharmer, & Salas, 2000; Hooper & Hannafin, 1988; Watson & Marshall, 1995). Hence, we designed the tools so they could create 4 types of teams, which were teams with high indexes of creativity and affinity, teams with low indexes of creativity and affinity and teams opposing in their indexes of creativity and affinity.

The Wikideas and Creativity Connector tools are implemented with two of the most important Web 2.0 technologies, namely, wiki technology and social networking. Web 2.0 technologies comprise tools, mechanisms and standards that facilitate collaborative actions of user communities in Web sites. Wiki technology allows large communities of users to create and edit Web pages online simultaneously, and all versions are stored for later viewing (Leuf & Cunningham, 2001). Social networking technologies use graph algorithms (Pujol, Sangüesa, & Delgado, 2002) and collaborative filtering systems (Resnick & Varian, 1997) to build connections between participants (Jensen, Davis, & Farnham, 2002) and show each user a personalized view of information. These characteristics led us to believe that Web 2.0 technologies are the most appropriate to implement computer tools to support students in generating ideas and forming project teams.

2.1. Wikideas

Wikideas facilitates the generation of ideas in nominal groups and small groups, as well as the evaluation of ideas in brainstorming networks generated by the Creativity Connector tool. It is a Web-based interactive tool based in the WakkaWiki software, which provides functionality beyond other electronic brainstorming systems (Prante, Magerkurth, & Streitz, 2002). It is very easy to use because every idea is transformed into a Wiki page and has four main functions: generating, communicating, analyzing, and assessing information.

1. Generating ideas. This task is performed in a digital private space, in which each user can develop, express, and store his/her new ideas as private Wiki pages containing a detailed description of the idea and can be revised as many times as necessary to improve it.
2. Communicating ideas. Information saved in the above-mentioned private space can be published anonymously so that other users can have access to them. This task is carried out in the following way. After clicking on the information a user wishes to share, the user drags and drops it onto a panel of public ideas as indicated by an icon that symbolizes shared idea. From then on, the information can be viewed by other application users.
3. Analyzing ideas. Published information can be commented on and examined by other users, who can then formulate questions anonymously. Then in a low-risk environment, the author can answer these questions in the corresponding Wiki page, either redefining the idea or adding a pertinent observation. The ideas that have been commented on by other users are marked on the "idea generator" panel so that their creator can respond to the comments.
4. Assessing ideas. Using a Likert scale that range from 1 (very small interest) to 5 (very high interest). Each user can pick up to a pre-specified number of ideas that he or she considers the most interesting.

Before team groups are created, ideas, comments and ratings are shown to other participants without any reference to its author; when final project teams are formed, names of authors appear alongside ideas, comments and ratings. All information relevant to each function can be visualized in its corresponding panel. Fig. 1 shows the interface of the initial Web page of this tool, which can be used to access the panels of each functions mentioned above.

2.2. Creativity connector

Creativity Connector is a social network tool that connects users who wish to participate in common projects. It is implemented using graph algorithms and a collaborative filtering system. This tool is integrated with Wikideas and uses the information generated by its users to relate and bring together participants. The first main function of Creativity Connector is to create a brainstorming network whose nodes are users of Wikideas, which are connected to N other participants. This network is used to show each participant's ideas only to those participants who have a link in that network. The second main function is to form creative affinity teams. Creativity Connector performs both functions automatically and presents results networks and teams graphically as shown in Fig. 2, in which 9 groups can be observed according to different indexes from affinity (major thickness of the lines represent major index of affinity). The class instructor can inspect the resulting teams and manually make some adjustments. The implementation of these functions is defined in the following way.

2.2.1. Brainstorming network creation

After idea generation sessions, the tool calculates the creativity indices of participants using the number of ideas proposed by each participant and the amount of development each participant has done for each idea by measuring the length of the description of each idea. Then the tool assigns to each participant a numerical value proportional to both quantities. The tool creates a brainstorming network connecting each participant with N users that have a similar value of creativity. In practice, each user is connected to N/2 participants with a higher creativity index and N/2 participants with a lower creativity index. This network is used to show each participant' ideas only to those participants who have a link in that user's network.

2.2.2. Formation of creative teams

To form creative teams, Creativity Connector makes use of the rating values assigned by each user to different ideas in Wikideas. With these values, the tool calculates the affinity between participants so that two participants who have similarly rated the same ideas will have a high affinity (Resnick & Varian, 1997). These pair-wise affinities are used to establish related teams in terms of the sum of pair-wise affinities between the members of the team. Team affinities are used to form teams for project development. These teams are selected from all possible combinations of teams. First, the team with the highest affinity among its participants is stipulated and then users in that team are removed from the pool of users used to form teams. This process continues until all participants are assigned to a team.

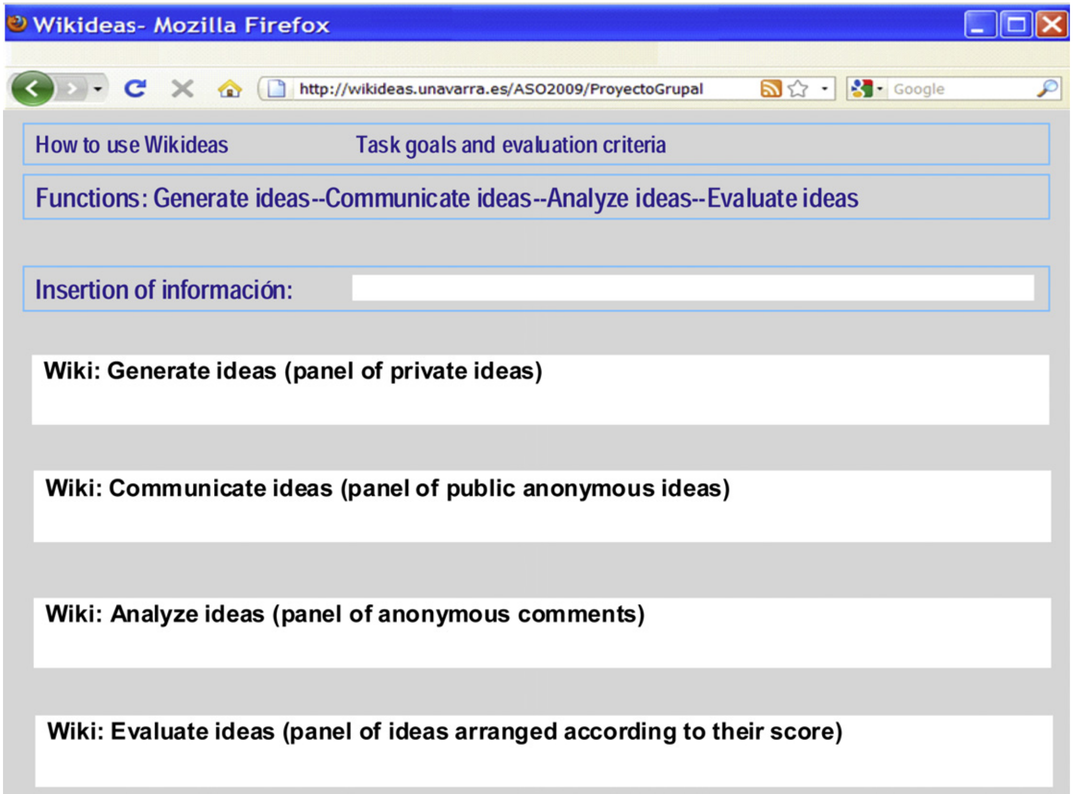

Fig. 1. The initial screen that provides access to Wikideas panels.

3. Purpose of the study

On the basis of the theoretical and empirical framework discussed previously, this work's main objective was to validate the Wikideas and Creativity Connector tools' ability to sustain the production of ideas, originality and formation of teams for project-based learning. The following three hypotheses were formulated.

First, Wikideas and Creativity Connector tools will support generation of creative ideas and originality by university students in a project-based learning course. With this goal in mind, several new functions beyond standard EBS systems (Prante et al., 2002) have being designed: 1) maintaining anonymity of ideas, comments and ratings, 2) calculating creativity and affinity indexes of participants and 3) the configuration of a network of brainstorming peers to limit the number of ideas that each subject can see and evaluate.

Second, teams formed by subjects with high indexes of creativity and high indexes of affinity between them (type α) would obtain better results in originality and academic achievement than those teams with low indexes of creativity and high indexes of affinity (type β), high indexes of creativity and low indexes of affinity (type γ) and low indexes of creativity and low indexes of affinity (type δ). This hypothesis was proposed because, according to the literature reviewed, the complex tasks that are involved in a challenge to the members of a team require high levels of creativity and a strong intrinsic motivation (Bantel, 1994; Bowers et al., 2000; Uzzi & Spiro, 2005). We guessed that the planning and implementation of an innovative distributed application project is a difficult task for students in their third year. Teams will be created by Creativity Connector using participants' creativity and affinity indexes obtained in idea generation and evaluation sessions.

Third, Wikideas and Creativity Connector tools adequately integrated into the project-based method called "Think Actively in a Social Context (TASC)" will create a positive classroom climate that will help them to achieve the aims of the academic course and to create an original project. This environment will influence favorably the intrinsic motivation of the students, their teamwork and their learning.

4. Method

4.1. Participants

The subjects of this study were 34 students from the Public University of Navarre Software Engineering Degree Program enrolled in the third-year course entitled "Advanced Operating Systems" during a semester-long (15 weeks) period for the academic year 2009–2010. The student's mean age was 20.3 years and the standard deviation was 1.1. In addition, 30% of participants were female and 70% were male. Eleven project groups were formed, each of which had three members except one with four.

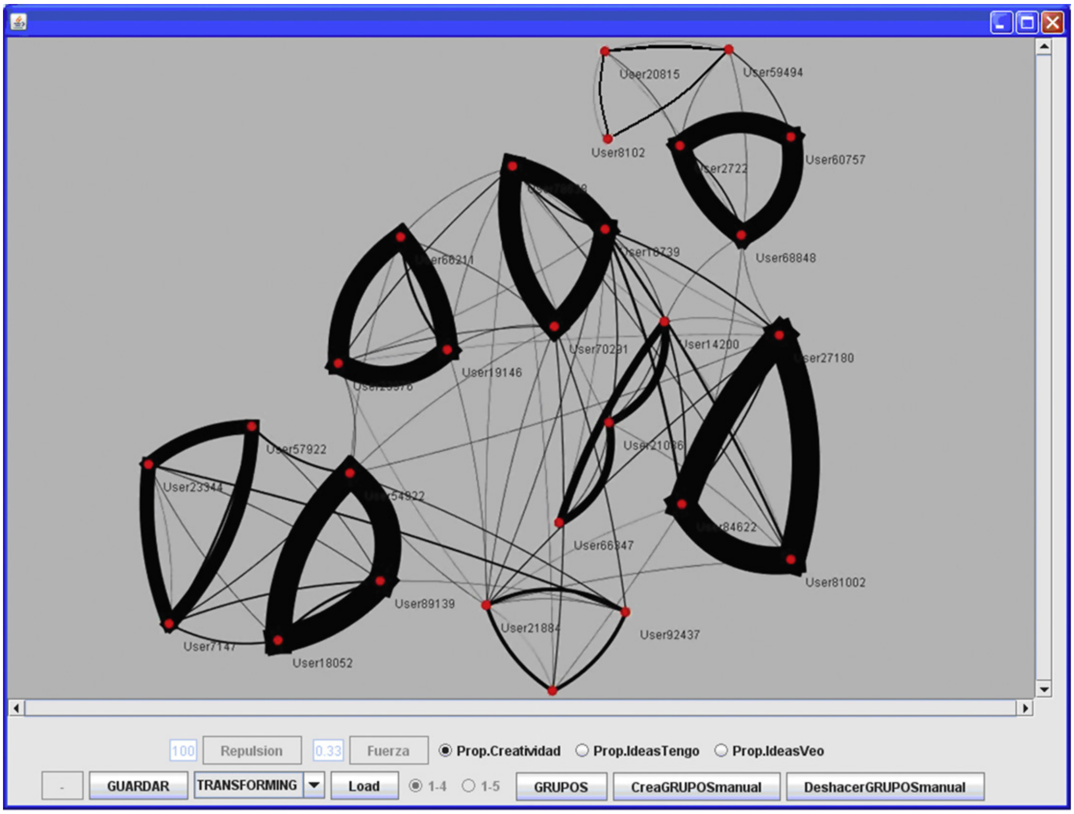

Fig. 2. The graphical user interface of Creativity Connector to visualize affinities of brainstorming networks and teams generated automatically.

4.2. Procedure

The procedure consisted of the implementation of the 8 phases of the method TASC proposed by Wallace and Adams (1993). Fig. 3 shows the sequence of the phases, the tools used, the form of work, and the duration of every phase. The following are descriptions of the tasks that the teacher and the students performed in the different phases.

1. Gathering and organizing. On the first day of class, the teacher explained to the students the following points: (a) the purpose of the course entitled “Advanced Operating Systems”, (b) the importance of creative development for the engineering profession, (c) the use of two tools, Wikideas and Creativity Connector, which would help in achieving the course objectives, (d) the method that was used in the course called “Thinking Actively in a Social Context, TASC” that also would help them in creativity, (e) how learning in the course would be evaluated, and (f) that to achieve these goals, they should work responsibly, both individually and as a group. Then the teacher conducted some brainstorming exercises about several topics, for example, “how can you use a Web search engine?” to familiarize to students with this technique. They had to undertake these reflexive and creative tasks using materials provided by the teacher and Internet information sources such as Wikipedia and Google.
2. Setting goals. In the spaces provided by Wikideas, the students, with the help of the teacher, defined the course goal, which was “the design and performance of a creative software product that was a distributed application composed of at least four different subsystems: a Web robot, a processing server, a storage module, and a Web server”. In addition, they also fixed the evaluation criteria that they would use to assess the obtained results, namely, the student’s active participation in both individual and group activities, implementation of a new project that could have some usefulness outside of the class, and defense of that project in front of the class.
3. Generating ideas. The students, individually, proposed ideas about possible projects using the “generate ideas” function of Wikideas. After this step, the Creativity Connector tool was used to create a brainstorming network so that students could see ideas from eight different students.
4. Evaluation of ideas. In this phase, students communicated their ideas to their classmates anonymously and analyzed their classmate’s ideas using a score of 1–5. Then the Creativity Connector tool used those ratings to form three-person project groups according to affinity. After this phase, the teacher conducted the first interviews of the study.
5. Developing the Project. Organized in groups according to their creativity indexes and interests, the students monitored the execution of their project, always taking into account the fact that it should display clear signs of originality. During this stage, each group met with the teacher weekly to report on their work, to clarify doubts and to specify the tasks to complete for the next meeting. To carry out this task, to communicate with the classmates, to exchange files, and so on, students also used other tools, such as Wikis, e-mail, and Blogs.
6. Assessment. The students reflected upon their own work and their participation in a small group. Then they sent their conclusions to the members of their group. Later, working together, they drafted a comprehensive assessment of their workgroup.
7. Presenting the projects. In various class meetings, each group defended its project in front of the class, underlining its achievements with regard to creativity. They also compared their results with those of other groups and commented on the help provided by the

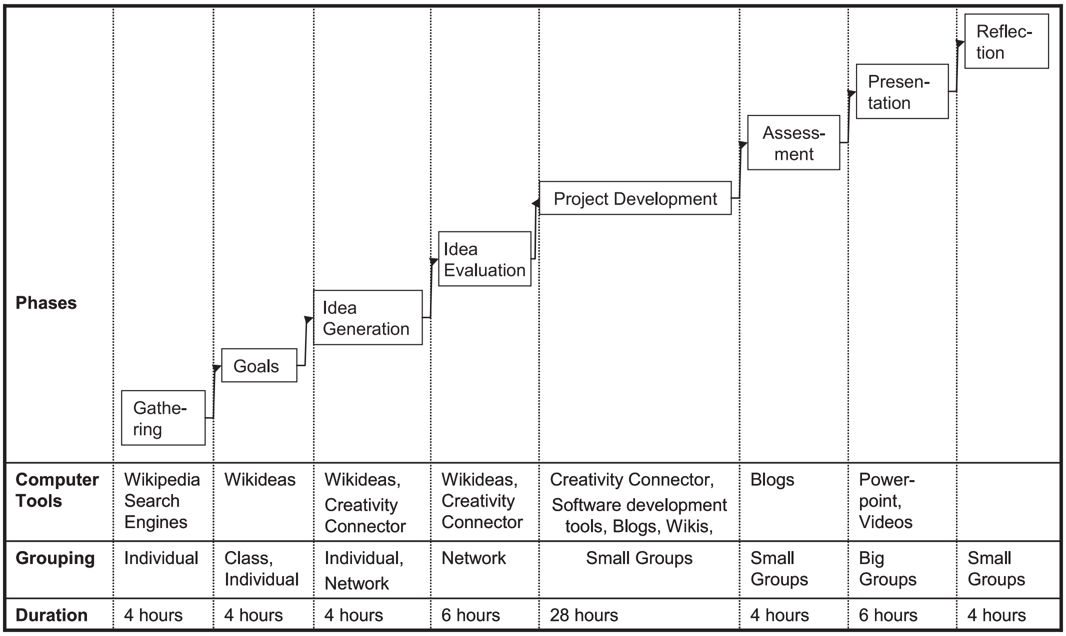

Fig. 3. The phases of the TASC method, tools used, form of work, and duration of the phases.

computer tools and the limitations observed in the execution of the project. This phase allowed other students to see what their course mates had done and to provide feedback to them where necessary. The groups carried out this activity using additional tools, such as Video Editing and Presentation software, which allowed them to present their work in a professional manner.

8. Learning from experience. The students reflected on how to transfer their learning to society and businesses. They commented in detail on the aspects of the project and the tools that should be improved in future experiences and on the significant changes achieved in their creative competencies. In the end, students responded individually to the questionnaire.

During all of these procedures, the teacher's task was to provide guidance and to set up some criteria to help the students complete their projects. They would also come to the teacher for advice on technical as well as design problems. This provided the teacher with the opportunity to monitor their progress and to make sure no team was left behind. Some class lectures were converted to consultation periods for both the students and the teacher to gather feedback from one another. The role of the teacher was that of a facilitator.

4.3. Instruments

4.3.1. Interviews

Two semi-structured interviews with each project team were undertaken. They were more like a conversation or a dialogue than a question–answer interview. One interview was conducted after the formation of the teams to find out if they had accepted the project team assigned by the tool according to affinity and if they had accepted the challenge of carrying out an original project. The other interview was conducted after finishing the project to find out the level of satisfaction of the students in relation to the usefulness of the tools and of the "Think Actively in Social Context" method. Each of these objectives was rated by teams using a scale ranging from 1 to 5 points.

4.3.2. Questionnaire

A questionnaire was designed ad hoc (see Annex) to evaluate the perception of the students about the effectiveness of the tools to support creativity (15 items), and the efficiency of the TASC method (3 items) and the classroom climate created by the tools and method (3 items). Items of the tools gather information about their adequacy for the generation of ideas (3 items), the communication of ideas (3 items), the evaluation of ideas (3 items), the anonymity of the participants (3 items), and the formation of work groups (3 items). The answers were evaluated using a Likert scale ranging from 1 (minimum score) to 7 (maximum score). The total punctuation of the variable tools is 105 points, the punctuation of the variable method is out of 21 points, and the punctuation of the variable classroom climate is also 21 points. These values were divided for his interpretation into three categories: low, medium, and high.

The degree of the relation between each item and the total score was estimated using the corrected item-questionnaire total ratio. This indicator provided values ranging from .45 to .59, which showed that each item in the questionnaire was relevant. The reliability of the questionnaire items was also obtained by Cronbach's alpha coefficient, which was within the acceptable range at .78.

4.3.3. Registry tools

Every action that the participants performed with tools, for example, the generation of ideas, comments and rating, was stored in a database created by researchers for his later statistical analysis.

5. Results

This section is structured around the information that provides the tools, the interviews, the questionnaire and the project created by the students.

5.1. Tool data

The most relevant information obtained by the Wikideas and Creativity Connector tools is described in the following paragraphs.

First. The number of ideas generated by students in the Wikideas tool during the third phase of the method TASC was 320. The average and the standard deviation of the generated ideas were of 9.9 and 7.5, respectively. The high value of the standard deviation is noteworthy because it indicates that the number of ideas generated by each participant was very different.

Second. The total number of comments issued by the participants to the ideas of eight classmates assigned for the tools (4 with high indexes and 4 with low indexes of creativity) was of 305, with an *M* 9.1 and an SD 7.2. Although each of the students could see an average of 64 ideas and evaluate them by giving them a score of 1–5 points, they only evaluated on average 11.5 with a standard deviation of 6.3. These data suggest that students had too many ideas to evaluate.

Third. The index of creativity of every participant, which was calculated automatically by the software tools according to the formula $\sum[1+\log(\text{length}(i))]$, in other words, the summation for every generated idea (i) of one plus the logarithm of the length of the description of the idea, reached an average of 17.5 and a standard deviation of 11.7. Fig. 4 shows the existing relation between the number of generated ideas, the index of creativity and the number of ideas visualized by every participant. We note that there is a certain parallel between the values represented in the figure.

Fourth. The index of affinity between the participants also calculated by the tools according to the formula $\sum(\text{Rating}_{(i),x}\ {}^*\text{Rating}_{(i),y})$, which takes the summation for all generated ideas (i) of the multiplication of the rating of two subjects (x and y) for idea (i) (note that ratings are normalized between 0 and 1 and that if a user does not rate an idea its value is automatically 0). For example, an affinity index of 1 means that two users have rated the same idea with the highest value, in other words, these two users take a very high interest in the same idea. The average of the pair-wise affinities was 2.0 and standard deviation was 1.5, which means that on average any two users take a very high interest on two same ideas.

Fifth. The tools created four types of teams on the basis of the indexes of creativity of every participant and the indexes of affinity between them that consisted of the following groups: (a) three teams were composed of subjects with high indexes of creativity and high indexes of affinity (type α), (b) one team was composed subjects with low indexes of creativity and high indexes of affinity (type β), (c) two teams were composed of subjects with high indexes of creativity and low indexes of affinity (type γ), and (d) five teams were composed of subjects with low indexes of creativity and low indexes of affinity (type δ). Two type δ teams were created with students with zero affinity among them. Table 1 presents, among other information, the averages and standard deviation of the indexes of creativity and affinity of the mentioned teams. This information indicates that the average creativity indexes of type α teams with high index of creativity and affinity (*M* 22.0) and type γ teams with high index of creativity and low affinity (*M* 23.9) were higher than type β teams (*M* 10.6) and type γ teams (*M* 9.1). In addition, the average team affinity of type α and type β teams (*M* 15.1 and 11.3, respectively) was significantly higher than the affinity of type γ and type δ teams (*M* 1.6 and 1.7, respectively).

Therefore, based on the data presented, it seems clear that Wikideas and Creativity Connector tools supported ideational creativity, calculated as the indexes of creativity of subjects and indexes of affinity among the participants. In addition, the tools structured different types of teams bearing in mind the indexes of creativity and of affinity.

5.2. Interview data

In the first interview, which consisted of a total of 11 teams, eight answered (73%) that they agreed completely with the group they had been assigned by tools; one team answered (9%) that it agreed, and two teams answered (18%) that, though formed with affinity zero, they accepted the composition of the group and were willing to do a good project. 100% of the teams stated that they felt very motivated to do the

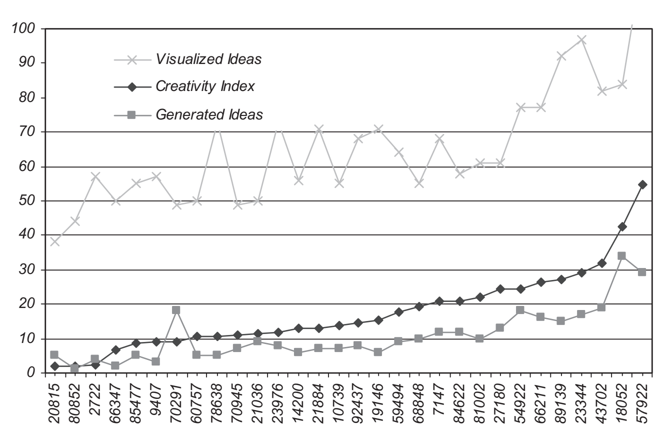

Fig. 4. The number of ideas generated, index of creativity, and number of visualized ideas (*N* 34). The numbers along the *x*-axis are the ids of the tool users.

Table 1
The averages and standard deviations of indexes of creativity and affinity, the originality of the projects and the academic notes of 4 types of groups created by the Wikideas and Creativity Connector tools.

Type of Teams	Number of Teams	Creativity Index		Affinity Index		Originality Project		Academic Grade	
		M	SD	M	SD	M	SD	M	SD
Type α	3	22.0	8.1	15.1	6.2	8.3	.6	8.0	.9
Type β	1	10.6	–	11.3	–	7.0	–	7.1	–
Type γ	2	23.9	10.4	1.6	.4	7.0	.7	7.7	.4
Type δ	5	9.1	3.4	1.7	2.0	5.6	1.5	5.8	1.2

work in a creative way. Among the comments that the students made during the interviews, we highlighted, for example, that "they preferred developing a project with classmates who had similar creative ideas than with those classmates who were only friends."

During this interview, each team was briefed in different ways according to their problems. Case teams with high creativity and affinity were better oriented in their decision-making because they had enough original ideas to choose from; teams with low levels of creativity and affinity required additional support to define their project idea, some commented “we cannot decide (on any idea) because we are not sure if our ideas are good enough.”

In the second interview, eight teams (73%) affirmed that they were very satisfied with the help provided by the tools during the entire academic course, and three teams (27%) affirmed that they were satisfied. This perception was equally observed in some manner formulated by the students as, "it was easier to think creatively with the help of the tools". Regarding the method used, ten teams (91%) evaluated it as very good and one team (9%) evaluated it as good. The only complaint was that “we spend too much time in the early phases and not enough time was left to develop the project.” We could conclude that most of the teams had a favorable opinion of the support provided by the tools and of the efficacy of the TASC method. Almost all of them were prepared to develop an original project, and in turn, all of them developed their project with highly satisfactory results.

5.3. Questionnaire data

The analysis of the answers given by the students to the questionnaire is summarized in Table 2. Regarding the tools variable, we observed that four of its functions obtained a high average perception and the function of the "Evaluation of ideas" reached a medium average opinion. The global average of all the items corresponding to the evaluations of the tools was very high (*M* 80.65 and DS 3.00). This result indicates that, in the opinion of users, the Wikideas and Creativity Connector tools effectively support their creative skills and the formation of project teams.

The second variable, which was the project-based method (TASC), also reached an average in the high category (*M* 17.06). Similarly, the third variable, which was classroom climate, had an average in the high category (*M* 16.88). Thus, these data indicate that the TASC method is highly valued by students as a methodology for developing original projects and that the classroom climate created by the tools and the method proved to be very positive for achieving the aims of the academic course. Students commented that they were challenged to learn more about their chosen subject material and to develop their abilities to analyze, organize, and construct their project successfully.

In short, the information provided by the questionnaire supports both the first and the third hypothesis of this research.

5.4. Project data

Projects undertaken by the 11 teams were assigned an academic grade according to the evaluation criteria established between teacher and students and the official scale of our university education system ranging from 0 to 10 points. The students failed if they received less than 5.

In addition, researchers examined the originality, also on a scale of 0–10 points, of these projects based on the following criteria: (1) novelty, if it was common or unusual; (2) applicability, if it was useful outside of the classroom; (3) complexity, if it used additional subsystems based on the four proposed by the teacher; and (4) defense of the project, if it was clear, precise and complete. Examples of projects undertaken by students may include “a shop to make purchases online from multiple merchants” or “a search engine for rural hostels”.

Table 2
Averages and standard deviations of the perception of the students on the tools, the TASC method, and the climate of the classroom (*N* 34).

Variables	M	DS
TOOLS	80.65	3.00
A) The generation of ideas	17.41	1.46
B) The communication of ideas	15.68	1.51
C) The evaluation of ideas	13.97	1.53
D) Anonymity	15.24	1.33
E) The formation of project teams	18.35	.98
TASC METHOD	17.06	1.43
THE CLASS CLIMATE	16.88	1.32

Table 1 is an evidence that more original projects were created by those teams that had high levels of creativity and affinity (type α, *M* 8.33) than teams with low levels of creativity and affinity (type δ, *M* 5.6). In addition, it appears that all project teams obtained passing grades and those who obtained high grades were type α (*M* 8) and type γ (*M* 7.7). The results obtained by different teams in their originality score and academic grades support the second hypothesis, which predicted that teams with high affinity and creativity indexes would be more original in the creation of their projects than other groups.

6. Discussion

In this study, we intended to validate the effectiveness of Wikideas and Creativity Connector tools to support idea generation and originality in university students organized into different project teams, taking into account their levels of creativity and affinity. The study also aimed at evaluating whether the classroom climate created by the two tools and the project-based learning (PBL) method called "Thinking Actively in a Social Context" was appropriate to carry out an innovative project and, consequently, to achieve the goals of the course.

6.1. Idea generation

The results suggest that the tools promoted both the generation of ideas in students and originality in the development of a software project, which consisted of a distributed application composed of a Web robot, a processing server, a storage module and a Web server. This statement is based on information provided by the tools, the questionnaire and the project accomplished.

First. The tools helped students in the production of ideas, in the visualization of a large number of ideas of the other students (*M* 65), in the assessment of some of the ideas (*M* 11), and in the selection of the best idea for subsequent implementation in a project. The students expressed that in relation to this discrepancy between the number of ideas they had accessed and the number of ideas selected by them, many of the ideas of their colleagues were either very similar or seemed too difficult to implement. These tasks were performed by students in private and public digital spaces in conditions of anonymity, allowing them to choose the ideas of their colleagues that seemed to be the best regardless of their friendship. In this context, a student said, "At first the task was difficult, but gradually, with the help of the tools, the ideas flow in my mind and immediately wrote them in the generate ideas panel with great ease."

Second. The results of the questionnaire revealed that students had highly positive perceptions of the support they received from the tools for generating ideas, communicating their own ideas to others, evaluating the ideas of other students and developing all project stages.

Third. The assessment carried out by researchers on the originality of the project also supports the assumption that the tools helped students to execute their tasks with a degree of originality, a level of complexity and some interesting applicability in society. The contribution of the above three sources allows us to assert that the first hypothesis of the study was confirmed.

These results point in the same direction as other studies that have researched creativity and creativity support by computer tools (Florida, 2002, 2005, Jang, 2009, Johnson et al., 2002, Li, 2002, Shneiderman, 2007), although they surpassed some previous findings. For example, the traditional brainstorming phase ends with the generation of new ideas (Chidambaram & Tung, 2005; Dornburg et al., 2009; Michinov & Primois, 2005). In contrast, our study participants also had to design and implement a project with the best ideas selected; this resulted in students discussing whether ideas could be implement when they could see each other's ideas, instead of generating more ideas as is reported in studies which consider brainstorming as an end in itself. Being able to determine the number of ideas a user has to visualize and evaluate without interfering with his creative process, is another advantage offered by our tools. However, the best mechanism still remains in debate. We conducted a pilot study testing other configurations of tools so that participants could see a different number of ideas. In the current version, they could see the ideas of eight companions; however, both studies only evaluated a small number of them. We hope to provide to the scientific community more definitive data about this in future publications. Moreover, the tools we developed automatically calculate indices of creativity and affinity; to our knowledge, this has not been provided by other tools, which are used to evaluate the productivity of a subject and establish project teams. As a consequence, our tools have resulted, as stated by Shneiderman (2002), in students working collaboratively and expressing individual and social creativity in new ways.

6.2. Team formation

Wikideas and Creativity Connector formed four types of project teams, which consisted of the following groups: (1) subjects with high levels of creativity and affinity (type α), (2) subjects with low levels of creativity and high levels of affinity (type β), (3) subjects with high creativity and low levels of affinity (type γ) and (4) subjects with low levels of creativity and affinity (type δ). Of these categories, we postulated that type α would be better in originality and academic achievement than other categories. The data of Table 1 and the results of the survey and questionnaire, support our second hypothesis. That is, students with high levels of creativity and affinity were able to propose a more innovative project, implemented the components recommended by the instructor, sought the practicality of the idea and presented the project before their peers well.

Students themselves recognized these in their assessments, commenting that "the fact that all members of the team had a lot of ideas and the motivation to achieve the same goal helped us to work in a coordinated way to implement the project in an original way." It, thus, appears that the homogeneity of a team about their ideational creativity and an interest in a common goal can be an important factor to ensure the implementation of an original project, as highlighted by Bantel (1994) and Bowers et al. (2000).

Another important result achieved was that type γ project teams formed by high creativity and low affinity students also achieved very good results in originality and academic performance, which suggests that, once accepted, the members of the teams who came up with the project idea were motivated and worked responsibly and with originality in their development. These data show that students can change their interests and thus direct their efforts towards achieving new goals to compete successfully with other groups (Paulus & Brown, 2003). The tools helped these project teams to avoid spending too much time and effort in analyzing which idea they could choose to implement in their project and was considered an important advantage in the study of Yang and Cheng (2010).

Most participants said in interviews that they were satisfied with the structure of the team and only a few were a bit uncertain in working with partners who initially did not share the same interests. However, as mentioned, this feeling changed for the better with the help of the teacher and the receptive attitude of the students. Therefore, these students needed more guidance at the early stages of development of the project, but soon the team began to function properly. Similarly, the results provided by the questionnaire confirmed that the teams formed by the tools were highly accepted by students.

The data of Table 1 also indicate that tools were able to arrange teams in clearly defined categories in term of the average creativity and affinity indexes of teams. However, the resulting number of teams in each category (3 type α, 1 type β, 3 type γ and 5 type δ teams) indicates that it is difficult to form many teams with high levels of affinity and creativity among members, as was expected. Furthermore, a significant proportion of the teams with low levels of affinity and creativity among members were formed. Organizing small teams out of a large group is a complex problem that has no ideal solution if too many restrictions are applied; this is likely the scenario we confront in the case of our study. Our grouping strategy might have to be evaluated in the future, but if we can classify the resulting teams in terms of a small number of variables as we did, it is easy to provide guidance tailored to each team.

6.3. Classroom climate

The tools and the "Thinking Actively in a Social Context" method created a positive classroom climate for students. Indeed, the integration of both resources, tools and methods, offered continued support in implementing the project, helped them overcome the challenges in every step of the learning process, prepared them for creative action by using the tools in the steps of the method that best encouraged creativity and encouraged the interaction between the learning social context and the exercise of their cognitive processes. A classroom climate with these characteristics could contribute to all students achieving their academic objectives. As the data in Table 1 indicate, teams finished their projects with fairly high grades. Type δ teams, which were composed of low creative members with low affinity among them, performed well and passed their projects. They commented, "we have learned many things during this academic year, one of which is how to work in a team, which prepares us significantly for professional practice." These results support our third hypothesis as well as the fact that it is also expressed by participants in the questionnaire.

These results corroborate the theories of Adams (2006), Laffey et al. (1998) and Nagel (1996) that relate PBL with an active, responsible and collaborative participation of student in learning and "learn how to learn" characteristic to the constructivist perspective. Moreover, as some researchers have emphasized (Sanz de Acedo et al., 2009, Wallace & Adams, 1993), the effect of the TASC method in creativity skills has proven to be significant. We have observed, like many researchers (Anderson, 2002; Hunder et al., 2007, Laffey et al., 1998; Yang & Cheng, 2010), that the classroom climate and method of instruction used is vital to encourage students in developing their creativity.

6.4. Limitations

Regarding the limitations of this study, we can note the lack of an experimental design, which reduces the possibility of generalizing the results to other participants and contexts. The findings obtained were based on a qualitative strategy, which is quite acceptable in exploratory studies. Shneiderman (2007) considers observations over a period of four months sufficient to gather evidence about what works and what does not with respect to computer tools for creativity support. This study lasted 4 months. The goal was to collect quantitative and qualitative evidence on how two creativity support tools benefit users. Another limitation was the use of a relatively small sample, which may reduce the external validity of our findings. In future research, we will evaluate other configuration values of the tools; we will try other methods of team formation with larger samples, and we will examine the relationship that may exist between the indices of creativity provided by the tools and creative ability as measured by other instruments.

6.5. Conclusion

In conclusion, this study validates the potential of the Wikideas and Creativity Connector tools to enhance creative skills, especially the generation of ideas and originality in university students. Similarly, it confirms that the project teams with high levels of creativity and affinity may create more original projects and obtain good academic results as well as the fact that the tools and the method TASC contribute to creating a positive classroom climate. These conclusions are based on a satisfactory perception of the participants on the support of the tools, the structure of the groups and the sequence of steps of the method in the implementation of the project, and its spontaneous assessments issued during different phases of the followed method. Finally, we cannot close without mentioning a conclusion felt by the researchers: “after performing this study, we have a deeper understanding of the role that computer tools can play in the learning and creative process."

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Appendix. Questionnaire on the perceptions of students about.

Tools

A) The generation of ideas
1. - Do you think that the tools helped you to generate ideas for a possible project?
2. - Do you think that the tools helped you to add suggestions to the ideas of classmates?

3. - Do you think that the tools helped you to realize an original project?

B) The communication of ideas
4. - Do you think that knowing the ideas of other participants helps to generate new ideas?
5. - Do you think that communicating your ideas to classmates generated in them new ideas?
6. - Do you think that knowing comments realized to your ideas helps to generate new ideas?

C) The evaluation of ideas
7. - Do you think that you were creative when you evaluated the ideas of others?
8. - Do you think your classmates were creative when they evaluating your ideas?
9. - Do you think that the evaluation of ideas helps to generate new ones?

D) Anonymity
10. - Do you think that it is important to generate ideas in an anonymous format?
11. - Do you think that anonymity promoted the originality of your ideas?
12. - Do you think that anonymity stimulated the originality of the ideas of your classmates?

E) The formation of project teams
13. - Do you think that system-generated teams were appropriate for the project?
14. - Do you think that system-generated teams helped to work in a collaborative manner?
15. - Do you think that system-generated teams encouraged to work in an original manner?

TASC method

16. - Do you think that the "Thinking Actively in a Social Context" method helped in reaching the objectives of the course?
17. - Do you think that the "Thinking Actively in a Social Context" method provided the necessary steps for realizing an original project?
18. - Do you think that the "Thinking Actively in a Social Context" method helped to work in a systematic way in the design and implementation of the project?

Classroom climate

19. - Do you think that classroom climate was positive for learning?
20. - Do you think that classroom climate created by tools and method "Thinking Activity Creativity Context" influenced your motivation?
21. - Do you think that classroom climate favored teamwork?

References

Adams, K. (2006). *The sources of innovation and creativity*. NationalCenter on Education and the Economy. http://www.skillscommission.org/pdf/commissioned_papers/Sources%20of%20Innovation%20and%20Creativity.pdf.
Amabile, T. M. (1996). *Creativity in context*. Boulder, CO: Westview.
Amabile, T. M., Barsade, S. G., Mueller, J. S., & Staw, B. M. (2005). Affect and creativity at work. *Administrative Science Quarterly, 50*(3), 367–403.
Anderson, D. R. (2002). Creative teachers: risk, responsibility, and love. *Journal of Education, 183*(1), 33–48.
Baer, M. (2010). The strength-of-weak-ties perspective on creativity: a comprehensive examination and extension. *Journal of Applied Psychology, 9*(3), 592–601.
Bantel, K. A. (1994). Strategic planning openness. *Group and Organization Management, 19*(4), 406–424.
Becker, H. J. (2000). Access to classroom computers. *Communications of the ACM, 43*(6), 24–25.
Bowers, C. A., Pharmer, J. A., & Salas, E. (2000). When member homogeneity is needed in work teams. a meta-analysis. *Small Group Research, 31*(3), 305–327.
Cennamo, K., & Vernon, M. (2008). *Fostering creativity in the classroom: A case study of a multi-disciplinary design project*. (Proceedings of the NSF Creative-IT workshop at Arizona State University).
Chidambaram, L., & Tung, L. L. (2005). Is out of sight, out of mind? An empirical study of social loafing in technology-supported groups. *Information Systems Research, 16*(2), 149–170.
Cooper, B., & Brna, P. (2002). Supporting high quality interaction and motivation in the classroom using ICT: the social and emotional learning and engagement in the NIMIS project. *Education, Communication, and Information, 2*(1/2), 113–138.
Cubukcu, E., & Dündar, S. (2007). Can creativity be taught? An empirical study on benefits of visual analogy in basic design education. *A|Z ITU Journal of the Faculty of Architecture, 4*(2), 67–80.
Dawson, S. (2008). A study of the relationship between social networks and sense of community. *Educational Technology and Society, 11*(3), 224–238.
Dornburg, C. C., Stevens, S. M., Hendrickson, S. M., & Davidson, G. S. (2009). Improving extreme-scale problem solving: assessing electronic brainstorming effectiveness in an industrial setting. *Human Factors, 51*(4), 519–527.
Feist, G. J. (1999). The influence of personality on artistic and scientific creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 273–296). Cambridge UK: Cambridge University Press.
Fleming, L., Mingo, S., & Chen, D. (2007). Collaborate brokerage, generative creativity, and creative success. *Administrative of Management Annals, 52*(3), 443–475.
Florida, R. (2002). *The rise of the creative class. How it's transforming work, leisure, community and everyday life*. New York: Basic Books.
Florida, R. (2005). *The flight of the creative class*. New York: Harper Collins.
George, J. M. (2007). Creativity in organizations. *Academy of Management Annals, 1*(1), 439–477.
Hooper, S., & Hannafin, M. J. (1988). Cooperative CBI: the effects of heterogeneous versus homogeneous group on the learning of progressively complex concepts. *Journal of Educational Computing Research, 4*(4), 413–424.
Hunder, S. T., Bedell, K. E., & Mumford, M. D. (2007). Climate for creativity: a quantitative review. *Creativity Research Journal, 19*(1), 69–90.
Jang, S. J. (2009). Exploration of secondary students' creativity by integrating web-based technology into an innovative science curriculum. *Computers & Education, 52*(1), 245–255.
Jensen, C., Davis, J., & Farnham, S. (2002). *Finding others online: Reputation systems for social online spaces*. Proceedings of SIGCHI conference on Human factors in computing systems, Minneapolis, Minnesota, USA.
Johnson, S. D., Suriya, C., Yoon, S. W., Berret, J. V., & Fleur, J. L. (2002). Team development and group processes of virtual learning teams. *Computers and Educations, 39*(4), 379–393.
Laffey, J., Tupper, T., Musser, D., & Wedman, J. (1998). A computer-mediated support system for project-based learning. *Education Technology Research and Development, 46*(1), 73–86.
Lazzeretti, L., Boix, R., & Capone, F. (2008). Do creative industries cluster? Mapping creative local production systems in Italy and Spain. *Industry and Innovation, 15*(5), 549–567.
Leuf, B., & Cunningham, W. (2001). *The wiki Way: Collaboration and sharing on the Internet*. Reading, MA: Addison-Wesley.

Li, Q. (2002). Exploration of collaborative learning and communication in an educational environment using computer-mediated communication. *Journal of Research on Technology in Education, 34*(4), 503–516.

Lin, Y. T., Huang, Y. M., & Cheng, S. C. (2010). An automatic group composition system for composing collaborative learning groups using enhanced particle swarm optimization. *Computers & Education, 55*(4), 1483–1493.

McLoughlin, C., & Lee, M. J. W. (2009). *Future learning landscapes: Transforming pedagogy through social software*. Retrieved from May 20, 2009. <http://www.innovateonline.info/index.php?view=article&id=539>.

Michinov, N., & Primois, C. (2005). Improving productivity and creativity in online groups through social comparison process: new evidence for asynchronous electronic brainstorming. *Computers in Human Behaviour, 21*(1), 11–28.

Mumford, M. D., Mobley, M. I., Uhlman, C. E., Reiter-Palmon, R., & Doares, L. (1991). Process analytic models of creative thought. *Creativity Research Journal, 4*, 91–122.

Nagel, N. G. (1996). *Learning through real-word solving: The power of integrating teaching.* CA: Corwin Press.

Neo, M., & Neo, T. K. (2009). Engaging students in multimedia-mediated constructivist learning- student's perceptions. *Educational Technology & Society, 12*(2), 254–266.

Niu, W., & Sternberg, R. J. (2003). Societal and school influences on student creativity: the case of China. *Psychology in the Schools, 40*(1), 103–114.

Nunamakar, J. F., Dennis, A. R., Valacich, J. S., & Vogel, D. R. (1991). Electronic meeting systems to support group work. *Communications of the ACM, 34*(7), 40–61.

Paulus, P. B., & Brown, V. R. (2003). Enhancing ideational creativity in groups: lessons from research on brainstorming. In P. B. Paulus, & B. A. Nijstad (Eds.), *Group creativity. Innovation through collaboration*. Oxford, UK: OxfordUniversity Press.

Paulus, P. B., Dugosh, K. L., Dzindolet, M. T., Putman, V. L., & Coskun, H. (2002). Social and cognitive influences in group brainstorming: predicting gains and losses. In W. Stroebe, & M. Hewstone (Eds.), *European review of social psychology, Vol. 12* (pp. 200–325). London: John Wiley.

Piirto, P. (1999). A survey of psychological studies in creativity. In A. S. Fishkin, B. Cramond, & P. Olszewski-Kubilius (Eds.), *Investigating creativity in youth* (pp. 27–48). Cresskill, NJ: Hampton Press, INC.

Pinsonneault, A., Barki, H., Gallupe, R. B., & Hoppen, N. (1999). Electronic brainstorming: the illusion of productivity. *Information Systems Research, 10*(2), 110–133.

Prante, T., Magerkurth, C., & Streitz, N. (2002). *Developing CSCW tools for idea finding - Empirical results and implications for design*. (Proceeding of CSCW).

Pujol, J. M., Sangüesa, R., & Delgado, J. (2002). *Extracting reputation in multi agent system by means of social network topology*. (Proceeding of First International Joint Conference on Autonomous Agents and Multi-Agent Systems AAMAS, Bologna, Italy).

Resnick, P., & Varian, H. (1997). Recommender systems. *Communications of the ACM, 40*(3), 56–58.

Runco, M. (2004). Creativity. *Annual Review of Psychology, 55*(1), 657–687.

Sanz de Acedo Lizarraga, M. L., & Sanz de Acedo Baquedano, M. T. (2007). *Creatividad individual y grupal en la educación [Individual and group creativity in Education]*. Madrid: Eiunsa.

Sanz de Acedo Lizarraga, M. L., Sanz de Acedo Baquedano, M. T., Goicoa Mangado, T., & Cardelle-Elawar, M. (2009). Enhancement of thinking skills: effects of two intervention methods. *Thinking Skills and Creativity, 4*(1), 30–43.

Shneiderman, B. (2002). *Leonardo's laptop: Human needs and the new computing technologies*. Cambridge, MA: MIT Press.

Shneiderman, B. (2007). Creativity support tools. Accelerating discovery and innovation. *Communications of the ACM, 50*(12), 20–32.

Shneiderman, B., Hewett, T., Fischer, G., Jennings, P., Czerwinski, M., Kules, B., et al. (2006). Creativity support tools: report from a U.S. national science foundation sponsored workshop. *International Journal of Human-Computer Interaction, 20*(2), 61–77.

Sternberg, R. J., & Lubart, T. (1995). *Defying the crowd: Cultivating creativity in a culture of conformity*. New York: Free Press.

Torrance, E. P. (1988). The nature of creativity as manifest in its testing. In R. J. Sternberg (Ed.), *The nature of creativity: Contemporary psychological perspectives* (pp. 43–75). Cambridge, UK: CambridgeUniversity Press.

Uzzi, B., & Spiro, J. (2005). Collaboration and creativity: the small world problem. *American Journal of Sociology, 111*(2), 447–504.

Wallace, B., & Adams, H. B. (1993). *TASC. Thinking actively in a social context*. Bicester, Oxfordshire: A B Academic Publishers.

Watson, S. B., & Marshall, J. E. (1995). Heterogeneous grouping as an element of cooperative learning in an elementary education science course. *School Science and Mathematics, 95*(8), 401–405.

Weisberg, R. A., & Hass, R. (2007). We are all partly right: comment on Simonton. *Creativity Research Journal, 19*(4), 345–360.

Yang, H.-L., & Cheng, H. H. (2010). Creativity of student information system projects: from the perspective of network embeddedness. *Computer & Education, 54*(1), 209–221.