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Fostering Creativity as a Problem-Solving Competence through Design: Think-Create-Learn, a Tool for Teachers

Abstract

Although there is no doubt about the relevance of creativity within education, theory has not been always translated into the practical level, for many reasons. In this paper we analyse the state of art, studying the methods through which creativity is understood and applied by teachers, and identifying problems and opportunities. Accordingly, we conducted a literature review to identify what should be considered to foster creativity in classrooms; from this review, we define fifteen key indicators of creativity in education: incorporation, practicality, novel, atmosphere, stimulation, analysis, cooperation, intrinsic motivation, participation, flexibility, uncertainty, time, divergence, self-evaluation, and redefinition. Based on these indicators, we provide a methodological proposal and a set of practical resources to help the teacher to encourage creativity in any classroom. 'Think-Create-Learn' relies on open, accessible, and intuitive design-based tools, facing challenges through a creative, problem-solving approach; connecting the contents with the student's interests and reality; and generating new competency learning possibilities. The assessment of the methodology, with teachers and students, demonstrates its positive integration into the lines of current teaching curriculums, its validity to support mentioned factors, and its ability to aid teachers to produce more creative people. In short, this paper evidences how design discipline and the methodology proposed could have a relevant role in the creativity development inside educational centres.

Keywords: Creativity; Design Thinking; Didactics; Methodology; Teaching Skills

1. Introduction

Decades ago, Guilford (1950) wondered why the schools failed to produce 'more creative people' and, finally, creativity has been considered one of the most important 21st century thinking skills (Ahmadi et al., 2019; Collard & Looney, 2014; Guo & Woulfin, 2016; Henriksen et al., 2016; Mishra & Mehta, 2017; Nakano & Wechsler, 2018). But do we really know how to develop and promote it? Has the theory been translated into the practical level?

Creativity is an essentially combinatorial process; it is the ability to connect learned knowledge to solve problems and create new things (Kleiman, 2008). Thus, it allows society to advance, looking beyond the established ways, answering to the changing world, and increasing the quality of life (De Bono & Castillo, 1994; Hernández-Torrano & Ibrayeva, 2020; Spendlove, 2008). Creativity tends to be related to problem-solving because 'the two share many processes' (Reiter-Palmon & Illies, 2004). Although there is a debate about their exact relationship (Kirton, 2004; Parkhurst, 1999), there are authors that understand that creativity is promoted by problem-solving (Fasko, 2001; Feldhusen & Treffinger, 1985; Guilford, 1967; Khalid et al., 2020) and that requires a cognitive process away from luck or divine spark (Howard et al., 2008).

Our point of departure is that creativity is not a talent limited to some people but is present in all humans, to a greater or lesser extent (Collard & Looney, 2014; Guilford, 1950), and that to awake, stimulate, and develop this potential requires training in a favourable environment (Burkus, 2013; López, 2008). Obviously, the educational environment has a key role in this matter: people spend a lot of time there, and it reaches all kind of social classes (Chan & Yuen, 2014; Davies et al., 2013; Shaheen, 2010). In fact, for many, it should be transversally embedded within the whole curriculum of the educational programs (Daly et al., 2014; Fasko, 2001), being present in four pillars: educator, student, environment, and methodological resources (López, 2008). In this way, the learning environment could favour student's own development, boosting productivity, adaptability, and efficiency (Craft, 2003; Davies et al., 2013; Simonton, 2000).

It is true that a few years ago, a change in education policy began to spread throughout the world with the objective of combining creativity and knowledge as an engine of school improvement (Burnard, 2006; Collard & Looney, 2014; Dickhut, 2003). Creativity has transformed into one of the curriculum and pedagogy spotlights (Wilson, 2005) at several educational levels, from the early years to primary education for most countries and up to higher education, for some of them (Shaheen, 2010).

Unfortunately, although there is no doubt that interest in creativity within education has increased, in practice, it remains difficult to achieve, and it is often reduced as a separate area from other educational objectives (Spendlove, 2008). This is caused by barriers of widely varied natures, complex and difficult to address for educators (Henriksen et al., 2017).

Perhaps one of the biggest problems is the strong prevalence of the traditional methods of teaching that still exist in formal education, both in public or private schools, and at all educational levels. Methodology is based on the student as a blank slate onto which information is etched by the teacher; on the use of conferences and passive learning, where students listen or watch how the instructor solves problems; and on the textbooks. Some factors that may influence the prevalence of traditional methodologies are the teacher profile (age, motivation/vocation, personal situation), as well as on the administrative structure of the educational centres — in terms of resources availability, restricted hours, class size, comfort, time constraints, and level of communication and joint work among teachers (Lee & Erdogan, 2007; McMullan, 2016; Nguyen et al., 2017; Qi, 2017; Zhang & Guo, 2017; Zhao & Meng, 2015).

Another important factor is that, as a knowledge area, creativity is a multifaceted, and a relatively new and unknown activity. As López (2008) highlighted, '*Creativity aims to promote the divergent in a converged environment; the indefinite in a system that aims to transmit the defined and known*', hence placing the educator in an uncertain position. Also, the term 'creativity' is sometimes used incorrectly; creativity and imagination are used interchangeably (Craft, 2002), and creativity is linked, by default, to arts or leisure (Henriksen et al., 2017; Seltzer & Bentley, 1999). Additionally, the term is surrounded by ingrained myths (Burkus, 2013; Cropley, 2016; Cropley, 2018; MacLaren, 2012) oblivious to the idea of creativity as a process.

Considering this background, the need is clear for practical solutions that help teachers to encourage creativity in the classrooms. One of the knowledge areas that can have a very positive influence on this task is the design field, and Design Thinking in its broadest sense. Creativity and design are closely related, and many authors recognise Design Thinking, *per se*, as a creative process (Elwood et al., 2016; Henriksen et al., 2017; Hernández-Leo et al., 2017; Jordan, 2016; Koehler & Mishra, 2005). Design thinking is an iterative process that repeatedly reformulates a problem to find its core and then analyses possible solutions to find the most favourable, allowing for the formation of 'creative bridges' between problems and solutions (Cross, 2011; Dorst & Cross, 2001). As Blanco (2016) stated, '*the approach from the design represents a differential advantage, both for the approach to the problem, and for the efficiency, affordability and adaptability of its tools'*. In this sense, Design Thinking achieves a balance between convergent and divergent processes, both of which are essential to develop transversal creative thinking skill (Elwood et al., 2016; Gu et al., 2019; Hadar & Tirosh, 2019).

In the education field, Design Thinking can foster open-mindedness in students, create an effective framework to promote creativity as a transversal element (Mosely et al., 2018; Page & Thorsteinsson, 2017; Thorsteinsson & Page, 2017), and improve skills such as collaboration, problem-solving, and innovation, among others (Brown, 2008; Razzouk & Shute, 2012). By developing these skills, the student can achieve what is known as 'creative confidence' (Rauth et al., 2010). Therefore, teachers should employ Design Thinking in their classrooms (Brown, 2008; Carroll et al., 2010; Lin et al., 2020; Lor, 2017; Razzouk & Shute, 2012; Retna, 2016).

For these reasons, the need to support educators with tools and approaches from the point of view of this discipline has been already detected (Elwood et al., 2016; Henriksen et al., 2017; Hernández Leo et al., 2017; Hoogveld et al., 2005; Jordan, 2016; Norton & Hathaway, 2015; Retna, 2016). In this sense, some initiatives have been launched; for example, Ideo (2013) provided some guidance for teachers to design certain solutions, but focused on the schools' facilities.

To address the problem, in the next sections of this paper, we present a methodology called Think-Create-Learn (TCL). Section 2 shows the theoretical bases, stressing the training of more creative individuals. Section 3 collects the results of TCL assessment, carried out in a real educational environment with end users (teachers and students of 15 to 16 years old), by qualitative and quantitative methods. Finally, Section 4 discusses TCL's utility, the advantages, difficulties, and limitations derived from its implementation, and the feedback necessary for its improvement.

2. Materials and Methods

As explained in the introduction, in order to develop a resource that encourages creativity in the classroom, some challenges must be addressed, such as the frequent use of traditional educational methodologies, the education system limitations, and the interpretation of the term 'creativity'.

2.1 Theoretical Bases

Evidently, developing a resource that fosters creativity is not a direct task, and its purpose must be based on a scientific approach. Therefore, the first step was to identify, as a theoretical basis, those factors which influence the development of creativity. To accomplish this, we conducted a literature search, in accordance to Lodico et al., (2010), employing ScienceDirect, Google Scholar, Libraries, and ERIC. We used the term 'creativity' in combination with the terms 'factors', 'aspects', 'evaluation', 'theory', 'education', 'teaching', and 'materials'. As inclusion criteria, we selected those publications that described creativity characteristics, how to introduce creativity in education, or how to teach creativity.

Under these criteria, from the title and the abstract, it was determined which studies met the inclusion criteria. In the selected publications, we identified ideas and concepts related to the creative process, which could be developed in the educational environment, and which defined key aspects for introducing and fostering creativity in classrooms. Despite not considering a specific field during the search, the authors of the selected publications turned out to be mostly from psychology and education fields. It is understandable, given the scope of the research, and also because we excluded those quotes that were directly related to other environments (e.g. business, industry). In any case, the fields of reviewed authors give an idea of the theoretical bases on which the determination of the factors is based. The next step in the process was based on taxonomic sorting method (Withers et al., 2014), specifically the open card sorting method (Spencer & Warfel, 2004). We wrote the selected quotes on sticky notes (cards) and placed them on a large blackboard. Then, we combined these cards to make conceptual and thematic groups, which were no pre-established. Finally, we named each group to describe the content. As a result, we isolated 15 thematic groups, which are the 15 creativity factors shown in Table 1. The factors were organised according to the hypothetical sequence of use of teaching resources, and we collated them with colleagues from design and education field.

Table 1

Creativity Factors

Factor	Definition	References
1. Incorporation	It is adapted correctly to the curriculum	(Feldhusen & Treffinger, 1985; Finke et al., 1992; Logan et al., 1980; López, 2008; Şendurur et al., 2016; Sternberg & Lubart, 1997; Torre & Violant, 2006)
2. Practicality	The materials are logical, useful, and sensitive to the needs of the teacher and student	(Finke et al., 1992; López, 2008; Şendurur et al., 2016)
3. Novel	It is original and attractive	(Finke et al., 1992; Guilford, 1950; Huidobro & González, 2004; Şendurur et al., 2016; Simonton, 2000; Sternberg & Lubart, 1997; Torrance, 1972)
4. Atmosphere	It seeks to escape the monotonous, dogmatic, and traditional work	(Craft, 2003; Feldhusen & Treffinger, 1985; Gervilla, 2003; Lewis, 2009; Logan et al., 1980; López, 2008; Peterson, 2001)
5. Stimulation	It helps to awaken interest	(Craft, 2003; Feldhusen & Treffinger, 1985; Gervilla, 2003; González, 2006; Huidobro & González, 2004; Torre & Violant, 2006)
6. Analysis	The concepts are understood	(Hennessey & Amabile, 1987; Huidobro & González, 2004; Simonton, 2000)
7. Cooperation	It promotes communication and teamwork	(Amabile, 1998; Gervilla, 2003; Huidobro & González, 2004; Torre & Violant, 2006)
8. Intrinsic Motivation	Students are motivated in order to perform actions by themselves	(Amabile, 1998; Craft, 2003; González, 2006; Guilford, 1950; Huidobro & González, 2004; Logan et al., 1980; López, 2008; Simonton, 2000; Sternberg & Lubart, 1997; Torrance, 1972; Torre & Violant, 2006)
9. Participation	It encourages participation, welcoming opinions, questions, and answers	(Fasko, 2001; Feldhusen & Treffinger, 1985; Gervilla, 2003; González, 2006; Huidobro & González, 2004)
10. Flexibility	It allows changes or variations as required	(Finke et al., 1992; Gervilla, 2003; González, 2006; Guilford, 1950; Huidobro & González, 2004; Logan et al., 1980; Simonton, 2000; Sternberg & Lubart, 1997; Torrance, 1972; Torre & Violant, 2006)
11. Uncertainty	It fosters curiosity, inquiry, research, and	(Fasko, 2001; Feldhusen & Treffinger, 1985; Gervilla, 2003;

	experience and allows for making mistakes	González, 2006; Guilford, 1950; Hennessey & Amabile, 1987; Huidobro & González, 2004; Lewis, 2009; Logan et al., 1980; Peterson, 2001; Simonton, 2000; Sternberg & Lubart, 1997; Torrance, 1972)
12. Time	It allows time for reflection	(Feldhusen & Treffinger, 1985)
13. Divergence	It allows for looking at things from different perspective to find more than one possible solution	(Feldhusen & Treffinger, 1985; González, 2006; Guilford, 1950; Huidobro & González, 2004; Simonton, 2000; Sternberg & Lubart, 1997)
14. Self-evaluation	It requires self-evaluation for reflection and enrichment	(Gervilla, 2003; Logan et al., 1980; Torre & Violant, 2006)
15. Redefinition	It requires the student to take feedback and redefine the problem/solution/etc.	(Gervilla, 2003; Guilford, 1950; Torrance, 1972)

2.2 Methodology Rationale

Despite the advantages of Design Thinking for students' education, as happens with creativity, its application in the classroom is not a straightforward labour. Thus, TCL has three fundamental bases: the 15 creativity factors, the adaptation of Design Thinking models, and the development of didactic materials. Additionally, we designed the methodology based on our experience in design and didactics, as well as on a collaborative approach between both disciplines. During the development of TCL, we closely cooperated with teachers from different training cycles; they provided feedback on and a full perspective of the educational environment.

One of our first decisions was to order the phases of the methodology, which, as well as the factors, were organised from the general characteristics of didactic material to the specific impact of the material on the students. Figure 1 details the relationship between TCL phases (identified with different colours) with the creativity factors enhanced in each of them.

The first and second phases are carried out individually by the teacher before the class; the first has a formative nature and the second an operative nature. The third phase constitutes the core of the action with the students in the classroom, and the fourth phase requires the student to reflect on their learning and allows for the dissemination of the results.

The development of each phase was formed to materialise one or more creativity factors (see Figure 1). The first phase, 'Integrate', introduces the teacher to the theoretical basis of the methodology and identifies the initial creativity factors which are focused on adapting the materials into the environment. The second phase, 'Prepare', helps the teacher to set the operational resources. In this case, attention was given to provide enough flexibility to be adapted to each educator's needs. The third phase, 'Apply', implements the material in the classroom and fosters the development of the factors by the students. The evolution of this phase and its steps was inspired by the Design Thinking model 'Double Diamond'; the first diamond involves exploring an issue widely or deeply (divergent thinking) and then focusing on a challenge (convergent thinking), and the second diamond involves giving different answers to the challenge (divergent thinking) and then defining the solution (convergent thinking) (Design Council, 2005). Finally, the fourth phase, 'Assess', evaluates learning after the methodology application and allows for the student to reflect on their new knowledge. In this manner, the methodology considers assessment as a key part of the learning process.

Overall, TCL aims to help teachers to apply Design Thinking in the classroom and is focused on transforming knowledge into solving challenges, all in order to foster creative ability in students and set new competency learning possibilities.

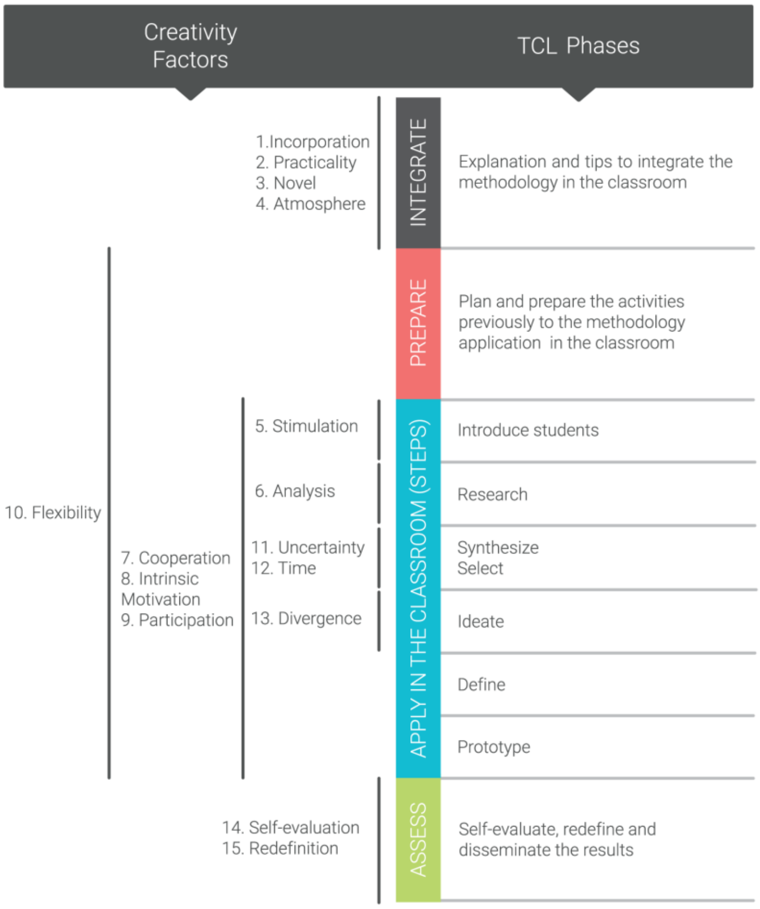


Fig. 1. Think-Create-Learn methodology

2.3 Methodology Materials and Methodology Implementation

As mentioned in the introduction section, both the visual and the tactile nature of the materials are crucial in Design-Thinking processes. TCL is embodied in a practical kit (see Figure 2) that consists of three material types: a manual to teach by challenges, complementary templates to fill and follow the steps, and other tangible support materials. Every resource has a careful, simple appearance, adapted to both teachers and students.

Fig. 2. Very first kit's physical prototype developed to assess TCL

The manual consists of 22 guide cards which explain to the teacher step-by-step how to use TCL in the classroom. Figure 3 shows a card example, where the structure and elements designed for consistency with the other materials are described.

The complementary templates are wide sheets that make application of theory possible (see supplementary files). Their main function is to save the teacher time in materials preparation and to optimise students' activities execution. They provide the added benefit of avoiding potential blocks caused by the fear of the blank page.

The support materials are tangible and colourful resources such as post-its, stickers, a stopwatch, markers, etc., aimed to facilitate students' work and to favour the activation of the right side of their brains.

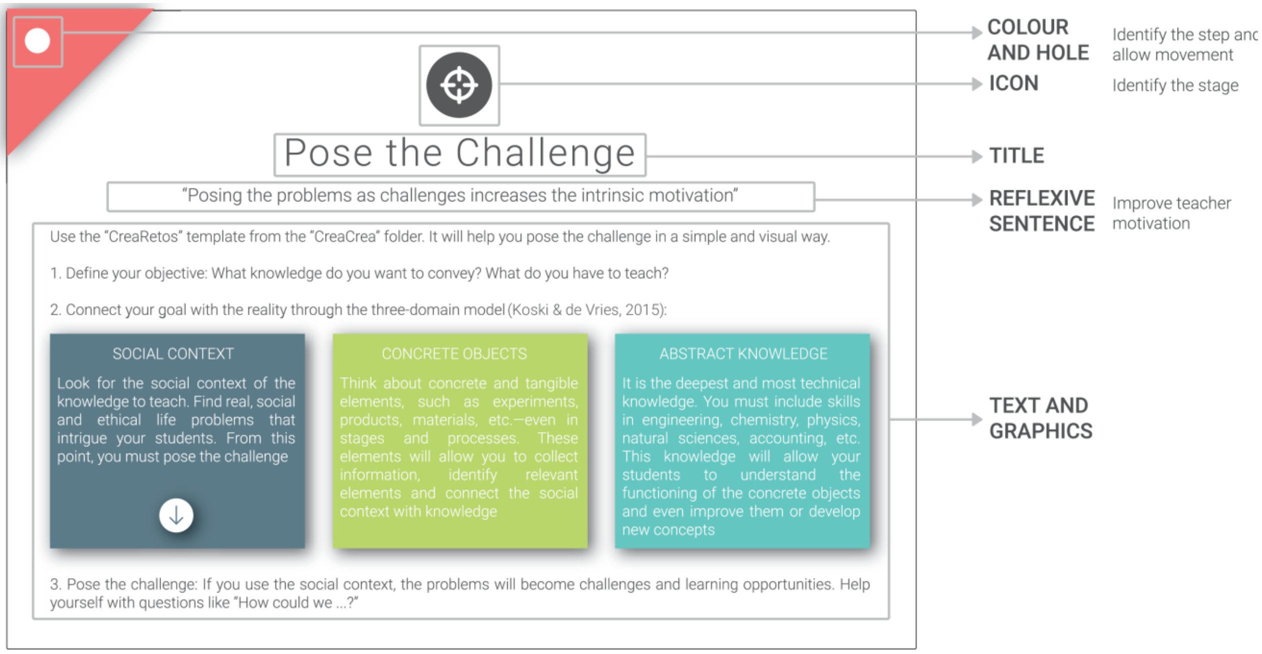


Fig. 3. Card elements

Figure 4 depicts the methodology steps and relates them to the specific materials. The first three columns describe the materials mentioned above. Additionally, the fourth column includes how TCL was applied and assessed in the real environment, as detailed in section 2.4.

Fig. 4. Scheme of steps, kit materials, and implementation

2.4 Assessment

TCL was designed and developed following an iterative process in which we situated two separated assessments with different objectives and strategies, following the Xassess evaluation methodology (Blanco et al., 2016). We selected Xassess because it is a validated evaluation method centred in multidisciplinary teams, that offered several advantages, e.g. it can be easily adapted to the context; considers the assessment from the initial stages of the project; merges qualitative and quantitative approaches; and includes the vision of all the disciplines involved in the project. Xassess poses three evaluation strategies: (1) 'complementation' (each product dimension is evaluated with one qualitative or quantitative technique), (2) 'triangulation' (each dimension is evaluated with two or more parallel techniques), and (3) 'combination' (each dimension is evaluated with two or more successive techniques). In this study, we followed strategies of both complementation and combination of mixed methods. Tables 2 and 3 illustrate the general and detailed overview of evaluation objectives, strategies, and dimensions. We conducted the assessment in accordance with relevant ethical guidelines (Lodico et al., 2010), providing a verbal explanation and obtaining written consent from the participants (parental consent was obtained for participants under 18 years old).

Table 2
Evaluations and General Objectives

	Mid-term Evaluation	Second Evaluation (after TCL redesign)
Objectives	The objective was to validate the initial methodology idea and clear design doubts in a controlled environment, in order to redesign a final version of TCL.	The objective was to validate the whole methodology in a real environment, with end users (both students and teachers) and no time constraints in material preparation.
Strategies	Qualitative methods in a complementary relationship (each TCL dimension was evaluated with an evaluation method).	Combinatorial strategy of mixed methods, qualitative and quantitative (each TCL dimension was evaluated with several evaluation methods that complement each other).

The first evaluation was carried out within the development process of TCL. We selected a sole but significant user, as an 'expert in the field' (in line with the User-Centred Design premises), who provided a triple vision: as a teacher, as a professional in teacher training, and as a proxy of other users, the students. The prototype (Figure 2) was presented to the user by the evaluator, in a large room with a warm atmosphere. The user was asked to handle the TCL kit in order to raise a use case related to one of the subjects she was teaching at the moment. She utilised the methodology kit, reviewing the theoretical bases and designing the educational activities for the classroom, while the evaluator observed in a non-intrusive manner. At the end, we discussed barriers and enablers in a semi-structured interview, placing a special emphasis on the TCL adequacy to curriculum objectives. We called this discussion the 'Theoretical curriculum review' (see Table 3).

After having redesigned the methodology from the mid-term evaluation results (see Section 3), the second evaluation took place in a real educational environment with end users (teachers and students). The framework was set in two classes (A and B) of a high school, with a total sample of 48 people: 46 students (each group consisted of 23 students) aged 15 to 16 years old, and two teachers with different profiles: main teacher (MT) and trainee teacher (TT). We considered teachers as the first level users because they interpret and apply the methodology, while the students represented the end user who benefits from the methodology implementation.

In the assessment procedure, TCL was mainly managed by the TT, less experienced, but having knowledge and sensitivity in new methodologies; the MT acted as supervisor, from his extensive experience in the centre and with students, and as quantitative evaluator of the students' achievement. Finally, a team of three technical evaluators conducted and assessed the whole process.

In this second evaluation, the TT used the TCL kit autonomously from the beginning, planning and determining the activities by himself, while the evaluators acted as a support team and observers. The TT read cards, completed templates, and selected the support material, considering restrictions regarding the subject topic, time, space, number of students, and students' skills. Subsequently, methodology was implemented in the classroom (see Figure 4), being overseen by the TT.

Starting from the Blanco et al. (2016) theoretical assessment framework, we adapted our evaluation strategy to the idiosyncrasy of the education scenario, focusing on the collaborative analysis offered by the different perspectives (the external vision from the three technical evaluators specialised in engineering design; the fresh and involved vision from the TT; and the experienced and objective vision from the MT).

Table 3 shows how, why, and by whom each creativity factor was evaluated, including indicators, resources, and techniques applied during the experimentation, as well as the actors and scenarios involved. Although the phases were consecutive, the table assembles every dimension, regardless of whether they correspond to the first or second evaluation phase.

Table 3

Objective, Indicators, and Evaluation Tools

Creativity factors	Evaluation objective	Perspective	Indicator	Technique
1. Incorporation 10. Flexibility	Incorporation and adaptation to the environment and curriculum	Teachers	TCL adequacy to the curriculum objectives	Theoretical curriculum review, identifying proposed kit consistency
			Methodology's flexibility to be adapted to the topic	Observation and field notes (while teacher uses the tool); Semi-structured interview
			Difficulties detected when adapting it	
2. Practicality 3. Novel	Material suitability	Teachers	Teacher acceptance/perspectives about the methodology, manual, and resources.	Observation and field notes; Periodic internal discussions; Semi-structured interview
			Opinion about design techniques	Semi-structured interview
			Interest in using the methodology	
			Analysis material usage by students	Observation and field notes; Periodic internal discussions
		Student	Student acceptance/perspectives about the methodology	Survey (closed question)
			Comparison to other materials used in classes	Survey (closed and open question)
4. Atmosphere 9. Participation	Warm atmosphere and participation	Teachers	Increased participation and communication, compared to other classes	Observation and field notes; Periodic internal discussions; Semi-structured interview
			Dialogue between teacher-student, student-student, student-teacher	
			Students' attitudes analysis	
		Student	Perception of how they felt during class	Survey (closed question)
			Opinion about the atmosphere	Survey (closed and open question)

			Perception about participation level	Survey (closed question)
			Participation level in the classroom compared to other classes	Survey (closed and open question)
5. Stimulation. 8. Intrinsic motivation 9. Participation	Students' motivation.	Teachers	Students' participation level, questions, opinions compared to other classes.	Observation and field notes; Periodic internal discussions; Semi-structured interview
			Students' interest analysis in the classes	
			Amount of information collected by students	
			Comparison with other classes and previous works	
		Student	Interest aroused by classes	Survey (closed question)
			Attitude and disposition	
			Students' motivation to solve challenges and activities	
			Related concepts with their lives	
6. Analysis 11. Uncertainty	Knowledge acquisition	Teachers	Students' level in Geology	Semi-structured interview
			Learning concepts different to memory	Observation and field notes; Periodic internal discussions
			Students' marks	Group work qualitative-quantitative evaluation Final exam
			Evolution of students' marks.	
		Student	Student perception about learning Geology	Observation and field notes; Periodic internal discussions Group work and final exam
			Geology concepts understanding	
7. Cooperation	Teamwork	Teachers	Communication, coordination, and commitment among the members	Semi-structured interview
		Student	Team spirit	Observation and field notes; Periodic internal discussions
			General opinion about teamwork	Survey (closed and open question)
			Opinion about own team (2 good aspects and 1 to improve)	Sheet 'CreaEvaluation'
			Opinion about other teams (2 good aspects and 1 to improve)	
13. Divergence	Divergence	Teachers	Amount of students' ideas	Observation and field notes; Periodic internal discussions; Semi-structured interview
			Ideas analysis	
			Relation between ideas and the topic	
		Student	Students' perception about the quality of ideas	Sheet 'CreaEvaluation'
12. Time	Think time	Teachers	Relationship between reflection time and work	Semi-structured interview
14. Self–evaluation 15. Redefinition	Self–evaluation and redefinition	Teachers	Teachers' feedback (likes, comments, etc.) quality and quantity	Observation and field notes; Periodic internal discussions; Semi-structured interview
		Student	Opinion about own work within the team (2 good aspects and 1 to improve).	Sheet 'CreaEvaluation'
	General opinion about methodology	Teachers	General opinion about classes and methodology	Semi-structured interview
			Suggestions to improve the methodology	Semi-structured interview
		Student	Use of the methodology in other subjects	Survey (open question)
			Know what they liked most and least	

The techniques shown in Table 3 were chosen from those described in the literature (Lodico et al., 2010), in accordance with each of the 15 indicators, and were classified under two perspectives: teacher and student. Likewise, the selection of methods was based on the time available, the number of users, and the teachers' previous experience.

During application of the methodology in the classroom, the teachers (TT and MT) acted as evaluators in the field, conducting 'observation' and taking 'field notes' in a non-intrusive manner. To facilitate this process, a guide that included key concepts to be observed was provided to the teacher (TT). This guide had questions particularised for each activity, including: Has the class been interesting to the students? Have the students experienced difficulties? Have the students been involved? Have they collaborated as a team? Have they been motivated? How much time have they invested?

All these observations were shared in 'periodic internal discussions' between the teachers (TT and MT) and the three technical evaluators. In these discussions, the teachers acted as users, that is, as participants assessed by the technical evaluators. Overall, six periodic internal discussions of 40 minutes each were conducted. In each session, one of the technical evaluators guided the group and inquired about the specific indicators shown in Table 3. After each of these sessions, the three technical evaluators met to discuss the conclusions obtained, which are considered in Section 3.

After the TCL application in class and to gain the teachers' perspectives, one of the technical evaluators conducted a 'semi-structured interview' with TT and MT, in which the voice was recorded. The interview included questions and comments such as: What perception do you have about design and creativity? How would you define the material used during the classes? How would you define students' attitudes during the classes? In order to avoid bias that evaluators may introduce, the formulation of the questions was carefully examined, trying not to affirm preconceptions of the researchers, and prevent the Hawthorne effect, that is, the tendency to the positive response of the interviewees due to the special treatment they receive from the evaluator (Adair, 1984; Diaper, 1990).The interviews were transcribed and coded according to the thematic analysis approach (Patton, 2014) and using the objectives shown in Table 2 as themes. The full transcriptions were sent to the teachers for review (Merriam, 1988) and were read several times separately by each of the three technical evaluators. Afterwards, the researchers discussed their reflections; in this discussion, the evaluators agreed to justify their suggestions with verbatims and to avoid inserting their judgments, directions or beliefs without data from the conducted research. Once a consensus was reached, the latent content and implicit messages of each theme were described in the results section.

Additionally, to gather students' experiences and opinions, we used several techniques. 'Survey' included several closed and open items and Likert scales to obtain perceptions on the assessment objectives. The survey included questions and comments such as: Have you found a difference with the materials used in other classes? Why? Have you felt motivated when solving the activities and challenges posed? Then, the students completed the self-assessment form, namely 'sheet CreaEvaluation'. Each student reflected and wrote about their work, the work of their team, and the work of another group. The self-assessments were coded by one of the technical evaluators, who grouped similar reflections. Additionally, we administered an exam. To analyse the students' knowledge acquisition, the teachers (MT and TT) discussed the results of the group work and the final exam. All these evaluation tools permitted us to extract the findings described in Section 3.

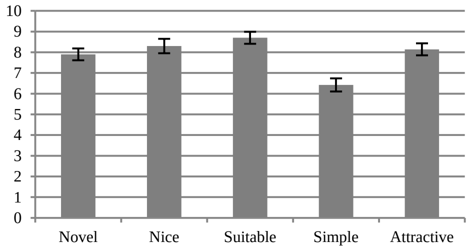
3. Results

The mid-term evaluation with the mentioned expert user was aimed to improve its quality before its application in the classroom and involved changes in TCL. The expert user stressed the importance of the writing to improve its adaptation to the educational environment, replacing design language for educational language – for example: ‘Use “content” and “competence” instead of “objective”. The teacher does not work with the “objective” but works with “content” or “competence”’. She emphasised the need to use direct language with clear instructions: ‘Summarise paragraphs; write directly and in a more informal manner (...); use more icons to make the methodology more accessible. The end goal then, was to reword certain sentences and improve the graphic content. Specifically, some cards and templates were redesigned, since she commented that they could generate confusion or mistrust. For example, she wrote, ‘In the planning template, I have to code and create the plan myself (…); however, the template should indicate how to achieve this task. Many teachers do not know what resources to use to plan their classes (…) they use a textbook, not because it is the best material, but because it is guided’. She also determined the need to include new templates: ‘I propose to include an agreement sheet at the beginning. In my classes, students sign an agreement or contract to have a specific role. This contract increases their participation, assuming their responsibility’. Finally, she stressed the importance of paying more attention to some less-contemplated factors, such as ‘redefinition’: ‘We are not ensuring that the teacher redefines. It seems obvious that the teacher reviews and provides feedback to the students, but believe me, it is not’. Therefore, feedback stickers were included so that the teacher could write comments and ‘likes’, and the students could annotate their doubts in situ.

The collaborative analysis (between the three technical evaluators and the teachers) of all the evaluation layers, mid-term evaluation and second evaluation, gave rise to the results shown in Table 4, presented in sections corresponding to the evaluation objectives collected in Table 3.

Table 4

Assessment Results

Objective	Teachers perspective	Students perspective
Material Suitability	Material quality was considered by teachers as a key element for the success of the tool. They claimed the materials were suitable. They valued positively the design discipline importance for materials development: *‘This material increases student curiosity and participation. (...) the results would not have been the same. Things are not only what you say, but how you say them’* (TT). In addition, the MT confirmed, *‘The material employed has been key, and students noticed the difference with respect to the materials of other classes’*. However, when teachers used the methodology materials, they detected the possibility of including previous teacher training: *‘The guide templates are great and very important, but I think that previous training on design and methodology would be beneficial’* (expert user).	Students valued the methodology very positively, although ‘simple’ is the factor they punctuated as the lowest (Table 5), and they judged the methodology as demanding. Most (85.2%) considered there to be a difference with the materials used in other classes. *‘It is more didactic, innovative, and practical than others. We are not used to work like that’.* **Table 5** *Survey Results for the Question Related to ‘Material valuation’; Likert Scale from 0-10.*  Average results. 95% Confidence interval.

<table>
<tr>
<td><u>Warm Atmosphere and Participation</u></td>
<td>Both teachers considered that the atmosphere during the lessons was pleasant thanks to the activities, fostering the good attitude of students: ‘Participation has been much more favourable and frequent than normal’ (MT). This was reflected in most of the sessions. For example, during the brainstorming (Figure 5a) participation was very high in both classes. The students were comfortable and used informal assertions, opinions, and drawings: ‘It would not be cool to be there when it (the natural catastrophe) happened’, talking about geology concepts.
Both teachers were surprised: while they expected noise and disturbance, students were calm, respected their classmates, and payed attention to everyone.</td>
<td>The majority of students (81.5%) confirmed they had participated more than usual. ‘It wasn’t a normal class, so we were more open to participate. Everybody has participated in everything’. This was confirmed by the statistics (with an average score of 7.4 in the participation level of each student, and an 8 in the classmates’ participation level) and by the teachers’ testimony.
All students confirmed the suitability of the learning atmosphere. ‘Comfortable’ is the most used adjective, followed by ‘satisfied’ and ‘motivated’. The three main factors detected by them were: the teamwork, the activity’s nature (enjoyable and entertaining), and the teachers’ work and attitude. ‘I really liked such a different way of teaching, your closeness, and how you valued our work. Thank you’.</td>
</tr>
<tr>
<td><u>Students’ Motivation and Interest for the subject</u></td>
<td>Both teachers agreed that motivation of students was constant throughout the sessions. The MT stressed the improvement over other classes. Among other examples, during the first session (Fig. 5a), ‘Their questions evidence that they find [the material] stimulating (…) since the Geology subject is not usually very attractive’ (MT); in the second session (Figure 5b), ‘They synthesised the information with mind maps, speaking, drawing, using attractive materials’; in the fifth session (Figure 5c), ‘When they used the 6-3-5 methodology, they were very focused and interested’ (TT).
A clear indicator is the interest shown outside the classroom. TT stressed, ‘Even during the weekend, students worked and shared information on Drive’. Likewise, he met casually with a group of students attending an outside event related to geology; he added, ‘This was really striking’.</td>
<td>81.5% of students declared they felt more motivated than in other classes: ‘I liked the enthusiasm and the effort I had in doing the activities’. This agrees with the teachers’ observations.
In the survey, they were asked to describe their mood before the class started; most chose ‘happy’ (48%), followed by ‘entertained’ (22%) and ‘bored’ (15%). During the class, 63% affirmed to be ‘entertained’, followed by ‘glad’ (15%) and ‘motivated’ (11%); when the class finished, most of the students admitted to being ‘happy’ (48%), followed by ‘motivated’ (19%) and ‘glad’ (15%). It should be pointed out that two students chose ‘bored’ for all times, although they admitted being more motivated than in other classes.
Also in accordance with teachers’ observations, 44.4% of students affirmed that these sessions made the geology topic more interesting for them, and 51.2% found the subject related with some issues of their life. ‘We have worked more dynamically in a boring subject, and now I see it as more interesting’.</td>
</tr>
<tr>
<td><u>Knowledge acquisition</u></td>
<td>Results were good, but higher in Group A. For both teachers, the concepts were successfully understood, with a low failure rate (40 pass vs 6 fail) on the exam, while in the group work, all students passed (Table 6).
Table 6
Student Qualification Results (0-10).
<table>
<tr><th></th><th>Group Work</th><th>Test</th><th>Final Mark</th></tr>
<tr><td>Group A</td><td>9.3 ± 0.5</td><td>7.9 ± 1.3</td><td>8.7 ±0.8</td></tr>
<tr><td>Group B</td><td>8.1 ±0.8</td><td>5.4 ± 2</td><td>7 ± 1.1</td></tr>
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</td>
<td>The qualitative results improve the statistic if we look at some of the students’ reflections:
- A different learning has been achieved: ‘I have learned without studying too long with books; [I learned the subject] simply with research and listening’.
- Students’ autonomy has been improved: ‘I liked researching because I discovered data [and] curiosities…’.</td>
</tr>
</table>

Teamwork	Both teachers detected differences between the groups. In Group A, all members worked adequately and equitably, while in Group B, not all students worked equally. Although the MT's opinion was, *'Students find it hard to organise teamwork; they are somehow inefficient'*, he also highlighted that they had worked better than in other activities: *'Their work has been better than I expected since the motivation here has been higher'.*	Most students (85.2%) also noticed a difference as a group and reflected upon the benefits obtained thanks to the interaction with their classmates*: 'It is better than working alone because we all learn from each other' and 'My team has provided me knowledge and positive personal experiences'.* In addition, they recognised their commitment with the group, since the rest of the members depended on their work: *'My role as coordinator was essential to carry out the work'.* However, some students reported that not all classmates worked equally: '*I would like if all students were involved equally in all activities'*; this coincides with the teachers' perspective.
Divergence	The TT observed that students were restricted: *'They are guided day-to-day, and when they do something different, they find it hard to be proactive and creative'.* Equally, the TT added, *'The ideas that they chose to develop weren't the most amazing'.* The TT observed three reasons to justify this choice: greater ease, fear of failure, and less social influence in students who proposed it.	Students noted the importance of divergent thinking: *'It allows me to think more and differently about something'.* They also noted the importance of putting knowledge learned into effect: '[It is necessary] *not only to study but to put knowledge into effect and provide a solution (moderately possible) to a current problem'.* Solutions proposed were very diverse (Figure 5c): designing smart buildings and objects; ideas to stop the convection currents; research about the internal structure or traveling to the centre of the earth; and educational programs about emergencies were some of them.
Time constraints	The (short) times and the quickness of the activities were not a problem for the teachers. *'The stopwatch use has been very satisfactory; despite* [the limited] *time set, all students have finished the challenge since they have organised and adapted to the time proposed'* (TT).	Students offered two different stances: - There was a perception of lack of time for evaluated activities: *'I would like to have more classes to make the presentation better and to summarise the test content'.* - When they do not associate their work with a mark, they sense the quickness as beneficial: *'I liked having little time because it was spontaneous, and the classes weren't long or boring; I was very focused'.*
Self-evaluation	There was a special emphasis on the need for clear, dynamic, and interactive presentations: *'There was very little fluency in the oral presentation; several students needed to read a sheet'* (TT).	Among the students, the perception of the need for improvement regarding their oral skills was also common: *'I would like to explain better, more easily, and without shame. I am not good at presenting'.* Some of them criticised the presentations when evaluating other groups: *'I would have liked to see clearer presentations with better explanations from my classmates'.*
General Opinion about Methodology	Both teachers agreed that the methodology is interesting, and they would like to use it in their classes to get students more involved. *'My opinion is tremendously positive (...) the task (.) is achieved very broadly. In addition, despite being applied to an unpopular*	96% of students affirmed they would like to use this methodology in other classes: *'I wish we had the opportunity to work with this methodology, at least once a quarter'.* Even those initially sceptical recognised the validity of the method: *'I was afraid of the test because the class was practical, but in the end (...) I*

	topic, very good results have been achieved' (TT). However, MT commented, '*Maybe it is insufficient to assimilate all the contents of the subject'*. The expert user assured *'It is a demanding methodology for the student, since they must be fully active; thus, its use must be limited'*.	*learned the theory better'*. However, a student noted the lack of traditional classes: *'I would like to have had theoretical classes to take notes and specify the content for the exam (...) [because] the activity was more general than the exam, which was more specific'*.

Fig. 5. (a) Investigation/brainstorming; (b) information synthesis; (c) ideation and concepts

4. Discussion

The results show that the proposed methodology and materials for its implementation achieve their objectives and contemplate the 15 creativity factors of Table 1. It can be asserted that applying the methodology in the classroom has advantages for students and teachers: it boosts competence learning, fosters research and participation, facilitates putting knowledge learned into effect, and allows for knowing new techniques. Therefore, the experience validates the methodology's utility in the schools.

To frame the value of our results, it is interesting to analyse how other tools achieve the creativity factors in comparison to TCL. To accomplish this, we collected a total of eight representative tools from the educational field. We selected tools that 1) have a pedagogical basis similar to TCL; 2) seek learning through a different process than copying, memorisation, or reproduction; 3) are straightforward and easily adaptable; and 4) are easily accessible. The selected tools were presented to the three technical evaluators; individually, they reviewed each material and rated how each tool achieved the creativity factors. The authors then shared and discussed their assessments. By consensus, they determined to value each tool using a colour code in three levels: the resource considers the factor clearly (green), the resource considers the factor slightly (yellow), and the resource does not consider the factor (red). The indicators were reduced only to these three levels with the aim to ensure objectivity, assessing what could be observed in the available material of each proposal.

In this manner, Figure 4 shows the extent to which TCL and the other representative resources satisfy each creativity factor. As mentioned, each factor is associated with a number according to the hypothetical sequence of use of these resource types in class. The comparison allows us to display which stages are most and least represented.

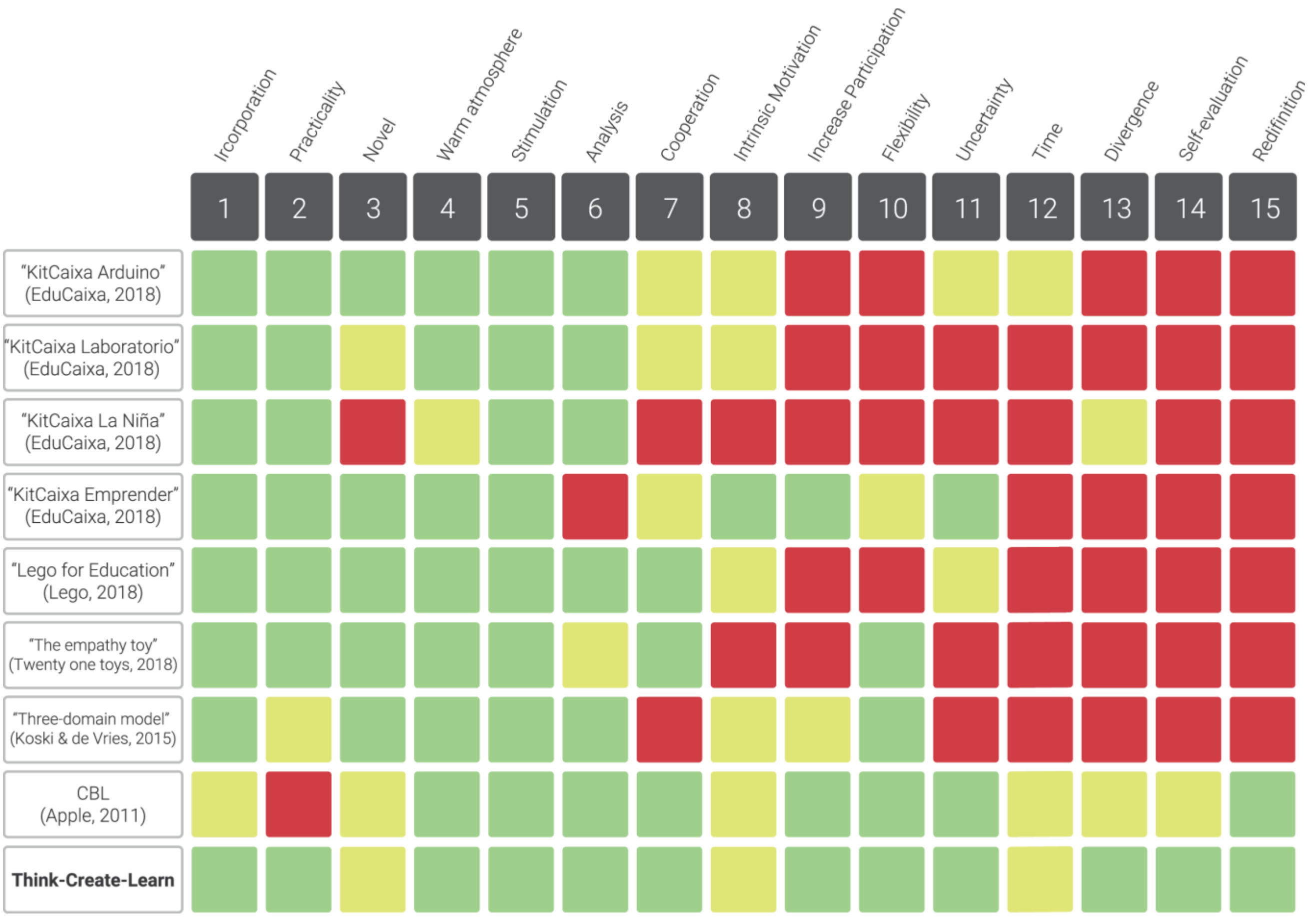

Fig. 6. Material analysis according to the creativity factors

As shown in Figure 6, the first half of factors is considered in the majority of cases. This seems logical, since they are key premises to apply this resource type in the classroom, related to the adaptation to the curriculum, the material characteristics, and the break of monotony. However, the factors related to the use of tools in the classroom and with the specific contributions to the students are less considered. Although they are fundamental for creativity promotion, the participation, divergence, and uncertainty factors are not worked enough; and self-evaluation, key in reflection and enrichment, is not entirely considered in any of the cases. It should to be noted that Challenge-Based Learning (CBL) (Apple, 2011) has a lot in common with our proposal, meeting almost all factors. However, CBL lacks one of the essential bases in any educational material, which is practicality. It is true that CBL has a theoretical base more extensive and profound than other tools; however, it lacks the materials that favour and simplify its direct application in the classroom, such as kits, templates, complementary objects, and the like.

In TCL, all detected factors were kept in mind from its inception, but in the evaluation process, aspects to improve were detected (yellow squares in Figure 4). The assessment process, conducted from the method Xassess, allowed the evaluation from the beginning of the project, as well as the collaborative assessment between different disciplines. Applying Xassess supposed a multidisciplinary challenge at all levels, considering teachers as users and also as members of the team, thus co-designers. This permitted the drawing of deep and structured conclusions, giving rise to key contributions at a methodological level. These are presented below organised upon the assessment objectives; some of them can be useful to improve the methodology; others can allow for the creation of new resources and new teaching methods to improve students' creativity.

Incorporation and adaptation to the environment and curriculum: To guarantee its feasibility in the classroom, any educational resource should start from these two premises. According to Blanco et al. (2016), the x-disciplinary perspective to which we attended favoured the factors' compliance and allowed us to adapt the methodology to the real environment. The results evidence it, both in the teachers' views and in the students' marks. It is also important to highlight the value of TCL in the more and more relevant competencies-based educational approach (Blanco et al., 2017) and its weight for students' future employment and role in society (Tuning, 2003): it broadens the scope of normally addressed competencies and enhances students' soft skills. However, it is undeniable that to use this methodology requires an extra effort on the part of the teachers. They must consider: first, the preparation of the materials, since the teacher should understand and plan the methodology; then, the development of classes, where the teacher is in an unknown situation; and finally, the assessment of the results, about which the expert user commented, *'Evaluating the transversal competences of each student is not a direct task; it proves a challenge'*. Likewise, the difficulty of complying in time and scope with the curriculum, as well as the lack of specific training, could make the application of this methodology difficult. To face this challenge, we are now working on specific material to train and involve the teacher in the use of TCL, which will contribute also to the teacher's professional development.

Material suitability: Design influence on methodology and materials was found relevant and positive. One of the main objectives of Design Thinking and design development processes is to adapt the materials both to the context and to the different users, adding connotative and denotative value. Students' cumulative opinion about the material was positive, although it should be noted that some students did not describe it as a simple process *'some activities were really laborious'*. This is understandable, considering that the student must be fully active and participative, far from the passive stance adopted in the traditional methodology (Lee & Erdogan, 2007; McMullan, 2016; Nguyen et al., 2017; Qi, 2017; Zhang & Guo, 2017; Zhao & Meng, 2015) to which they were habituated. Thus, as well as for teachers, TCL constitutes a demanding methodology which requires an extra effort on the part of students, but it also offers them important advantages. Despite these benefits, as the expert user commented, *'TCL usage should be limited'*. On another level, it should be considered that, nowadays, new technologies offer stimulating possibilities to create and share ideas and content (Henriksen et al., 2016; Lombardi, 2007) and link well to the students' and teachers' reality. This idea was supported by the TT, who asked, *'Have you considered the digital option? A teacher could do this with a tablet'*. It suggests that technology inclusion could make a difference in the methodology materialisation, which would be a significant improvement.

Warm atmosphere and participation: In TCL, one of the teachers' tasks is to bridge the division between teacher and students, so that the students relax and get involved in the activities in an uninhibited way. The methodology endeavoured to establish a comfortable climate based on trust and communication between teacher-student and student-student by different means: students and teachers used the material as a communication tool; the teacher was also asked to motivate the students with certain messages ('nothing is wrong', for example) and attitudes. And this type of relationship and dialogue brings significant benefits to students; as different authors assert, an adequate psychosocial environment boosts a didactic environment that promotes and encourages students to interact and participate with opinions, questions, and answers, increasing their academic learning (Thapa et al., 2013; Vass, 2017; Voelkl, 1995), and offering identity, security, familiarity, autonomy, and liberty (Thapa et al., 2013; Voelkl, 1995). Nevertheless, the atmosphere is affected by the duration of the sessions: *'Creating the right climate takes extra time and effort (...); when it is achieved, it is a pity to stop the class'*. Additionally, it is significant that the experience made the students appreciate the teachers' work, as seen in the students' comments. Therefore, we can affirm that, to some extent, the image of the teachers is improved, and the respect between students and teachers is fostered. This is a relevant point because one of the most repeated conflicts in society is that teachers are sometimes devalued in their work (Fort & Plaza, 2015).

Students' motivation: The results also evidence a high student motivation and interest during the activities. TCL permits a proactive learning environment, fostering investigation and experimentation, and showing that posing problems as challenges increases the students' intrinsic motivation, in line with López (2008) and Amabile (1998). This even leads them to quench their curiosity outside the classroom, which is significant. However, in several moments, it can be observed how students are concentrated on their own marks (test and presentations): *'How will the exam be?'*. Thus, with this reflection in mind, we consider that the intrinsic motivation factor is 'slightly' fulfilled in our methodology (see Figure 6). This is a logical response to the established system; we cannot run away from the whole reality, but, of course, we align with Sternberg & Lubart (1997) and others about the necessity of devaluing the importance of marks as the first extrinsic motivator.

Knowledge acquisition: Also related to motivation, the methodology generated curiosity and attention for its materialisation and because students worked differently than in other classes. These coincide with the first two steps of the Neuroeducation sequence (Figure 7) (Acaso, 2017). The emotion came when the theory was linked to the real world. According to Gerver (2017), '*Great teachers have the ability to connect the concepts with the students' lives. And when students care about things, they learn them'*. We must not forget that the novelty of the material can play in our favour, but the design of the methodology allows us to totally refresh the stimuli from one project or subject to another. Additionally, the 'peer learning' (Topping, 2005) process is also evidenced since other teams' presentations are perceived as a source of learning and skills acquisition. Students learn from their classmates, seeing the different approaches and solutions that other groups have found for the same issue.

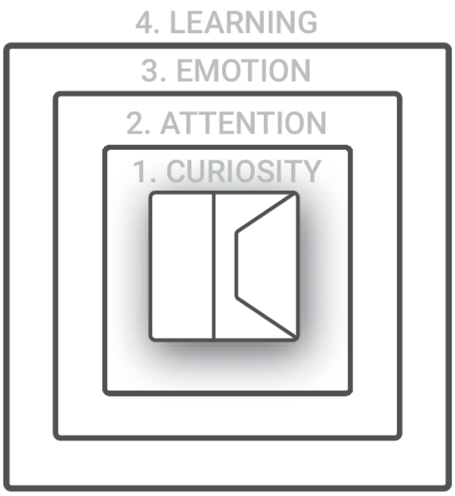

Fig. 7. Learning process according to Neuroeducation, adapted from Acaso (2017)

Teamwork: Teamwork is considered one of the key skills to access the professional world (Daly et al., 2012; Tulsi & Poonia, 2015; Valero, 2018). We formed groups of four or five in accordance with Fowler (1990) and Blanco et al., (2017), and we corroborated that it is an ideal number since they were manageable groups where everyone was able to contribute, and in general, the opinions were positive. The positive influence of the peer learning effect was achieved not only between groups but also inside the groups' members, as we can see in the comments. However, the teacher should be alert to help students work as a team, in terms of effectiveness, organisation, and bad attitude prevention; for example, those students that take advantage of teamwork to avoid tasks: *'During the investigation, a classmate did not search for information'*. Maybe it would be useful to include a guide in the methodology for teaching students how to work in teams in terms of commitment (to carry out the tasks), communication (to listen to different opinions), complementarity (to put things in common), coordination (to reach agreements), and trust (to express their own ideas).

Divergence: TCL contributes to fostering the divergent thinking drawn from uncertainty, risk-taking, and making mistakes, in line with Craft (2003). The teacher has an important role here as the resources provider and director; in this sense, TCL provides him or her the opportunity to train students on managing materials, tools, concepts, ideas, and structures, in line with what Feldhusen and Treffinger (1985) and Gervilla (2003) claim. In the experience, we included some rules related to the methods included in TCL; for example in brainstorming (avoid judgment and criticism, build on the others' thoughts, address only a conversation at a time, note all ideas, use simple sketches, etc.). However, we observed that, in some ways, the lack of practice restricted students, so allowing them to make decisions for themselves was a major challenge. In this regard, TT remarked, *'They constantly wanted my approval, despite the freedom offered during classes'*. The conclusions drawn from the teachers were very enlightening: greater ease, fear of failure, and the social influence of certain students could all play a limiting role. For these reasons, it can be said that TCL considers the divergence factor slightly (see Figure 6).

Time and self-evaluation: TCL provides times in which the student evaluates his/her progress and performance, in order to promote reflection about what they has learned. The most repeated thought raised by the students themselves (and validated by teachers) is about the need for resources and training to carry out an effective public presentation, another soft skill that is usually missing; *'I get very nervous when I speak in public'*. Although the methodology contributes to practicing presentations and to speaking in public, it does not include materials focused on learning this skill. Thus, in future versions of TCL, it would be interesting to add resources to help in this competence formation. Additionally, it is interesting to observe the double standards in some students' perception, which unfortunately have to do with traditional systems based on extrinsic motivators. In particular is the case of the times assigned to each task, perceived as insufficient or sufficient depending on whether the student perceived this as related or not with a quantitative mark, sensing the evaluation separate from learning. This is, of course, a tough matter, but we believe that the adoption of methods such as the proposed could contribute to mitigate this phenomenon.

Some limitations need to be acknowledged, and further work needs to be conducted to address them. First, the scope of this study is confined only to a small sample of high school students in a Geology class, and the outcomes may not be fully generalisable to other disciplines and/or a broader population. Second, it should be noted that the research techniques used are mostly qualitative. In this type of research, the participants rely on their individual experience, memories, and expectations, which prevents the study from achieving total objectivity, complete neutrality, and biases the research to some extent (Ponterotto, 2005). Nonetheless, to minimise this effect and provide greater credibility, as commented before, we assessed each indicator with different methods. Third, the TCL application requires an extra effort on the part of the teacher, since they should act as a coach, a provider of resources, and a designer, facing complex and varied challenges. Therefore, the teacher needs to be familiar with new methodologies and Design Thinking or needs to be trained in some of these areas. Fourth, in the same manner, TCL is a demanding methodology for the student, since they must be fully active. Thus, the students' workload should be well-balanced, since an overload could be detrimental for their learning and their perception of active methodologies. In this regard, in order to enrich the students' experience and learning, further, and more ambitious, research could be conducted, with longer sessions and more detailed activities. Finally, it should be noted that the participants of this study were used to traditional methodology, such that understanding and developing the concepts about design and creativity as problem-solving was a complex task. Design and creativity introduce mess, divergence, and novelty in a defined, convergent, and traditional environment. Thus, understanding and developing design and creativity cannot be solved solely with the use of the proposed methodology, but TCL can be considered an aid to introduce these concepts.

5. Conclusions

In this paper, we proposed the Think-Create-Learn (TCL) methodology aimed at fostering creativity in the class through design. During the development of this methodology, we also contributed to the identification of 15 factors to be considered in the creation of new resources that foster creativity as a problem-solving skill. Thus, TCL is based on two pillars: the design thinking processes and these 15 factors.

In TCL, theory and practicality are balanced. It is embodied in a practical kit with several types of resources. A manual of 22 guide cards explains to the teacher step-by-step how to use TCL in the classroom. The templates make application of TCL theory easier, offering tools flexible enough to be adapted to any subject and helping the teacher to manage uncertainty. Both the visual and the tactile nature of every support material are crucial and contribute to the success of the tool.

TCL was assessed quantitatively and qualitatively in a real educational context with teachers and students. The results of this assessment showed that the proposed methodology contemplated all the key factors to enhance creativity, supporting the teacher's work, and fostering students' competency-based learning. Thus, we can affirm that this methodology provides a good tool to aid scholars, teachers, even designers to develop design and creativity.

This study also reflects the potential of applying Design Thinking in education. Design and creativity are multidimensional and difficult to teach, so further studies are needed to support teachers in this task. In this paper, we contribute to reaffirm (a) the need to create new resources for the development of creativity in educational centres, (b) the relevant role that the design discipline could have, and (c) the relevance of the 15 creativity factors to assess new proposal's effectiveness. Research in these directions would enhance students' 21st century thinking skills.

References

Acaso, M. (2017, September 22). *Del design thinking al art thinking: las artes como metodología para cualquier asignatura.* Paper presented at the I International Congress of Educational Innovation, Zaragoza, Spain.

Adair, J. G. (1984). The hawthorne effect: A reconsideration of the methodological artifact. *Journal of Applied Psychology*, *69*(2), 334.

Ahmadi, N., Peter, L., Lubart, T., & Besançon, M. (2019). School environments: Friend or foe for creativity education and research? *Creativity under duress in education?* (pp. 255-266) Springer.

Amabile, T. M. (1998). *How to kill creativity*. Harvard Business School Publishing.

Apple. Challenge Based Learning (CBL). (2011). https://images.apple.com/education/docs/CBL_Classroom_Guide_Jan_2011.pdf Accessed 15 June 2018.

Blanco, T. (2016). *Metodologías de diseño como plataforma para la x-disciplinaridad en proyectos tecnológicos: Surfing disciplines* (Doctoral dissertation, Universitat Politècnica de València, Valencia, Spain). Retrieved from https://riunet.upv.es/handle/10251/77149?show=full

Blanco, T., Berbegal, A., Blasco, R., & Casas, R. (2016). Xassess: Crossdisciplinary framework in user-centred design of assistive products. *Journal of Engineering Design, 27*(9), 636-664.

Blanco, T., López-Forniés, I., & Zarazaga-Soria, F. J. (2017). Deconstructing the tower of babel: A design method to improve empathy and teamwork competences of informatics students. *International Journal of Technology and Design Education, 27*(2), 307-328.

Brown, T. (2008). Design thinking. *Harvard Business Review, 86*(6), 84.

Burkus, D. (2013). *The myths of creativity: The truth about how innovative companies and people generate great ideas.* John Wiley & Sons.

Burnard, P. (2006). Reflecting on the creativity agenda in education. *Cambridge Journal of Education, 36*(3), 313-318.

Carroll, M., Goldman, S., Britos, L., Koh, J., Royalty, A., & Hornstein, M. (2010). Destination, imagination and the fires within: Design thinking in a middle school classroom. *International Journal of Art & Design Education, 29*(1), 37-53.

Chan, S., & Yuen, M. (2014). Personal and environmental factors affecting teachers' creativity-fostering practices in Hong Kong. *Thinking Skills and Creativity, 12*, 69-77.

Collard, P., & Looney, J. (2014). Nurturing creativity in education. *European Journal of Education, 49*(3), 348-364.

Craft, A. (2002). *Creativity in the early years: A lifewide foundation*. A&C Black.

Craft, A. (2003). The limits to creativity in education: Dilemmas for the educator. *British Journal of Educational Studies, 51*(2), 113-127.

Cropley, A. (2016). The myths of heaven-sent creativity: Toward a perhaps less democratic but more down-to-earth understanding. *Creativity Research Journal, 28*(3), 238-246.

Cropley, A. (2018). The creativity-facilitating teacher index: Early thinking, and some recent reflections. *Creativity Fostering Teacher Behavior: Measurement and Research*, 1.

Cross, N. (2011). *Design thinking: Understanding how designers think and work.* Berg.

Daly, S. R., Adams, R. S., & Bodner, G. M. (2012). What does it mean to design? A qualitative investigation of design professionals' experiences. *Journal of Engineering Education, 101*(2), 187-219.

Daly, S. R., Mosyjowski, E. A., & Seifert, C. M. (2014). Teaching creativity in engineering courses. *Journal of Engineering Education, 103*(3), 417-449.

Davies, D., Jindal-Snape, D., Collier, C., Digby, R., Hay, P., & Howe, A. (2013). Creative learning environments in education. A systematic literature review. *Thinking Skills and Creativity, 8*, 80-91.

De Bono, E., & Castillo, O. (1994). *El pensamiento creativo.* Editorial Paidós.

Design Council. The 'double diamond' design process model. (2005). https://www.designcouncil.org.uk/news-opinion/what-framework-innovation-design-councils-evolved-double-diamond Accessed 1 July 2020.

Diaper, G. (1990). The hawthorne effect: A fresh examination. *Educational Studies, 16*(3), 261-267.

Dickhut, J. E. (2003). *A brief review of creativity.* Retrieved from http://www.personalityresearch.org/papers/dickhut.html

Dorst, K., & Cross, N. (2001). Creativity in the design process: Co-evolution of problema-solution. *Design Studies*, *22*(5), 425-437.

EduCaixa. Educational platform. (2018). https://www.educaixa.com/es/home Accessed 15 December 2018.

Elwood, K., Savenye, W., Jordan, M. E., Larson, J., & Zapata, C. (2016). *Design thinking: A new construct for educators.* Paper session presented at the Annual Convention of the Association of Educational Communications and Technology, Las Vegas, Nevada, United States.

Fasko, D. (2001). Education and creativity. *Creativity Research Journal*, *13*(3-4), 317-327.

Feldhusen, J. F., & Treffinger, D. J. (1985). *Creative thinking and problem solving in gifted education.* Dubuque, IO: Kendall/Hunt Publishing Company.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications.* MIT Press.

Fort, J. T., & Plaza, Y. M. (2015). Malestar en la escuela. Conflictos entre profesores. *Educar, 51*(1), 169-188.

Fowler, T. C. (1990). *Value analysis in design*. CRC Press.

Gerver, R. (2017, September 22). *Crear hoy la escuela del mañana: El futuro de la educación.* Paper presented at the I International Congress of Educational Innovation, Zaragoza, Spain.

Gervilla, A. (2003). Creatividad aplicada. *Una Apuesta De Futuro, 1.*

González, C. A. (2006). Evaluación de la creatividad: más allá de una operatoria funcional. *Comprender Y Evaluar La Creatividad.Volumen, 2*, 25-45.

Gu, X., Dijksterhuis, A., & Ritter, S. M. (2019). Fostering children’s creative thinking skills with the 5-I training program. *Thinking Skills and Creativity, 32*, 92-101.

Guilford, J. P. (1950). Creativity. *American Psychologist*, *5*(9), 444-454.

Guilford, J. P. (1967). Creativity: Yesterday, today and tomorrow. *The Journal of Creative Behavior*, *1*(1), 3-14.

Guo, J., & Woulfin, S. (2016). Twenty-first century creativity: An investigation of how the partnership for 21st century instructional framework reflects the principles of creativity. *Roeper Review*, *38*(3), 153-161.

Hadar, L. L., & Tirosh, M. (2019). Creative thinking in mathematics curriculum: An analytic framework. *Thinking Skills and Creativity, 33*, 100585.

Hennessey, B., & Amabile, T. (1987). *Creativity and Learning: What Research Says to the Teacher.* NEA Professional Library.

Henriksen, D., Mishra, P., & Fisser, P. (2016). Infusing creativity and technology in 21st century education: A systemic view for change. *Journal of Educational Technology & Society*, *19*(3).

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking Skills and Creativity*, *26*, 140-153.

Hernández Leo, D., Agostinho, S., Beardsley, M., Bennet, S., & Lockyer, L. (2017, July 3). *Helping teachers to think about their design problem: A pilot study to stimulate design thinking.* Paper presented at 9th International Conference on Education and New Learning Technologies, Barcelona, Spain. Retrieved from http://hdl.handle.net/10230/32247

Hernández-Torrano, D., & Ibrayeva, L. (2020). Creativity and education: A bibliometric mapping of the research literature (1975-2019). *Thinking Skills and Creativity*, *35*, 100625.

Hoogveld, A. W., Paas, F., & Jochems, W. M. (2005). Training higher education teachers for instructional design of competency-based education: Product-oriented versus process-oriented worked examples. *Teaching and Teacher Education*, 21(3), 287-297.

Howard, T. J., Culley, S. J., & Dekoninck, E. (2008). Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies, 29*(2), 160-180.

Huidobro, T., & González, J. (2004). *Una definición de la creatividad a través del estudio de 24 autores seleccionado.* (Doctoral dissertation, Universidad Complutense de Madrid., Madrid, Spain). Retrieved from https://eprints.ucm.es/4571/

Ideo. Design thinking for educators. (2013). https://designthinkingforeducators.com/ Accessed 2 November 2018.

Jordan, M. E. (2016). Teaching as designing: Preparing pre-service teachers for adaptive teaching. *Theory into Practice, 55*(3), 197-206.

Khalid, M., Saad, S., Hamid, S. R. A., Abdullah, M. R., Ibrahim, H., & Shahrill, M. (2020). Enhancing creativity and problem solving skills through creative problem solving in teaching mathematics. *Creativity Studies, 13*(2), 270-291.

Kirton, M. J. (2004). Problems with creativity. *Adaption-innovation: In the context of diversity and change* (135-141). Routledge.

Kleiman, P. (2008). Towards transformation: Conceptions of creativity in higher education. *Innovations in Education and Teaching International, 45*(3), 209-217.

Koehler, M. J., & Mishra, P. (2005). Teachers learning technology by design. *Journal of Computing in Teacher Education, 21*(3), 94-102.

Koski, M., & de Vries, M. (2015). An aid for teachers to teach science and technology concepts: Two studies to test the three-domain model. *International Journal of Technology and Design Education, 25*(2), 169-195.

Lee, M., & Erdogan, I. (2007). The effect of science–technology–society teaching on students' attitudes toward science and certain aspects of creativity. *International Journal of Science Education, 29*(11), 1315-1327.

Lego. Kit lego for education. (2018). https://education.lego.com/en-us Accessed 4 December 2018.

Lewis, T. (2009). Creativity in technology education: Providing children with glimpses of their inventive potential. *International Journal of Technology and Design Education, 19*(3), 255-268.

Lin, L., Shadiev, R., Hwang, W., & Shen, S. (2020). From knowledge and skills to digital works: An application of design thinking in the information technology course. *Thinking Skills and Creativity, ,* 100646.

Lodico, M. G., Spaulding, D. T., & Voegtle, K. H. (2010). *Methods in educational research: From theory to practice* (Vol.28). John Wiley & Sons.

Logan, L. M., Logan, V. G., & García, A. R. (1980). *Estrategias para una enseñanza creativa*. Oikos-tau.

Lombardi, M. M. (2007). Authentic learning for the 21st century: An overview. *Educause Learning Initiative, 1*(2007), 1-12.

López, O. (2008). Enseñar creatividad: El espacio educativo. *Cuadernos De La Facultad De Humanidades Y Ciencias Sociales.Universidad Nacional De Jujuy,* (35), 61-75.

Lor, R. (2017, May). *Design thinking in education: a critical review of literature.* Paper presented at Asian Conference on Education & Psychology, Bangkok, Thailand.

MacLaren, I. (2012). The contradictions of policy and practice: Creativity in higher education. *London Review of Education, 10*(2), 159-172.

McMullan, M. J. (2016). How using technology enhanced learning could help modernise traditional large group teaching or lecturing. *International Journal of Innovative Research in Medical Science (IJIRMS)(Online), ,* 2245-8737.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach.* Jossey-Bass.

Mishra, P., & Mehta, R. (2017). What we educators get wrong about 21st-century learning: Results of a survey. *Journal of Digital Learning in Teacher Education, 33*(1), 6-19.

Mosely, G., Wright, N., & Wrigley, C. (2018). Facilitating design thinking: A comparison of design expertise. *Thinking Skills and Creativity, 27*, 177-189.

Nakano, T. d. C., & Wechsler, S. M. (2018). Creativity and innovation: Skills for the 21st century. *Estudos De Psicologia (Campinas), 35*(3), 237-246.

Nguyen, K., DeMonbrun, R. M., Borrego, M., Prince, M., Husman, J., Finelli, C. J., Waters, C. (2017, June 24). *The variation of nontraditional teaching methods across 17 undergraduate engineering classrooms.* Paper presented at the 2017 ASEE Annual Conference & Exposition, Columbus, Ohio.

Norton, P., & Hathaway, D. (2015). In search of a teacher education curriculum: Appropriating a design lens to solve problems of practice. *Educational Technology* , 3-14.

Page, T., & Thorsteinsson, G. (2017). Teaching creativity across the curriculum through design education? *I-Manager's Journal of Educational Technology, 14*(1), 7.

Parkhurst, H. B. (1999). Confusion, lack of consensus, and the definition of creativity as a construct. *The Journal of Creative Behavior, 33*(1), 1-21.

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage publications.

Peterson, R. E. (2001). Establishing the creative environment in technology education: Creativity doesn't just happen by chance; the prepared environment nourished it. *The Technology Teacher, 61*(4), 7-11.

Ponterotto, J. G. (2005). Qualitative research training in counseling psychology: A survey of directors of training. *Teaching of Psychology.*

Qi, J. (2017). An optimization approach for flipped classroom and multimedia teaching innovation by contrast with traditional teaching. *Boletín Técnico, ISSN: 0376-723X, 55*(8).

Rauth, I., Köppen, E., Jobst, B., & Meinel, C. (2010, November 29). *Design thinking: An educational model towards creative confidence.* Paper presented at the 1st international conference on design creativity (ICDC 2010), Kobe, Japan.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important? *Review of Educational Research, 82*(3), 330-348.

Reiter-Palmon, R., & Illies, J. J. (2004). Leadership and creativity: Understanding leadership from a creative problem-solving perspective. *The Leadership Quarterly, 15*(1), 55-77.

Retna, K. S. (2016). Thinking about “design thinking”: A study of teacher experiences. *Asia Pacific Journal of Education, 36*(sup1), 5-19.

Seltzer, K., & Bentley, T. (1999). *The creative age: Knowledge and skills for the new economy.* Demos.

Şendurur, E., Ersoy, E., & Çetin, İ. (2016). The design and development of creative instructional materials: The role of domain familiarity for creative solutions. *International Journal of Technology and Design Education* , 1-16.

Shaheen, R. (2010). Creativity and education. *Creative Education, 1*(03), 166.

Simonton, D. K. (2000). Creativity: Cognitive, personal, developmental, and social aspects. *American Psychologist, 55*(1), 151.

Spencer, D., & Warfel, T. (2004). Card sorting: A definitive guide. *Boxes and Arrows, 2*, 1-23.

Spendlove, D. (2008). Creativity in education: A review. *Design and Technology Education: An International Journal, 10*(2).

Sternberg, R. J., & Lubart, T. I. (1997). *La creatividad en una cultura conformista: Un desafío a las masas.* Paidós.

Thapa, A., Cohen, J., Guffey, S., & Higgins-D’Alessandro, A. (2013). A review of school climate research. *Review of Educational Research, 83*(3), 357-385.

Thorsteinsson, G., & Page, T. (2017). Teaching creativity across the curriculum through design education. case studies. *Educatia 21*, (15), 13-22.

Topping, K. J. (2005). Trends in peer learning. *Educational Psychology, 25*(6), 631-645.

Torrance, E. (1972). Can we teach children to think creatively? *The Journal of Creative Behavior, 6*(2), 114-143.

Torre, d. l. S., & Violant, V. (2006). *Comprender y evaluar la creatividad.Cómo investigar y evaluar la creatividad.* Albije.

Tulsi, P., & Poonia, M. (2015). Expectations of industry from technical graduates: Implications for curriculum and instructional processes. *Journal of Engineering Education Transformations* , 19-24.

Tuning, P. (2003). *Tuning educational structures in Europe. Informe Final.* Bilbao: Universidad de Deusto.

Twenty one toys. The empathy toy teacher's kit. (2018). https://twentyonetoys.com/collections/toys-games-play-based-learning/products/empathy-toy-teachers-kit Accessed 19 December 2018.

Valero, A. (2018, November 14). Así es el aula que prepara para las habilidades del futuro, según bMaker. *Business Inside.* Retrieved from https://www.businessinsider.es

Vass, E. (2017). Building dialogic spaces through inclusive conversations. *Engaging Schooling: Developing Exemplary Education for Students in Poverty*, 63.

Voelkl, K. E. (1995). School warmth, student participation, and achievement. *The Journal of Experimental Education*, *63*(2), 127-138.

Wilson, A. (2005). *Creativity in primary education: Theory and practice (achieving QTS cross-curricular strand).* Learning Matters.

Withers, C., Methven, L., Qannari, E., Allen, V., Gosney, M., & MacFie, H. (2014). Taxonomic free sorting: A successful method with older consumers and a novel approach to preference mapping. Journal of Sensory Studies, 29(3), 182-189.

Zhang, W., & Guo, A. (2017, July 1). *Research on the blended teaching mode for computer network course*. Paper presented at the 4th International Conference on Social Science and Humanity, Madrid, Spain.

Zhao, J., & Meng, Z. (2015). Information transfer technique in classroom interaction. *US-China Foreign Language*, 357.