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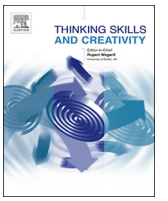

Creative interdisciplinary collaboration: A systematic literature review

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ABSTRACT

A systematic literature review was conducted to condense recent contributions on interdisciplinary collaboration for creativity as a strategic approach to aim innovation. Sixty-one documents from the period of the last five years were selected from Scopus. Findings were analyzed to identify what has currently been investigated about interdisciplinary collaboration in creativity; namely, what types of problems emerge within interdisciplinary collaboration and what elements are important to consider regarding interdisciplinary collaboration to foster creativity. A rising tendency for research in interdisciplinary groups and creativity was detected. Results of the studied texts include working definitions, knowledge domain aggrupations, highlights on organizational, educational and research fields and arguments that enhance creativity in the individual, collective and environmental dimensions. Their practical implications for management and theoretical models are also identified. This review integrates studied ideas with a proposition of a more detailed definition of creative interdisciplinary collaboration in the given framework.

1. Introduction

Parjanen and Hyypiä (2019) see interdisciplinary methods as a requirement to support collective creativity, Runco (2017) explains interdisciplinarity is relevant to "where we are going" (p.308), and Edmondson and Harvey (2018) find interdisciplinarity "an increasingly popular strategy for innovation" (p.347). This study aims to investigate the relation between interdisciplinarity, creativity and innovation. Contemporary literature tends to define creativity as the production of original and effective ideas that are related to certain products, services, processes, procedures and the involvement of open-ended problems. Innovation has generally been conceptualized as comprising both the production of creative ideas and the implementation of the ideas. Creativity is often understood not only as the first step of innovation, but also as something that accompanies almost all the innovation implementation process (Dino, 2015; Oddane, 2015; Tang & Werner, 2017). Recent trends have involved an integrated, interdisciplinary approach to creativity. They take into account psychology, socio-cultural and management perspectives. For example, Frascara (2017) emphasizes the fundamentals of social sciences for the support of design.

Interdisciplinarity is relevant in organizational, educational and academic contexts. Despite the literature evidence regarding the significance of combining collective creativity and interdisciplinary methods for innovation (Parjanen & Hyypiä, 2019), no creative interdisciplinary collaboration definition was found in the studied texts. Brem, Puente-Diaz, and Agogué (2016) offer an overview of the state of the art for creativity for the innovation management and call for more interdisciplinary as the needed approach. Park, Im,

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and Sung (2017, p.563) report knowledge diversity creates synergies between different types of knowledge by strengthening the linkages, which eventually leads to improved innovation and performance. However, despite the critical role of teams in fostering creativity, the question of how to configure such teams remains a critical problem (Han, Han, & Brass, 2014). While, for Timmis and Williams (2017) the idea of successful interdisciplinarity has become widely accepted across academia, they still argue "it rarely fulfills its promise in practice and there has been relatively little research into how to foster and promote interdisciplinary research groups" (p. 258).

The relation between creativity and interdisciplinary collaboration is a relatively new management intersection that lacks clarity. A proper understanding of this relation is still dubious and open to diverse interpretations. Besides, as a complex phenomenon, the abundance of limited approaches makes it difficult to integrate their common elements and rather challenging to investigate.

The main purpose of this study is to describe and summarize contributions in recent literature that reflect current understanding of group creativity within interdisciplinary collaboration. More specifically, the focus lies in exploration of what has been investigated so far. The focus is further elaborated on, providing, in this way, an up-to-date overview of the current state of the topic. The questions that define our research are:

RQ1: What has currently been said about interdisciplinary collaboration in creativity?

RQ2: What kind of problems have been identified as emergent within interdisciplinary collaboration?

RQ3: Which elements were identified regarding interdisciplinary collaboration that are important to consider in order to foster creativity?

Answers to the research questions bring a critical condensation of recent contributions, integration of different notions within the field and a new proposal of how creative interdisciplinary collaboration can be defined.

2. Methodology

An integrative review attempts to find common ideas and concepts in order to comprehensively understand a specific topic. It is appropriate for reviewing literature on new or emerging topics trending in various fields, such as interdisciplinary creativity, in order to gain critical understanding of the application of terms in published articles (Pautasso, 2013; Perignat & Katz-Buonincontro, 2019). To conduct this systematic literature review we follow a five step procedure: (i) identification of research; (ii) selection of primary studies; (iii) study quality assessment; (iv) data extraction and monitoring and (v) data synthesis (Kitchenham, 2004).

2.1. Identification of research

To find as many recent primary studies related to the objective of this review as possible, a set of searches were made on Scopus on the 24th November 2018. In accordance with Bradbury-Jones et al. (2019), we have imposed a time limit on the searches, conforming, thus, to the common practice in literature reviews with the main criterion being the ability to answer the review question. The agreed time restriction has been set for the past five years, as this timeframe should be sufficient to provide a reliable insight into current research (Said-Metwaly, den Noortgate, & Kyndt, 2017).

Preliminary searches on Scopus were aimed at both identifying existing systematic reviews, assessing the volume of potentially relevant studies and trial searchers using various combinations of search terms derived from the research aim. Table 1 shows inclusion criteria for the review.

2.2. Selection of primary studies

The search resulted in a list of 161 documents. The selection criteria procedure started with the organization of the information retrieved from Scopus. We transported the information to an excel spreadsheet, where it was thoroughly and precisely classified. To identify relevant studies to the research questions, an analysis of titles, keywords and abstracts was conducted. One hundred texts were excluded due to the fact that the information present was not relevant to the purpose of our study. Interactions between animals and humans, social risk children, sleep for drug recovery and overweight are only some examples of the main topics of the excluded papers.

Table 2 shows a rising tendency on the topic over the last five years. It brings the evidence that the number of publications in this area increased in more than 2.5 times. Up to the research date, documents corresponding to 2019 were already found.

Table 1
Inclusion criteria for the review.

Inclusion Criteria: 2013–2018		
Search strings in the titles, abstracts and key words	Subject areas	Document Type
(i) "interdisciplinary" and "creativity", (ii) "cross-boundary teaming", (iii) "knowledge diversity" and "creativity", (iv) "collaborative creativity" and "management", (v) "collective creativity" and "innovation", (vi) "interdisciplinary collaboration" and "creativity" (vii) "creativity" and "competence" and "team".	"Social Sciences", "Business, Management and Accounting", "Arts and Humanities", "Psychology".	Articles, articles in press, reviews, conference papers, and conference papers in press

Table 2
Document output classified according to year of publication.

Year:	2013	2014	2015	2016	2017	2018	2019	Total
Number of Documents Found	15	20	26	24	34	38	4	161
Number of Selected Documents	3	6	11	9	16	13	3	61

2.3. Study quality assessment

After full-reading, six more documents were excluded from further analysis. Those papers considered collective creativity topics but they had no focus on interdisciplinarity (Harrison, 2017; Warhuus, Tanggaard, Robinson, & Ernø, 2017; Leahy, 2016; van Oortmerssen, van Woerkum, & Aarts, 2015; Brix & Jakobsen, 2013; Ehlen, van der Klink, Stoffers, & Boshuizen, 2017).

To understand how the phenomenon of creative interdisciplinary collaboration is being studied, selected documents were classified as theoretical (14 documents, 23 %) or empirical works (47, 77 %). Empirical works were sub-classified according to their methodology: qualitative method (31, 66 %); quantitative method (10, 21 %), mixed qualitative and quantitative method (4, 9 %), and experimental methods (2, 4 %).

Regarding the environment of the unit of analysis, we classified each document into three types: education, organization, and reviews. Creativity among interdisciplinary collaboration can be studied in education from graduate, post graduate, MBA, doctoral or practices through student perspective as the analysis unit. This setting represents almost half (49 %) of the scenarios where researchers chose to study this phenomenon. Almost 48 % of the studies belong to the organization type, which includes working environments, communities of practice, projects or entrepreneurship. We identified two reviews (3 %), which include educational and organizational considerations regarding creativity within interdisciplinary teams (Brem et al., 2016 and Perignat & Katz-Buonincontro, 2019).

A wide range of contexts are used to provide interdisciplinary learning experience and evidence. For instance, Almond and Power (2018) present a case of pattern cutting, Brazile, Hostetter Shoop, McDonough, and Van Citters (2018) a health case between medical and engineers staff, Hurley, Trischler, and Dietrich (2018) a case of co-creation for adolescent alcohol consumption solutions, Li and Liu (2018) a tourism and hospitality environment, Park et al. (2017) a comparison regarding IT venture companies or Wilkes and Miodownik (2018) interdisciplinary projects from materials library.

2.4. Data extraction and monitoring

Idea mapping was constructed based on the research questions. In order to monitor the progress of the analysis, we included different columns in the excel spreadsheet, so that each document is related to a series of veriication lists, as Chicaíza-Becerra, Riaño Casallas, Rojas-Berrio, and Garzón Santos (2017) indicates to fill out extraction matrices in systematic literature reviews. The procedure was the following: Every selected document was saved with an identification number. Each document correspond to a line in an excel spreadsheet. While thoroughly read, each line of the excel spreadsheet corresponding to each selected document was completed, including document descriptors, identifications, methods strategy, findings and limitations, among other elements (Chicaíza-Becerra et al., 2017). Individual ideas in each document were highlighted and reviewed, notes and direct quotes were recorded and coded by an inductive approach, with the aim to identify different patterns, similarities and differences across the articles. Main ideas and selected quotations were integrated into one document, the information was structured according to the three research questions posed in the introduction section. Every step was monitored in the columns of the excel spreadsheets. Verified and closely corresponding main ideas were included in the integrated text. The result structure is represented by the subtitles of the results section of this work.

In order to display which authors referred to or were working in the area of our research questions Table 3 was created. It provides the amount of works that correspond to each question and idea, and references ordered by year. Within individual years, names are listed alphabetically.

The interpretation, transportation and content integration are synthesized in the result section of this review.

2.5. Data synthesis

We found evidence that supports the importance of knowledge diversity in creativity, as discussed in detail in the result Section 3.1. We also found evidence that supports the importance of fostering synergy among interdisciplinary collaboration, training, exercises and experiences. Moreover, literature highly recommends promotion of the above mentioned types of interactions in education. Without restriction, as a reference to design groups from a variety of domains, the STEAM (Science, Technology, Engineering, Arts, and Mathematic) aggrupation was found.

Apart from the interdisciplinary opportunities, authors also recognize inherent problems that can emerge in this type of interactions, as discussed in the result Section 3.2. The individual, collective and environmental dimensions are addressed in order to understand means to avoid those problems and promote the best creative production within interdisciplinary collaboration. Practical implications for management identified are presented in the result Section 3.4. And finally, a brief summary of theoretical models related to interdisciplinary collaboration are included at the end of the result Section 3.5.

Table 3
Count of documents corresponding to each research question and related references.

Question & Idea Mapping	N.	References
RQ1: Interdisciplinary collaboration in creativity		
Inter-disciplinarity as a strategy to foster creativity	27	Kuo et al. (2019), Parjanen and Hyypiä (2019), Edmondson and Harvey (2018), Kim (2018), Wieth and Francis (2018), Ambrose (2017), Borge and Bröring (2017), Leahey et al. (2017), Park et al. (2017), Runco (2017), Tan (2017), Brem et al. (2016), Clapp and Jimenez (2016), Li and Liu (2015), Spuzic et al. (2016), Moskovskaya (2016), Baer (2015), Dino (2015), Hepp K. et al. (2015), Li and Liu (2015), Martimianakis and Muzzin (2015), Oddane (2015), Schulz et al. (2015), Han et al. (2014), Lim et al. (2014), Ness and Søreide (2014), Yong et al. (2014)
Working definitions	11	Perignat and Katz-Buonincontro (2019), Edmondson and Harvey (2018), Leahey et al. (2017), Park et al. (2017), Tang and Werner (2017), Timmis and Williams (2017), Li and Liu (2015), Han et al. (2014), Ness and Søreide (2014), Waller (2013), Harrison and Klein (2007)
Starting from education	17	Kuo et al. (2019), Brazile et al. (2018), Cuervo (2018), Kozlov and Shemshurina (2018), McDonald et al. (2018), Sun (2018), Tan (2017), Tang and Werner (2017), Brem et al. (2016), Hutchison (2016), Spuzic et al. (2016), Baranova and Valeev (2015), Bevan et al. (2015), Hepp K. et al. (2015), Martimianakis and Muzzin (2015), Amor (2014), Spoelstra et al. (2014).
Training for Inter-disciplinary Creativity	19	Kuo et al. (2019), Parjanen and Hyypiä (2019), Kozlov and Shemshurina (2018), McDonald et al. (2018), Wieth and Francis (2018), Runco (2017), Tang and Werner (2017), Tan (2017), Brem et al. (2016), Hutchison (2016), Peng and Lin (2016), Spuzic et al. (2016), Bevan et al. (2015), Dino (2015), Hepp K. et al. (2015), Schulz et al. (2015), Lim et al. (2014), Spoelstra et al. (2014), Horne (2013),
Domain aggrupation´s	12	**STEM/STEAM:** Kuo et al. (2019), Allina (2018), Ambrose (2017), Clapp and Jimenez (2016), Spuzic et al. (2016), Bevan et al. (2015), Martimianakis and Muzzin (2015), **Other:** Kim (2018), Sun (2018), Brazile et al. (2018), Tang and Werner (2017), Hutchison (2016)
RQ2: Inherent emergence of problems among interdisciplinary collaboration		
	20	Parjanen and Hyypiä (2019), Edmondson and Harvey (2018), Li and Liu (2018), Sun (2018), Wilkes and Miodownik (2018), Wieth and Francis (2018), Leahey et al. (2017), Lockhart (2017), Park et al. (2017), Tang and Werner (2017), Timmis and Williams (2017), Brem et al. (2016), Li and Liu (2015), Oddane (2015), Schulz et al. (2015), Han et al. (2014), Ness and Søreide (2014), Yong et al. (2014), Horne (2013), Carlile (2004)
RQ3: Elements to consider regarding interdisciplinary collaboration to aim creativity.		
Individual Dimension	11	Parjanen and Hyypiä (2019), Wieth and Francis (2018), Kuo et al. (2017), Runco (2017), Baer (2015), Bourgeois-Bougrine et al. (2015), Li and Liu (2015), Martimianakis and Muzzin (2015), Han et al. (2014), Ness and Søreide (2014), Spoelstra et al. (2014).
Collective Dimension	18	Parjanen and Hyypiä (2019), Edmondson and Harvey (2018), Kim (2018), McDonald et al. (2018), Wieth and Francis (2018), Borge and Bröring (2017), Lockhart (2017), Park et al. (2017), Runco (2017), Austin (2016), Moskovskaya (2016), Li and Liu (2015), Oddane (2015), Schulz et al. (2015), Han et al. (2014), Ness and Søreide (2014), Yong et al. (2014), 2014.
Environmental Dimension	18	Parjanen and Hyypiä (2019), Edmondson and Harvey (2018), Wieth and Francis (2018), Ambrose (2017), Borge and Bröring (2017), Lockhart (2017), Park et al. (2017), Runco (2017), Tan (2017), Tang and Werner (2017), Timmis and Williams (2017), Brem et al. (2016), Moskovskaya (2016), Spuzic et al. (2016), Hepp K. et al. (2015), Morisawa (2015), Han et al. (2014), Waller (2013).
Practical implications for management and facilitation	18	Parjanen and Hyypiä (2019), Brem et al. (2016), Edmondson and Harvey (2018), Hurley et al. (2018), Li and Liu (2018), McDonald et al. (2018), García-García et al. (2017), Kuo et al. (2017), Lockhart (2017), Moskovskaya (2016), Baer (2015), Li and Liu (2015), Morisawa (2015), Oddane (2015), Schulz et al. (2015), Han et al. (2014), Ness and Søreide (2014), Waller (2013).
Theoretical Models	4	Edmondson and Harvey (2018), Bevan et al. (2015), Li and Liu (2015), Ness and Søreide (2014).

3. Results

3.1. A significant role of Interdisciplinarity in creativity

Our first research question was related to the identification of what has currently been investigated in interdisciplinary collaboration in creativity. We found an increasing interest in the study of knowledge diversity on creativity (Brem et al., 2016; Han et al., 2014; Kuo, Tseng, & Yang, 2019; Park et al., 2017). Interdisciplinarity has driven into the center of attention as a widespread approach to enhance creativity, learning, team performance and innovation (Clapp & Jimenez, 2016; Edmondson & Harvey, 2018; Kim, 2018; Oddane, 2015; Runco, 2017; Tan, 2017).

In an era of rapidly changing society, which is characterized as the knowledge society, collective mechanisms of knowledge development as a joint activity in working teams are revealed. Having multiple areas of expertise or diverse pools of knowledge may allow to recognize ways of solving complex problems that would not be possible if one had expertise and skill in only one domain (Baer, 2015; Yong, Sauer, & Mannix, 2014). Interdisciplinary collaboration is likely to be important due to its ability to deliver a wide range of perspectives, deal with and solve multifaceted problems, analyze broad contexts, get closer to complexity, create widespread ideas or expands the range of perspectives that teams can draw upon to innovate (Moskovskaya, 2016; Baer, 2015; Dino, 2015; Edmondson & Harvey, 2018). Therefore, the participation and contribution of various expertise and backgrounds are required (Parjanen & Hyypiä, 2019; Schulz, Geithner, Woelfel, & Krzywinski, 2015).

Interdisciplinary collaboration is essential for innovation (Baer, 2015; Dino, 2015; Ness & Søreide, 2014). Kuo et al. (2019) argues it has a major impact on creativity because it can help optimize the requirements of desirability, feasibility and viability for

Table 4
Working Definitions by author.

Author	Notion	Definition
Waller (2013)	Interdisciplinary research	Based upon a conceptual model that links or integrates theoretical frameworks from those disciplines, uses study design and methodology that is not limited to any one field, and requires the use of perspectives and skills of the involved disciplines throughout multiple phases of the research process.
Perignat and Katz-Buonincontro (2019)	Transdisciplinary	Fully merged disciplines without boundaries rooted in authentic problems or inquiry.
	Interdisciplinary	Brings several disciplines together under a common theme, but each discipline remains discrete.
	Multi-disciplinary	Includes collaboration among two or more disciplines but are not merged.
Ness and Søreide (2014); Timmis and Williams (2017) and Leahey et al. (2017)	Interdisciplinary	Integration of perspectives, information, data, techniques, tools, concepts, and/or theories from two or more disciplines; not only brings knowledge and contributions of different disciplines together but also synthesizes them through intensive and active interaction and collaboration
Tang and Werner (2017)	Interdisciplinary	Is not the simple addition of different disciplines (1 + 1 = 2). Instead, it's a dynamic synthesis of different disciplines with a common goal or purpose so that the final result would be 1 + 1 > 2.
	Cross-disciplinary	It focuses on observing one discipline through the perspective of another, for example: the physics of music.
Ness and Søreide (2014),	Collaboration	As a shared construction of knowledge in which it is not enough that participants cumulatively share their knowledge but where the participants jointly build on each other's ideas and thoughts to construct new knowledge.
Li and Liu (2015)	Knowledge diversity	The variety of knowledge, know-how, and expertise to which individuals have access through their networks, is about both for acquiring news and gossip knowledge that may update existing knowledge and influence individual creativity is the extent to which the useful information acquired by the recipient through interactions with the source includes knowledge across distinct domains
Edmondson and Harvey (2018)	Knowledge diversity	Is understood as underlying differences related to knowledge and work, such as functional or educational background among a team.
Park et al. (2017)	Knowledge diversity	Is the variety in the domains of expertise, work fields, and the extent of multidisciplinary ideas available to employees within an organization.

developing products, services, and technologies for specific purposes. Heterogeneous knowledge exploration enlarges an individual's search scope, updates and adds new elements to individual knowledge and prevents core rigidity, the cycle of doing "more of the same" or unlocked-in behavior patterns (Li & Liu, 2015). Such groups show more innovation generating potential than homogeneous ones, even if the latter team is superior in terms of credentials and intellectual capacities (Ambrose, 2017; Schulz et al., 2015). Wieth and Francis (2018) confirm a positive role of diversity on knowledge in divergent and convergent processes. The central argument is that the synergy of creativity is significantly enhanced by connecting competences from different disciplines (Spuzic et al., 2016).

The growing prominence of interdisciplinary research is also reflected by the upward publication trend (Leahey, Beckman, & Stanko, 2017). New models of knowledge building and knowledge co-creation are emerging (Tan, 2017; Li & Liu, 2015; Hepp K., Fernández, & García, 2015; Lim, Lee, & Lee, 2014). Moreover, there is an increasing foundation of academic organizations targeting interdisciplinary research (Borge & Bröring, 2017). Also, universities are being reorganized in order to develop cross-disciplinary problem-focused centers (Leahey et al., 2017; Martimianakis & Muzzin, 2015).

To unfold the introduced arguments related to the identification of what has currently been investigated in interdisciplinary collaboration in creativity, we identify relevant definitions first. Then, we address specific arguments that expose the need of further work on interdisciplinarity in education and notions concerning training. Finally, we present the aggrupation's of domain varieties researchers use to study or managers use to promote in case of interdisciplinarity.

3.1.1. Working definitions

In order to clarify what we mean when we refer to interdisciplinarity, we reduce the identified definitions of the notion in Table 4.

As shown in Table 5, knowledge diversity may be classified into knowledge separation, variety and disparity (Edmondson &

Table 5
Tree types of knowledge diversity: variety, disparity and separation.

	Type	Refers to	Such as
Knowledge Diversity	Variety	distribution of differences in knowledge content	expertise, functional background, network ties, industry experiences
	Disparity	distribution of differences in socially valued assets or resources	pay, income, prestige, status, authority, power
	Separation	distribution of differences in mental models about how to work as a team	opinions, beliefs, values, attitudes

Harvey, 2018; Han et al., 2014; Harrison & Klein, 2007; Park et al., 2017).

3.1.2. Starting from education

As an important element related to interdisciplinarity to enhance creativity, there is the "when to start considering this" question. We found a broad agreement on considering interdisciplinarity from the same point of knowledge variety is being promoted. It means, education should specialize and integrate at the same time. In this regard, the 21 st century faces complex pedagogic challenges relative to collaboration and interdisciplinarity (Amor, 2014; Hutchison, 2016).

Fundamentals of the interdisciplinary approach to education and research as the way forward to promote innovation are suggested (Sun, 2018; Tan, 2017; Brem et al., 2016). Creative competence and a cross-curricular component, as educational establishments have to respond to society demands of creative skills profiles, have become relevant (Kozlov & Shemshurina, 2018; Sun, 2018; Brazile et al., 2018). There is an increasing demand for graduates equipped with the knowledge and skills to apply interdisciplinary approaches to the development of novel solutions (Spoelstra et al., 2014; Sun, 2018). Schools, therefore, cannot afford to remain detached from the fast-moving changes that are taking place, which is why they have made innovation one of their priorities (Hepp K. et al., 2015). McDonald, Gertsen, Rosenstand, and Tollestrup (2018) argue "a collective approach is required to facilitate student-centric outcomes that also meet management expectations" (p.8). In general, the educational field is perceived as a potential driver of creativity and innovation (Bevan, Gutwill, Petrich, & Wilkinson, 2015).

Further evidence confirms significant effect of interdisciplinary practices on the integral development of learners. By applying the interdisciplinary approach, students develop the ability to integrate concepts and ideas into a broader conceptual framework of analysis, raise their level of abstraction and generalization, and improve a better assimilation of content and construction of knowledge. The interdisciplinary approach unlocks untapped potential, increases the presence of cognitive functions such as originality, fluency and flexibility -creative results-, fosters creative self-efficacy and comfort, benefits the learner's acquisition, delves into and application of perspective-taking, dialectical and systematic thinking, higher order thinking, cooperation and collaboration, as well as written and oral communication skills. It also allows ethical and quantitative reasoning, critical thinking, it helps students develop and maintain self-direction, encourages them to explore and experience new ways of knowing, enhances problem-solving skills in real-world settings, improves student's learning motivation and enjoyableness of learning and recognizes the significance of learning to future career development (Baranova & Valeev, 2015; Cuervo, 2018; Kozlov & Shemshurina, 2018; Kuo et al., 2019; Martimianakis & Muzzin, 2015; McDonald et al., 2018; Spuzic et al., 2016; Tang & Werner, 2017).

3.1.3. Training for interdisciplinary creativity

Accompanying the first wave of creativity research in 1950s and 1960s, creativity training programs started to emerge and the effectiveness of creativity training has been proven (Tang & Werner, 2017). It was found that there is important evidence relating training to higher creativity (Wieth & Francis, 2018). Implementation of processes, methods, techniques and tools, such as training creative thinking skills and exposing learners to design opportunities, to train and encourage creativity has been widely explored (Runco, 2017; Lim et al., 2014: Brem et al., 2016). Regarding interdisciplinary collaboration, studies often emphasize the centrality of entrepreneurship, real world solving problem and project based learning as the selected approach because they have the capacity to unite staff and students problems from various fields, immersing the learners in a contextualized and authentic learning setting (Hutchison, 2016; Kuo et al., 2019; McDonald et al., 2018; Tan, 2017; Hepp K. et al., 2015; Spoelstra et al., 2014; Lim et al., 2014). In fact, for Kozlov and Shemshurina (2018) teaching creativity has almost zero impact if it is not immersed in problem solving exercises. To mention some application examples, Peng and Lin (2016) presents a case of rural innovation through entrepreneurship interdisciplinary collaboration, Dino (2015) integrates creativity, innovation, and entrepreneurship in a practice called Innovation Quest, and Hutchison (2016) reports the Empathy Project.

Researchers tend to agree games as a methodology foster creativity in interdisciplinary collaboration, not only computer based-games (Horne, 2013; Tan, 2017) but also board, tinkering and playful games (Parjanen & Hyypiä, 2019; Bevan et al., 2015; Schulz et al., 2015). It is argued gaming addresses the cognitive, emotional and social dimension of learning and can be used as a tool to enhance individual and collective creativity. The importance of the order of tasks, the role of the warming up exercises, engagement of players, generating a good spirit, support of cross boundaries of different knowledge, and help to players from different backgrounds and perspectives to communicate and build common ground are highlighted as critical elements of playing games for creativity purposes. In game framing, thinking together not only consists of re-finding the bodies of knowledge, competence, skills or solutions which already exist, but also of developing them, even after the activities finish (Parjanen & Hyypiä, 2019; Schulz et al., 2015).

It is strongly suggested that creative thinking and interdisciplinary creativity are directions educational curricula should take. Professionally-oriented interdisciplinary activities and access to professionals in their own field are also suggested to be equally important (Kozlov & Shemshurina, 2018; Spuzic et al., 2016; Spoelstra et al., 2014).

3.1.4. Domain agruppation´s

Regarding knowledge variety domain or expertise categories, we have found that there is an aggrupation that works as a reference to design groups, educational curriculums and training programs: STEM/STEAM -Science, Technology, Engineering, Arts, and Mathematic (Allina, 2018; Ambrose, 2017). The approach was first conceptualized as STEM (e.g. Martimianakis & Muzzin, 2015 and Bevan et al., 2015) and then the A was added (e.g. Allina, 2018). It is understood that including the "A" element contributes to a better understanding of the users and evaluation of the final products (Kuo et al., 2019). By adding an "A" to STEM to equal STEAM the interest to develop a more diverse, creative and innovative workforce and results was reflected (Allina, 2018; Spuzic et al., 2016).

There is a variety of interpretations for the "A" in STEAM. It may include visual arts (such as drawing, painting, photography, sculpture, media arts, and design), performing arts (such as dance, music, and theatre), creative writing/poetry, expressive arts and crafts, digital and graphic arts, and design, or other non-STEM disciplines like the liberal arts, humanities, environmental studies and community engagement. The "A" in STEAM is also used as a synonym for project-based learning, problem-based learning, technology-based learning, or making. The addition of the A is aligned with the workforce competencies demanded in the 21 st century (Allina, 2018; Clapp & Jimenez, 2016).

Apart from the STEM/STEAM conceptualization, we have found other knowledge variety aggrupation's for comparisons. For example: arts, humanities, social science, natural science and education (Kim, 2018); science and the humanities (Sun, 2018); medical and engineering students (Brazile et al., 2018), psychology, education, business, and engineering (Tang & Werner, 2017) or sociology, biology, neurological computer science, visual arts, business, history, psychology, mathematics, drama, sales, and literature academic disciplines (Hutchison, 2016).

3.2. Inherent emergence of problems among interdisciplinary collaboration

Our second research question was related to the identification of problems that might emerge within interdisciplinary collaboration, that might itself be understood as a boundary object (Timmis & Williams, 2017).

Benefits of interdisciplinary collaboration are mentioned simultaneously with tensions that arise as problems emerge within interactions (Wilkes & Miodownik, 2018), since teaming across knowledge boundaries can be difficult in practice (Edmondson & Harvey, 2018). Han et al. (2014) suggest to understand both sides of interdisciplinary collaboration as influenced by two types of team social capital: bridging and bonding social capital. To Ness and Søreide (2014), interdisciplinary collaboration is influenced by a complex dialogue of two opposing movements; one unifying and one centrifugal. These challenges can render disadvantageous knowledge diversity and decrease performance for a number of reasons (Li & Liu, 2015).

Interdisciplinary collaboration with too functional or too specific user experience may trap individuals in a mode of thinking that does not allow them to think outside the boundaries established by that knowledge. One can see evidence for this position in the classic expertise and problem-solving literature where mental fixation is often seen as an indication of less flexible thinking. Thus, expertise in a particular domain seems to act as a knowledge constraint that limits the expert's ability to solve problems creatively in that domain (Wieth & Francis, 2018). The use of discipline-specific methodologies can, over time, shape what we believe is important to know about a phenomenon or hinder initial conversations about that phenomenon among different disciplines (Waller, 2013). The lack of serious communication may end in mutual incomprehension and suspicion between disciplines (Sun, 2018).

Interdisciplinary groups must work through their improvisational nature and an inherent conflict associated with their functional diversity to realize their creative potential. It seems good intentions are not sufficient to cope with inherent challenges in interdisciplinary collaboration. Knowledge diversity will not be brought to bear on the task to boost team performance without focused effort to ensure the inclusion of unique knowledge, that is, groups do not automatically lead to creativity. A simply formation of a collaborative task group does not mean members will work well together, or fully build and use their capacity to generate solutions and achieve common goals. It should also be taken into account that the participants in such processes may be experts in their fields but not necessarily experts in creativity methodologies, for example (Lockhart, 2017; Oddane, 2015; Schulz et al., 2015; Yong et al., 2014; Ness & Søreide, 2014; Edmondson & Harvey, 2018).

Heterogeneous knowledge often requires extra resources and integrating relevant support mechanisms. Specialists of different domains have to intensively learn from each other and need to use a considerable expense in time and effort to incorporate, maintain and transfer the new knowledge into an individual's capabilities. This might as well bear inefficient–transaction costs. (Li & Liu, 2015, 2018; Parjanen & Hyypiä, 2019).

The abundance of different perspectives on the same issue can lead to a lack of consensus (Brem et al., 2016). Spanning disciplines may also be penalized because results may be, at the end, of lower quality or difficult allocate (Leahey et al., 2017). According to Li and Liu (2015), to reconcile conflicting views, members of the interdisciplinary group cannot simply incorporate heterogeneous views into their creativity processes; they are likely to face diseconomies of scale relating to difficulties in effectively utilizing the new knowledge. For instance, in one of the analyzed cases, it was not clear enough what to do with and how to finally use the new knowledge, which brought in confusion about the applicability of the results. The high costs of this adjustment and the need of restructuring existing know-how may encourage individuals to rationally decrease their explorative activities.

Common barriers to successful collaboration include disciplinary differences resulting in turf wars between collaborators (Lockhart, 2017). Edmondson and Harvey (2018) explain that most people take norms and values within their own professions, organizations or industries for granted, sharing largely unquestioned assumptions that can thwart communication across boundaries. They highlight that team members tend to discuss common (shared) knowledge rather than unique knowledge, even if the unique knowledge is crucial to their team's endeavor.

Boundary challenges can be related to transferring -syntactic boundaries- translating -semantic boundaries- or transforming knowledge -pragmatic boundaries- (Edmondson & Harvey, 2018; Han et al., 2014). Regarding this challenges, both authors root their studies on Carlile (2004) frame: syntactic boundaries are manifested through differences in how language is used. Semantic boundaries refer to systems of interpretation that produce translation challenges for diverse individuals. Finally, pragmatic boundaries refer to different and potentially competing interests or agendas across individuals. In this line of thinking, there is always a risk, as Wilkes and Miodownik (2018) explain, that collaborating partners will be unable to resolve conflicts in epistemologies, value systems and methodological traditions; similarly, for Timmis and Williams (2017) the expectations of ethics committees and associated procedures, for example, are different across disciplines.

It is also mentioned in interdisciplinary groups, pride in one's specialty can lead to protecting intellectual turf and the use of jargon can cause communication barriers between team members to the further detriment of team integration. Categorization can also lead to an us-versus-them mentality in which the formation of subgroups can lead to exclusion and distrust (Yong et al., 2014). Horne (2013) emphasizes the importance of monitoring social aspects to minimize the problems associated, such as bullying. In addition, engaging in deep conversations is demanding and comes with the risk of creating interpersonal conflict that can erode team relationships and make future teamwork problematic (Edmondson & Harvey, 2018). Also, Lockhart (2017) enumerates environmental factors such as lack of space to meet and work together, mismatched goals among collaborators, lack of experience or training to work collaboratively, and differences in terminology across professions. Similarly, on-line collaboration and social media can create "filter bubble" phenomenon on exposing people only to take news and knowledge that supports their preexisting beliefs (Park et al., 2017).

For Tang and Werner (2017) when diversity begins to threaten the group's safety and integration and reduces group members' clarity about the commitment to group objectives, the implementation of creativity and innovation implementation will suffer. Among research teams, Leahey et al. (2017) argues that rather than being perceived as innovative, offerings spanning multiple domains have an ambiguous identity that is difficult for audiences to understand and are thus devalued. They suggest that although interdisciplinary research is more visible, scientists do indeed experience lower productivity. Finally, Leahey et al. (2017) theorizes that interdisciplinary research is cognitively difficult and slow to produce when it blends disparate fields.

3.3. Elements to consider regarding interdisciplinary collaboration to aim creativity

Our third research question is oriented to detect elements that are important to consider interdisciplinary collaboration that aims at creativity. These elements are structured in three dimensions: the individual, the collective and the environmental, in accordance with the focus of an overwhelming number of creativity studies (Dino, 2015).

3.3.1. Individual dimension

People are different, and such differences will influence the patterns of interpersonal interaction (Han et al., 2014). With the exception of a study in Taiwan which showed the individual creative element had higher (most helpful) ratings than the interdisciplinary practice element (Kuo, Burnard, McLellan, Cheng, & Wu, 2017), there is a broad agreement about the mutual beneficial contribution between individual and group creativity, especially if they are interconnected in a dynamic movement (Ness & Søreide, 2014; Parjanen & Hyypiä, 2019; Runco, 2017).

Proper motivations, attitudes, priorities and incentives are critical to ensure members' engagement in boundary spanning (Han et al., 2014; Spoelstra et al., 2014). Thus, individual attributes such as openness, conscientiousness, self-acceptance, hostility, impulsivity, individual independence, unconventionality, risk-taking, personal wide range of interests, a "discovery" orientation and task intrinsic motivation are also correlated with collective creativity collaboration (Wieth & Francis, 2018). Baer (2015) introduces two more attributes, namely, openness to experiences and tolerance of ambiguity.

Bourgeois-Bougrine, Sandoz, Allena, and Dallez (2015) affirms teamwork seems to be influenced by the diversity of the thinking styles of the team members (Synthesist, Pragmatist, Realist and Analyst). They argue the most creative and better performed teams are composed by all the thinking styles. Li and Liu (2015) further argue past experiences also shape individual memory, reduce resistance to change, institutionalize learning mechanisms, legitimate the exploration process and establish and refine personal routines that enable future learning.

Martimianakis and Muzzin (2015) bring a different perspective and report generational differences. Older participants did not challenge the central role of disciplines in the construction of expertise and younger participants were more likely to resist being 'disciplined'; they identified both satisfaction and creativity from working in the margins of knowledge spaces.

3.3.2. Collective dimension

In concordance with the statement of Moskovskaya (2016) that "knowledge is collective" (p.82), recent research has turned to the social aspects of creativity (Han et al., 2014; Runco, 2017). Oddane (2015) argues it seems appropriate to challenge the understanding of creativity and innovation as a matter of initial individual creativity followed by subsequent collective innovation. It is also suggested teams should cultivate and maintain both internal bonding and external bridging social relationships to be creative.

It is an equally essential prerequisite of interdisciplinary processes to collectively shared understanding of an object under consideration that participants have to develop a common language to understand each other in terms of the desired innovation as well as regarding their cooperation processes (Ness & Søreide, 2014; Schulz et al., 2015). This collective emergent state is referred as knowledge platform.

To Moskovskaya (2016) the notion of 'situated knowledge' or 'communities of practice' can be applied to any instance of knowledge development and assumed 'engaged participation' that combines joint efforts and a common focus on searching for solutions. In fact, it was found that task conflict have a positive relationship with creativity (Yong et al., 2014). Thus, the group generates "knowledge quality" which refers to 'the fitness' of the knowledge to be used in the task at hand. To Park et al. (2017) successful task performance requires the right knowledge to be available at the right time and in the right place.

To achieve creativity, heterogeneous "neighborhoods" (Li & Liu, 2015) or combining different but seemingly related domains (Baer, 2015) can also be valuable. Han et al. (2014) indicates that knowledge variety facilitate creative generation when knowledge disparity is low, this is, when there are fewer differences among pay, income, prestige, status, authority or power.

Personal relationships are crucially important in interdisciplinary collaboration (McDonald et al., 2018). It is easier to contact and

possibly develop new ideas together -even in the future- when participants get to know each other and have shared discussions and experiences (Parjanen & Hyypiä, 2019). Yong et al. (2014) explain relationship conflict has a negative influence on creativity. Valuable knowledge can be acquired from the combination and exchange of diverse knowledge in strong social interactions, which has a significant impact on both creativity and productivity of job performance in the workplace (Li & Liu, 2015; Park et al., 2017). Through the duration and frequency of interactions, more creative actors are willing and able to work closely with other parties and consider a wider range of expertise and technologies (Li & Liu, 2015). The consilience between different disciplines is recognized as enabling more creativity and thinking skills while they are more integrated (Kim, 2018).

Austin (2016) reports the needs for acceptance, recognition and identity in interdisciplinary creative processes. Lockhart (2017) expresses development of trust between group members might change over time and impact how members participate. The beneficial engagement across disciplines requires trust and effective communication among all the partners involved (Borge & Bröring, 2017). Several studies show that when inhibitory control is low and inhibition is weaker, participants are more likely to consider more distant information, which in turn often leads to greater creativity (Wieth & Francis, 2018)

For Edmondson and Harvey (2018) interacting with other team members help to clarify roles, goals, norms, and routines, hence shaping collective states develops a sense of belonging and gain self-efficacy. Oddane (2015) illustrates how collective discussion helps to deal with unexpected problems that require creativity as the collective a “kaleidoscope of ideas developed from the multiple points of view” (p.50).

3.3.3. Environmental dimension

Finally, we found physical, virtual and material resources, artifacts and surroundings are important to consider to encourage creativity because they influence interdisciplinary collaboration.

For Edmondson and Harvey (2018) the context comprises a larger social system in which the team is embedded, which involves the characteristics of the task or work the team is tackling, the timeframe of the teaming effort and the governance structure under which the team is acting.

There are aspects that influence creativity, such as culture (Tang & Werner, 2017), time or experiences. Runco (2017) affirms time and time constraint have a notable influence on creative thinking. If participants know they are timed (or evaluated), they tend to be distracted and less original than otherwise; even worse, he reports, they will not have the time to explore associative pathways to the point where they find remote associates. Without environmental support, such as encouragement, social support, autonomy, resources or opportunities to present novel ideas, creativity may never come to fruition (Wieth & Francis, 2018), on the contrary, it will act as a barrier (Hepp K. et al., 2015).

Borge and Bröring (2017) conclude institutionalization and provision of a network are. They offer examples, such as organizing events, meetings, conferences or providing an online platform. They argue that such networks could set mandatory requirements to enforce interdisciplinary collaborations. Edmondson and Harvey (2018) and Han et al. (2014) mention tools, such as pre-established protocols or shared norms or training. Structural mechanisms, such as predetermined interdisciplinary seating, might set a context for interdisciplinary conversations at the beginning (Waller, 2013). Such structures, Morisawa (2015) argues, are a multi-dimensional and contingent artifacts and together with governance rights positively influence performance of diverse teams. Lockhart (2017) shows that the extent to which interdisciplinary members plan and distribute work is related to group outcomes. Closing behaviors on specific- clear task divisions may cause teams to miss flexibility and potential benefits of diversity and objects that could support their teaming effort (Edmondson & Harvey, 2018).

With performance pressure increased, teams seem to make greater use of general knowledge and less use of domain-specific knowledge because they tend to look for consensus, concentrate on common knowledge, shift focus from learning to project completion and conform to the status hierarchy (Edmondson & Harvey, 2018).

An inspiring atmosphere and a harmonious environment enhances the synergy of creativity as well (Parjanen & Hyypiä, 2019; Spuzic et al., 2016). When creativity is encouraged and stimulated without threat, the environment is well prepared for perspective shifts, patience and uncertainty (Parjanen & Hyypiä, 2019). As Brem et al. (2016) report, many studies have examined the elements that may constitute a creative climate, including the degree of individual freedom, the quality of support towards new ideas, a clear and inspiring vision provided by supervisors, and creative encouragement.

One of the most profound changes and innovations experienced in the last few years concerns digital technologies (Tan, 2017; Hepp K. et al., 2015). Technology represents one of the new domains in which creativity is often expressed together with a shift to new methodologies (Runco, 2017). Timmis and Williams (2017) note that engagement with digital technologies can be very challenging because it involves continual boundary crossing between personal and private, formal and informal, institutional and personal spaces. On one hand, significant evidence regarding the positive role of technology on creativity as a tool for learning, promoting a bigger picture thinking, multiple perspective thinking and connective thinking to flourish problem-solving and creativity was found (Ambrose, 2017; Borge & Bröring, 2017; Tan, 2017). On the other hand, there is a strong argument against technology mediation to foster creativity. Moskovskaya (2016) argues that electronic networking platforms contribute to the fragmentation of knowledge representation of participants, eluding a common sense and purpose. She reports such platforms blur the boundary between knowledge and information. The evidence shows a desire to increase the effectiveness of collective creativity via online communication but avoid true developing competencies, discretion, and exploration of experiences of the others from real-presence exchanges. For Park et al. (2017) it may be more productive to encourage employees to strengthen offline ties and diversify online communication.

3.4. Practical implications for management and facilitation

The key role of a leader, manager, coordinator or facilitator among interdisciplinary collaboration is evident (McDonald et al., 2018; Morisawa, 2015; Oddane, 2015; Parjanen & Hyypiä, 2019). For team-building, for example, they can select team members with low disparity (Han et al. (2014) moderate variety (Baer, 2015; Li & Liu, 2015) and low separation (Moskovskaya, 2016; Ness & Søreide, 2014; Schulz et al., 2015) Lockhart (2017) recommends leaders to take time to reflect on how the group structure may or may not contribute to the goal of interdisciplinary collaboration. He points out, it can be challenging to involve less active and new members (possible isolates) or reduce the influence of a few (degree centralization), yet the leadership can have a strong impact on outcomes. Working in previous stages (of the meeting, class or session, for example) is also considered essential (Parjanen & Hyypiä, 2019). For instance, before interdisciplinary encounters, anticipating and providing short summaries of participating disciplines' central paradigms and methodologies, if possible, might also be helpful to foster creativity (Waller, 2013). Edmondson and Harvey (2018) argue leaders influence team member interactions and emergent states in cross-boundary teaming by reinforcing the kind of behavior they expect from members, setting goal priorities, providing feedback on whether members have met these expectations, and rewarding those who do. They mention a case where identified knowledge diversity was positively related to individual creativity, but only when leadership was high.

Managers can provide training to prevent the lack of specific methodology or design tool competence. At least one of the team members must be trained in the required specific competence in order to achieve a good final resolution of the work (Hurley et al., 2018; García-García, Chulvi, & Royo, 2017). Such facilitators have a great number of tasks, for example, create a balance between shared understanding and maintaining diversity, alterity, intersubjectivity and ambiguity to ensure that shared knowledge platform and challenge present knowledge. Moreover, Li and Liu (2015, 2018) support the idea that knowledge workers or managers who are interested in being more creative should consider increasing their interactions with others and invest more effort in maintaining good relationships with partners and strengthen network ties.

Finally, let us present behaviors that are understood as key to the management of interdisciplinary collaboration, facilitate interaction and influence maturity states. They are ice-breaker activities and design tools that assist in developing trust; use of tools that reduce dominance (of the facilitator, a participant or sub-group) but avoid off-topic discussions at the same time; identification of the fine line between close guidance (to ensure progress and outcomes that align with the set targets) and giving voice to the users (to empower users to contribute their unique knowledge and skills); reframing problems and developing connections between the personal passions and the daily work of team members. Further on, such behaviors include asking questions; seeking feedback; experimenting; reflecting on progresses and results; discussing errors, problems and mistakes or unexpected outcomes of actions; talking about team goals, processes or outcomes; concluding sessions with short idea presentation to ensure that the content and purpose of the generated ideas are fully understood; recognizing everyone's contribution; and developing a sense of accomplishment (Brem et al., 2016; Edmondson & Harvey, 2018; Hurley et al., 2018; Ness & Søreide, 2014; Schulz et al., 2015).

3.5. Theoretical models

We identified four theoretical models regarding interdisciplinary collaboration to foster creativity. All of them refer to the phenomena as a process.

As a new way to understand early innovation work, Ness and Søreide (2014) present the model "Room of Opportunity", which shows that creative knowledge processes develop over time in six different phases and peak in the three middle phases in a "separate room", the opportunity one. The model is a contribution to how such invisible processes can be visualized and facilitated. The six phases of creative knowledge processes in initial stages of innovation include (i) ensuring diversity and setting goals; (ii) knowledge distribution - sharing knowledge across disciplines; (iii) the polyphony phase – discussing, challenging and processing the shared knowledge (this first 3 phases result in constructing a knowledge platform); (iv) utilizing the shared knowledge in imagining ideas; (v) idea formulation – narrowing focus and formulating ideas vi) consolidation - finalizing ideas (this last 3 phases -developing ideas- have the knowledge platform as a point of departure). At the same time, participation needs to actively integrate different perspectives. Such inclusion is particularly successful at early stages of interaction processes, which benefit from diversity more than the later stages.

The Tinkering Learning Dimensions Framework (Bevan et al., 2015) emphasizes creative, improvisational problem solving using a STEM-rich palette of activities, tools and concepts. The Learning Dimensions are: (i) engagement (a. spending time in tinkering activities; b. displaying motivation or investment through affect or behavior), (ii) initiative and intentionality (a. setting one's own goals; b. seeking and responding to feedback; c persisting to achieve goals in the problem space; d. taking intellectual risks or showing intellectual courage), (iii) social scaffolding (a. requesting or offering help in solving problems; b. inspiring new ideas or approaches; c. physically connecting to others' works), (iv) development of understanding (a. expressing a realization through affect or utterances; b. offering explanation(s) for a strategy, tool, or outcome; c. applying knowledge, d. striving to understand).

Li and Liu (2015) propose a framework to understand the relationships between knowledge diversity and creativity over three different moments. The relationship between the level of knowledge diversity and creativity is positive at the initial stage of diversity, negative at the middle stage, and positive again at high levels of diversity. That is, individuals tend to show an inverse S shaped relationship between individual knowledge diversity and creativity.

Finally, the model proposed by Edmondson and Harvey (2018) offers an integrative view to manage collective creativity, named Cross-boundary Teaming. The model considers the elements and relationships that explain the team dynamic interaction from an input-process-output frame and contribute to the state of the art by considering the "thickness" of the knowledge barrier to cross and

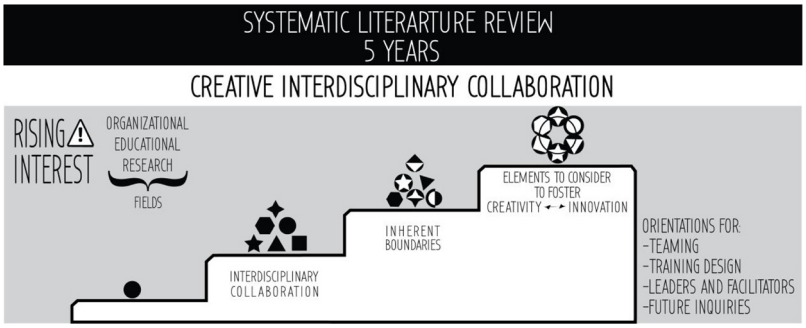

Fig. 1. Graphical abstract of the systematic literature review.

represent it as an input.

4. Final considerations

The main contribution of this study is the analysis of a great number of issues in the emerging field of interdisciplinary creativity. First, we determined the emergent topics of interdisciplinarity in the context of interdisciplinary collaboration and creativity, namely the strategy to foster creativity, working definitions, education backgrounds, training for inter-disciplinary creativity and domain aggrupation´s. Second, we identified problems arising in the context of interdisciplinary collaboration. Finally, we presented issues regarding interdisciplinary collaboration that aim on creativity–on an individual, collective and organization level. We also detected practical implications and four theoretical models that describe the creative interdisciplinary process. Fig. 1 helps clarifying the organization of the work as represent research questions with a graphical abstract.

Based on the findings in the recent literature, we can highlight a crucial role of interdisciplinarity for creativity in the educational, organizational and research fields. We found a wide range of methodologies, reference frameworks, approaches and arenas to study this prominent phenomenon. We can confirm an increasing interest in the topic, especially because it seems to contribute to the needs and challenges of the 21 st century. Interdisciplinarity as an approach is becoming more widespread thanks to its importance in increasing creativity, innovation, and team performance.

We found a particular need for promotion of interdisciplinarity since, traditionally, it is specialization that has been promoted as a great pedagogic strategy. The fusion of interdisciplinary approaches with the specific-domain education seems to impact both, development of the learner integrative formation and creativity, and enhancement of experiences and practices that contribute to a better integration later on when they meet organizational, research and management expectations. In other words, we found organizational, educational and research interest in developing interdisciplinary initiatives from specific-domain education. It seems entrepreneurship, real world solving problem and project based education are preferred current reference training approaches as they offer a complex ground to integrate a variety of perspectives and board solutions. We also found agreement regarding games as a methodology that fosters creativity in interdisciplinary collaboration as it offers scenarios that reduce inherent problems interdisciplinary collaborative interactions bring.

While pointing out the crucial role of interdisciplinarity, we also emphasize the need of work to balance it with the inherent problems that emerge from interdisciplinary collaborative interactions. This means, mere waiting for an interdisciplinary group to provide solution or produce an outcome without extra tools or strategies is not enough. An effort of time and management or facilitation is needed to cross knowledge boundaries and generate quality and valuable results. We found a need of actively managed collective mechanisms to transfer -syntactic boundaries- translate -semantic boundaries- or transform knowledge -pragmatic boundaries to take the full advantage of the benefits on interdisciplinarity. The thicker the boundaries, the bigger the challenge to avoid waste of energy, time, resources, pride, us-versus-them mentality, misunderstandings or relationship conflicts.

We structured the elements the literature presents regarding the interdisciplinary collaboration to aim creativity in three dimensions: the individual, the collective and the organizational. The three are inter-connected and generate a unique way of work.

We also confirmed the existence of personal attributes that contributes to the functional dynamism of an interdisciplinary collaboration in order to aim creative solutions. They are for example, openness, risk-taking, tolerance of ambiguity, conscientiousness, self-acceptance, having a wide range of interests, a “discovery” orientation and task intrinsic motivation. We have identified the vital importance of the allocation of a useful time to define roles and objectives; leverage methodologies that lead to creative solutions and team-effectiveness; explanations of main rules and other considerations groups should follow; or highlighting opportunities and benefits so that proper motivations and incentives ensure members’ engagement in boundary spanning. Looking at this same point from another perspective, it is always preferable to form a team from members that not only can share a different perspective, but also want to. Regarding the team design, all the above mentioned individual aspects should be taken into consideration.

Furthermore, we identified studies that bring evidence to the need to balance thinking styles. This may contribute to a better performance in interdisciplinary collective creativity collaboration. Regarding variety of knowledge, according to our findings, teams should be designed according to their final objective, outcome or task to pursuit; perhaps the reference of STEAM aggrupation’s (Science, Technology, Engineering, Arts, and Mathematic) is effective for certain type of projects. The references we studied mention

balancing the knowledge distance between the need of work that demands a profound technical-domain approach and work that demands different domain perspectives is essential.

Regarding the collective dimension, we found it is important to build an interpersonal net and knowledge platform. In order to do that, leadership, management and facilitation are main factors. It is equally important, for example, to integrate ideas, orientate and promote discussions, give a balanced voice to every one during the whole process, and help crossing the three boundary barriers. It seem clever to make sure objectives are understood, to establish clarity in role distribution, explain methodologies and expectations, organize working sequences, summarize agreements and reference points, and ensue a progressive agenda that can be felt useful for the members, so they can maintain adequate motivation to cross knowledge boundaries.

Regarding the mediator environment and context, the literature suggests the larger social system, culture, timeframe, institutionalization, resources, technology, governance structure and hierarchy, the higher influence on creative interdisciplinary collaboration process. An inspiring and harmonious atmosphere can have positive impact on preventing task conflict and minimizing relationship conflict. Regarding technology channels to foster interactions, it seems more efficient combining a variety of types of social networks in both on- and offline settings to improve creativity than avoiding some of them, for example, personal and face-to-face interaction.

Creativity within interdisciplinary groups might be understand from its individual, collective and environmental dimension and it can focus on the person, process or outcome. It can be managed and we have found four theoretical proposals regarding the management of this phenomenon. They offer diverse valuable process models.

Despite the fact all the studied research sheds more light on the notion of creative interdisciplinary collaboration, it is a relatively new and complex phenomenon. As such, the issue is not fully understood, offers various interpretations and deserves a continuous revision of its appropriation. Considering the study of research literature of the last five years and using the insights of researchers on the topic, the final section of this texts offers an integration of different notions identified into a proposal of a new definition of creative interdisciplinary collaboration. Before the definition is presented, we highlight notions of Edmondson and Harvey (2018); Park et al. (2017); Han et al. (2014), and Harrison and Klein (2007) in order to expose the barriers that have to be overcome in group interactions in order to build a knowledge platform and strengthen interpersonal relationships. We consider the notion of active in our definition to give an important place to facilitation or leadership (Parjanen & Hyypiä, 2019). We also base our definition on Harrison and Klein (2007) focus on knowledge variety, which includes expertise, network ties, industry experience, work-field, functional or educational range differences. Similarly, based on the agreement of Ness and Søreide (2014), Tang and Werner (2017), Timmis and Williams (2017) and Leahey et al. (2017), our definition refers to the notion of combination, which synthesizes knowledge variety fusion. Finally, from the result or outcome perspective, we include a proposal a competence notion that is close to the quality, effective and accurate aspect of desirable, feasible and viable creativity (Kuo et al., 2019; Park et al., 2017; Spuzic et al., 2016).

To conclude, our understanding of creative interdisciplinary collaboration based on the study of 61 papers corresponds to a shared and active construction of competent knowledge in a co-creative combination process that fuses a variety of knowledge into new knowledge which is accurate and functional in the context it may be used.

This definition should be understood as an open notion. As Ambrose (2017) explains, the field of creativity is fragmented and porous and includes conflicts over key ideas. However, the importance of knowledge variety in creativity in the 21th century is evident, and expectations and of further research are high, which is why this new definition should serve as a contribution to the gradual unification of terminology and more effective exploration of interdisciplinary collaboration in the context of creativity.

Author statement

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication before its appearance in Thinking Skills and Creativity Journal.

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