Creativity Support Tools and Convergent Thinking: A Preliminary Review on Idea Evaluation and Selection

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ABSTRACT

Creativity Support Tools (CSTs) have grown exponentially in the HCI field. However, this growth has always leaned towards divergent thinking, thus neglecting convergent thinking. We confirm this information based on a preliminary review between 2012 and 2022 in the ACM Digital Library. Our findings confirm that researchers and practitioners have been primarily interested in developing tools to support idea generation, minimizing studies on evaluating and selecting ideas. We focused our research on four major points: i) the domain of the tool, ii) the type of system and interface developed in the tools, iii) the methodology used, and iv) the creative context of the tools. Based on this information, we contribute six guidelines to support the improvement of existing CSTs and the development of new CSTs.

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**; • **Empirical studies in HCI**; • **Human- centered computing**; • **HCI design and evaluation methods**; • **User studies**; • **User centered design**;

KEYWORDS

Creativity, Creativity Support Tools, Divergent Thinking, Convergent Thinking

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1 INTRODUCTION

The promotion of creativity through technology has increased in recent years, and, as a result, the use of CSTs has proliferated. The field of human-computer interaction (HCI) is well known for studying these tools' impact, development, and design [1]. CSTs are distinguished by their ability to support and expand creative thinking and human abilities [2], and their diversity in the HCI community is vast and has been constantly studied [3, 4].

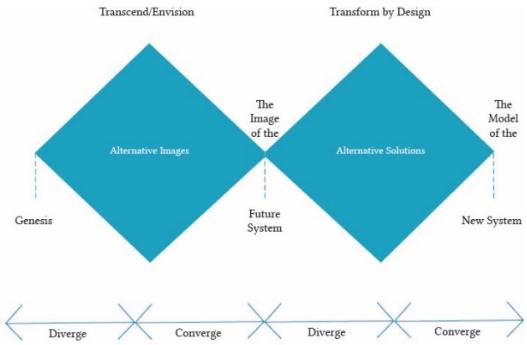

Figure 1: Adaptation of the Double Diamond model to our research.

Guilford [5] divided creative thinking into divergent thinking and convergent thinking. He associated divergent thinking with the ideation phase - the generation of ideas, and convergent thinking with the evaluation and selection of ideas. In Banathy's "double diamond" [6] (Figure 1), this classification was not only further explored but also linked. Despite the work of Guilford and Banathy, convergent thinking has mostly been associated with problem-solving tasks, for example, finding the correct (or best) answer. Although there are many theories about the underlying nature of creative processes and products, our specific interest is in the dichotomy between evaluating and selecting ideas. Because the focus of many works is still the framework presented by Ben Schneiderman [7–9], where he emphasized the quantity and not the quality of ideas: "Make more people more creative more often." We emphasize the importance of supporting convergent thinking because after generating ideas, people are left with an overload of ideas and need to choose some or just one to develop. Even some cases in the history of HCI demonstrate that people tend to reject good ideas, which can lead to weaker solutions to problem-solving [10].

Based on this information, we carried out a preliminary review on the CSTs that support convergent thinking to obtain insights that can guide us in the future development of these tools. We carried out this first analysis through the ACM Digital Library, which returned a sample of 10 CSTs that support convergent thinking.

The analysis of the tools was carried out through four major points: i) domain of the tool, ii) type of system and interface implemented in the tools, iii) type of methodology supported (Human vs. Machine), and iv) creative context of each CST. Our findings

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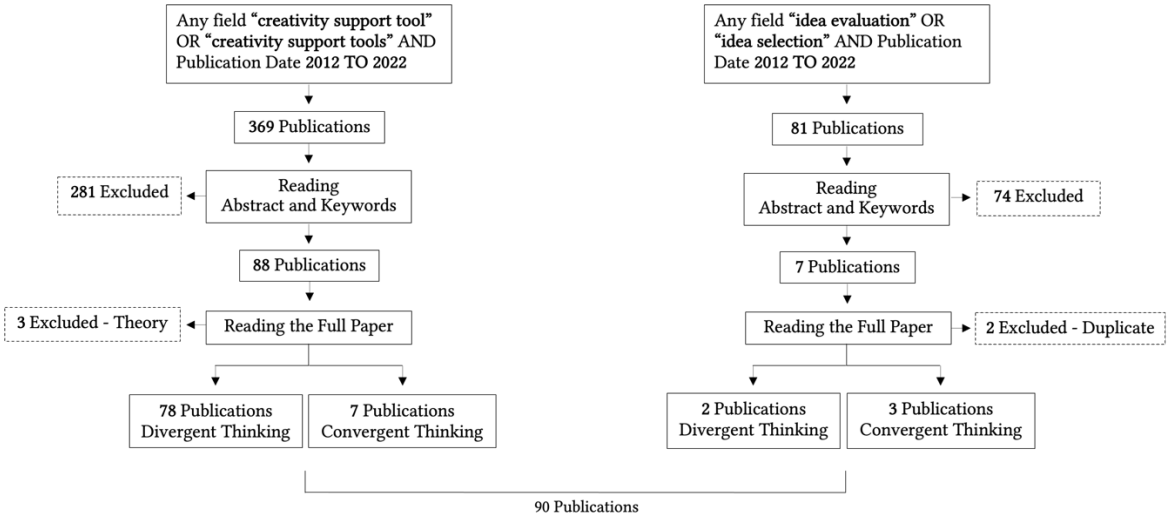

Figure 2: A descriptive flowchart of the search process.

confirm that researchers and professionals have been mainly interested in studying, developing, and designing tools that support the generation of ideas, failing to promote the evaluation and selection of ideas. We also identify possible expanding domains and technologies that can be considered new opportunities to incorporate into the tools. Our contribution in this paper is 6 guidelines that contribute to the improvement of existing CSTs and the development of new CSTs.

2 METHOD

The evolution of tools to support creativity in the HCI community has been widely monitored. Firstly, Frich et al. [4] reviewed the literature on creativity in HCI since the 1990s, thus covering the first 20 years of its existence. They presented the main trends in CSTs, including the importance of developing collaborative creativity. Then, in 2019, Frich et al. [3] presented a literature review in which they presented the main characteristics of CSTs and the definition of a tool to support creativity. Following the same line of thought and giving a more concrete trajectory, we present the initial part of a systematic review of the literature on CSTs focused on convergent thinking. The objective of this first phase was to analyze and evaluate the direction the CSTs are taking. Our methodology, as mentioned above, was based on the work developed by Frich et al. [3, 4] but updated for the last ten years of research (2012-2022) about CSTs and focusing its classification on convergent thinking. The library chosen was the ACM Digital Library (ACM DL) because it is the most comprehensive database in the literature on computing and information technology. We performed two independent queries, as shown in Figure 2. Our tool selection method was based on the CST definition given by Frich et al. [3] – "System that runs on one or more digital systems that encompass one or more resources focused on creativity and are employed to positively influence users of different knowledge in one or more distinct phases of the creative process."

In the first research, we used the term "Creativity Support Tool" both in the singular and in the plural to obtain a broader sample because researchers use the term in both ways. However, the search yielded few results on convergent thinking, only 7 articles, while the remaining articles support divergent thinking. In order to obtain more results, we carried out a second investigation focused on convergent thinking through the terms "idea evaluation" and "idea selection" where we only got 3 more articles on convergent thinking. The total sample consisted of 450 publications between 2012 and 2022. After the filtering process, as shown in Figure 2, we obtained a sample of 90 CSTs, with 80 articles focusing on divergent thinking and 10 on convergent thinking.

3 ANALYSIS AND RESULTS

3.1 Categorization of the total sample

We performed our preliminary analysis in two steps. In the first step, we studied the 90 articles through two parameters: i) domain classification, as shown in Table 1, and ii) type of system and interface implemented, as shown in Table 2. We performed this step together to compare the common points of the tools in both thoughts. In the second step, we deepen our analysis to study the tools that only support convergent thinking.

Of the 90 publications, 80 support idea generation (72%), and ten support idea evaluation and selection (28%), we conclude that divergent thinking has received particular attention in research over the past ten years. Studies on convergent thinking began in 2012, with 1 article, then 1 article in 2013, 1 article in 2015, 2 articles in 2018, 4 articles in 2021, and ending the sample with 1 article in 2022. This analysis shows that the focus of creativity support tools is divergent thinking. However, it has recently been reinforced that convergent thinking is equally critical in supporting creativity.

Based on the analysis presented by Frich et al. [3], we coded each article according to its category, in which we interpreted "Category" as the area supported by the tool. After our analysis, we obtained 32 categories that we later grouped into 5 general domains, as shown

Table 1: Summary of the categories and domains of the tools presented in the sample

Categories	Domains
Creative Writing	
Science Writing	Media & Communication
Journalism Writing	
Storytelling	
Industrial Design	
Fashion Design	
Multimedia	
Drawing	
Graphic Design	
Design	
Product Design	Visual Art & Design
Visual Art	
Game Design	
Digital Fabrication	
Web Design	
Storyboard	
Collaborative Ideation	
Narratives	
Photograph	
Arts	
Creative Workplace	
Collaborative Ideation	
Workshops	Undefined
Generations Sessions	
Crowdsourcing	
Rehabilitation	Health
Music Creation	Sound Production
Media Annotation	
Affective Computing	Affective Computing

in Table 1. With this coding, we can obtain an overview of the areas with greater support from the CSTs and perceive what has already been done, what is being done, and what remains to be done to renew the world of CSTs.

In the Media & Communication domain, we incorporated tools to support writing, as writing is one of the first artistic expressions of human beings [11]. In Visual Arts and Design, we incorporate disciplines such as drawing, photography, design, and applied arts such as industrial design, fashion design, and product design. In this domain, we also incorporate categories with strategic, technical, and creative activities, generally aimed at solving a problem. We also included the Crowdsourcing and Collaborative Ideation categories in this domain these categories were used to support the early stages of the design process. There were tools for which we could not define a domain because they can be introduced in different contexts, and the articles themselves did not indicate in which context they are used. So, we classify these articles as Undefined. In the Health domain, we incorporated articles that presented the development of support tools for people with aphasia. In the Sound Production domain, we incorporated the Musical Creation and Multimedia Annotation categories as they present tools designed to support the composition of new songs and the development of new chords. The last domain, Affective Computing, incorporates tools that support human creativity considering users' real states. It takes much work in the creative process for all domains found for both thoughts.

Second analysis together, we codified the type of system and interface developed in the CSTs. We obtained 7 types of systems and 11 types of interfaces, as shown in Table 2. According to our coding, the most developed type of system was Web Application with 60% of the articles, followed by Mobile Application with 11%. The most developed interface type was Graphical User Interface (GUI), with 52% of the articles, followed by Multimodal Interface, with 16%. We believe these choices are because users are already familiar with these technologies, minimizing prior learning.

3.2 Tools for evaluation and selection of ideas

Our objective was to map in this analysis the CSTs that support the evaluation and selection of ideas – convergent thinking. The analysis contributes to the community of investigators and developers working with CSTs by presenting i) the trends that emerged from the selected studies and ii) outlining possible opportunities and challenges for upgrading already by connecting the descriptive findings of our research in light of our conclusions on the topic.

The investigation of these stages began in 2012 with an article in the Affective Computing domain. The following year, an article was developed in the Visual Art & Design domain, but this domain reached its culmination in 2021 with 3 articles. In 2015, the impact of the Affective Computing domain on the creative process was again studied. The other articles were distributed between 2018 and 2022 and are Undefined. We closed our sample with an article in Sound Production in 2021. We concluded that the Web Application is the most developed system to support the evaluation and selection of ideas, with 50% of the articles. Then 30% were the Not defined systems, and the Stand-alone Application system had 20% of the articles, as shown in Table 3.

In addition to examining the trends and development of each tool, several points stood out in the process of coding and analyzing the corpus. Such as methodologies supported in each stage of convergent thinking (evaluation and selection of ideas) and the creative context of each CST that we present in the following sections.

3.2.1 Methodologies Supported. We summarize that the stages of convergent thinking were classified using two methodologies (Human vs. Machine), as shown in Figure 3. We verified whether humans performed the task of evaluating and selecting ideas or whether it was the machine that performed these tasks (we refer to the developed tool). We found that different techniques were applied to support the evaluation and selection of ideas.

The evaluation of the ideas was carried out using two methodologies: 5 articles [13, 14, 16, 19, 21] implemented an evaluation that was performed only by the machine, 3 articles [17, 18, 20] implemented a human-only evaluation, 1 article [12] implemented

Table 2: Summary of system type and interface type of tools that support divergent and convergent thinking. GUI stands for Graphical User Interface

Type of System	Type of Interface
Hardware Application	GUI
Web Application	Multimodal Interface
Mobile AR Application	VR Interface
Mobile Application	AR Interface
Virtual Reality Application	Tangible Interface
Stand-alone Application	Tangible and Multimodal Interface
Not defined	GUI and Multimodal Interface
	Tangible Interface and GUI
	VR and Multimodal Interface
	GUI and 3D Interface
	Not defined

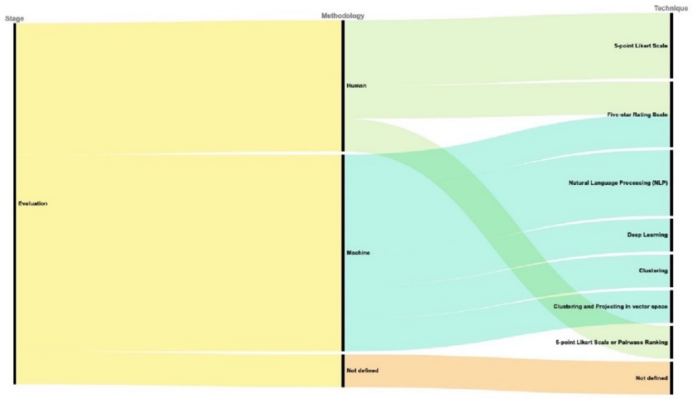

Figure 3: Grouping of the ten publications through the stage they investigated, the methodology used (Machine vs. Human), and which technique was used by each article.

both methodologies, using the same technique – Five -star Rating Scale and 1 article [15] did not define the type of methodology used.

As for the idea selection stage, it was performed only by humans. This is a good opportunity to introduce Artificial Intelligence (AI). In the sample, we found some CSTs infused with AI techniques. Many methods (e.g., Natural Language Processing, Clustering Algorithms, Greedy Algorithm, KMeans, and Dimensionality Reduction) help expose and compress ideas so that the user understands the importance of his ideas and selects the best one. Based on our preliminary analysis, we believe that the idea selection stage can benefit from an update of AI methods through the implementation of other methods in CSTs, e.g., Computer Vision methods, contributing to the analysis of other types of media such as images, sketches, and videos. More studies are needed in this area to understand when and how to adapt or customize future user interfaces supporting idea selection.

3.2.2 Creative Context. We analyzed the creative context of each tool through i) mode of use of the system - whether the tool is for individual use, group use, or both, ii) the level of expertise of the target audience - whether the tool is to support novices, semi-experts or experts and iii) the type of selection - whether the idea selection stage is an intrapersonal or interpersonal selection, Zhu et al. [10] - the selection of creative ideas can be carried out by the idea generator (intrapersonal selection) or by another person (interpersonal selection), as shown in the last column of Table 3. The system use category contains 9 tools for individual use and 1 for group use. The target audience also has points in common. Most developed tools are for beginners, two for experts, and one for semi-experts. The predominant type of selection is an intrapersonal selection with 5 articles, then 4 articles implemented interpersonal selection, and 1 article does not define the type of selection implemented.

4 DISCUSSION

In light of the thinking of Ben Shneiderman [7–9], where he emphasized the importance of generating the greatest possible number of ideas, because among the many ideas generated, there would be good ideas, and we could detect them, and in the light of our analysis, we point to an improvement in digital tools. Currently, most CSTs support divergent thinking, which overloads the range of ideas. There are already many ideas, and with the support of these tools, we are left with more ideas, and the main question is how to choose the best idea. The process of evaluating and selecting

Table 3: List of surveyed papers that address convergent thinking CSTs. GUI stands for Graphical User Interface

Ref.	Domain	Categories	Type of System	Type of Interface	Creative Context
[12]	Visual Art & Design	Graphic Design	Stand-alone Application	GUI and Multimodal	Individual use and support for novice users. Intrapersonal selection predominated.
[13]		Fashion Design	Not defined	GUI	
[14]		Product Design	Stand-alone Application	GUI and Multimodal	
[15]		Graphic Design	Not defined	GUI	
[16]	Undefined	Collaborative Ideation	Web Application	GUI	Individual use and expert users, with a selection of intrapersonal ideas.
[17]		Collaborative Ideation	Web Application	GUI	Individual or group use, support for beginners, with an intrapersonal selection of ideas.
[18]		Collaborative Ideation	Web Application	GUI	Individual use and support for beginners, with a selection of intrapersonal and interpersonal ideas.
[19]	Sound Production	Music Creation	Web Application	GUI and Multimodal	Individual use and support for beginners, with a selection of intrapersonal and interpersonal ideas.
[20]	Affective Computing	Affective Computing	Web Application	GUI	Group use supporting novices with an intrapersonal selection of ideas.
[21]		Affective Computing	Not defined	GUI	Individual use supporting novices with an intrapersonal selection of ideas.

ideas is not trivial, as it is in the act of evaluating and choosing that users have doubts about, following the line of thought presented by Rodrigues et al. [17], users need support to choose the idea(s). Responding to our initially proposed objective, we present 6 guidelines that can enhance the functionality of CSTs and increase integration in the users' workflow, as shown in Table 4.

We recognize that these guidelines only begin to touch on topics of fairness and broader futuristic considerations. These results aim to guide not only the future development of CSTs but also contribute to improving existing prototypes. Considering that one of the central issues in this area at the moment is a cooperation between humans and machines, we hope that our guidelines can contribute to finding a balance because too much filtering from the machine can reduce serendipity, while too much information can be hard to manage for the user. According to Shneiderman [22], AI techniques may support 100% of the user's decision. As the technology landscape is changing towards the increasing inclusion of facilitating human work using computing applications, we see significant value in refining and further developing the guidelines.

5 CONCLUSIONS AND FUTURE WORK

This article presents the initial phase of a first analysis of CSTs developed between 2012 and 2022. We synthesize guidelines found in

Table 4: Guidelines found in preliminary research, with detailed description and justification for use

Numeration	CST Guidelines	Goal
G1	**New domains: Media & Communication and Health** These domains were not included in the sample but could improve by introducing these tools.	Expand domains and thus contribute to an increase in CSTs that support convergent thinking.
G2	**Application of Human-Centered Artificial Intelligence (HCAI) [22]** Use AI methods based on Deep Learning [23] to capture human cognitive abilities, creating a hybrid human-machine system.	Highlight the acquisition, understanding, and creation of mental connections to obtain the best idea (s) and improve human performance through reliable, safe, and trustworthy systems.
G3	**Combining AI techniques with Information Visualization methods** The idea evaluation and selection steps can take advantage of classification, grouping, filtering, and recommendation techniques and present the information to the user through appropriate information visualization methods [24, 25].	Support the balance between human-machine decision-making, taking advantage of sensemaking, and the amount of information managed in the creative context.
G4	**Use of Ubiquitous Technology** CSTs for mobile devices, such as smartphones or tablets, are tools with a high degree of usability.	Insert in the context of the user's use a type of system that he is already familiar with. As they are ubiquitous systems, they are already part of the users' workflow, it does not require the introduction of an extra system.
G5	**Changing the type of environments - Support for groups and specialists** Beneficial to take advantage of the previous knowledge of the users, being able to take advantage of this information and thus develop CSTs with more functionalities, becoming more complete.	Monetize meetings, brainstorming sessions, and workshops so that CSTs can support novice and expert users.
G6	**Features Combination** Divergent thinking along with convergent thinking.	Supporting the entire creative process and reducing information overload.

our preliminary research on developing CSTs to support convergent thinking in 6 guidelines. We hope that applying these guidelines will result in better and more human-centered CSTs and that our synthesis could facilitate further research on the topic.

Although our results are promising, there is work to be done. Our future work is planned to start with two evaluations of the guidelines through i) a heuristics evaluation [26] and ii) a user study with HCI researchers to understand the applicability of the guidelines in the CSTs and to obtain feedback on the clarity of the guidelines. Subsequently, the expansion of the search is scheduled through queries in other databases (e.g., Google Scholar, IEEE, Web of Science, and Journals) and the use of other terms or combinations of terms, e.g., "creativity tool" or "support for creativity" in order to obtain a broader and more diversified sample, because many researchers carry out work in this area without specifying that the prototype is a CST. We will also modify our CSTs selection criteria, that is, we will incorporate design methods and commercial tools in our sample. This future line aims to compare the functions and resources implemented in this type of tool with our initial sample.

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