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Google Trend analysis of the evolution of collaborative innovation terms

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Abstract: A great variety of collaborative innovation terms – a concept associated with the process of engaging various stakeholders to innovate collaboratively – have been proposed. Prior studies have revealed significant popularity differences between the usage of these terms among scholars, while less is known about how widespread the usage of these terms is among general public. An altmetrics study grounded on Google Trend data is conducted to evaluate term adoption among the general public and to identify which of the terms show an increasing or decreasing trend. As a result, the number of upward, downward, and horizontal trends depended on whether monthly, quarterly, or yearly Google Trend data was used in the analysis. Out of 118 terms, 24 robust upward and 16 downward trends were identified. Only stakeholder engagement, design thinking, community engagement, customer based and hackathon term had strong positive trend while co-operation and co-development followed strong negative trend.

Keywords: Collaborative innovation, trend analysis, Altmetrics, Google Trends

1 Introduction

Collaborative innovation – a concept associated with the process of engaging various stakeholders to innovate collaboratively – has in recent years gained increasing interest (e.g. Baldwin and Von Hippel, 2011). Over the years, in various disciplines, a great variety of collaborative innovation concepts and methodologies with varying names, conflicting and overlapping definitions have been presented such as open innovation (Chesbrough, 2006) which emphasises collectively conducted research, development and innovation actions. A study by Santonen (2021) identified 97 different terms such as crowdsourcing, co-creation and design thinking, which can be associated with collaborative innovation terminology family. The study results revealed significant popularity differences between the terms, when number of publications including the terms was used as popularity indicator.

However, the referred study only evaluated the popularity of terms among scholars and not the general public, as it utilized scientific databases and publications as a data source. Over the past decade, there has been a growing trend to measure scientific impact beyond scientific communities by utilizing Altmetrics research (González-Valiente et al., 2016). Altmetrics is a term used to describe web-based metrics for the impact of publications and other scholarly materials (Bornmann, 2014). Currently, there are only a limited number of

altmetrics studies focusing on innovation management topics. Therefore, the main objective of this study is to evaluate the adoption of collaborative innovation terms among the general public, while focusing especially on which terms show an increasing or decreasing trend.

2 About Altmetrics and Collaborative Innovation

2.1 Altmetrics -- A complementary metrics for measuring scientific research impact

Altmetrics is a complementary metrics for measuring scientific research impact. However, scholars still debate the definition, and many types of metrics have been used, making it difficult to define clearly (Haustein, 2016). Altmetrics studies collect data from various sources, including web pages, social networks (e.g., Twitter, Facebook), traditional media, and dedicated online services that provide altmetrics data, such as Mendeley and Altmetric.com (Ortiz, 2021). The common unit of analysis in altmetrics studies can be manifold, such as publications, scholars, and organizations in which mentions (e.g., saves, views, or citations) act as impact indicators, while data sources could cover e.g., Wikipedia, social media (Facebook, Twitter), mainstream media, online reference managers, blogs, and scholarly social networks (Priem et al., 2012). Altmetrics studies provide many benefits over traditional scientific citation-based approaches (Bornmann, 2014), including 1) giving a better understanding of the broader social and cultural impact of research, 2) faster feedback than traditional citation metrics, and 3) higher diversity, since interest towards data sources can also be measured. However, this study does not focus on the impact of individual actors or publications but rather on the spread of a collaborative innovation phenomenon as a whole. Therefore, keywords related to collaborative innovation are utilized as search terms.

What is Collaborative Innovation?

The term "collaborative" is defined as the act of two or more individuals working together towards a common goal (Cambridge Advanced Learner's Dictionary & Thesaurus, entry for "collaborative"). The Merriam-Webster.com Dictionary defines it as "working jointly with others or together, especially in an intellectual endeavor" (entry for "collaborative"). The Oxford Advanced Learner's Dictionary describes it as a piece of work produced by two or more people or groups working together (entry for "collaborative").

Over the years, many definitions have been proposed for innovation. On the basis of literature review covering various scientific domains including business and management, economy, innovation and entrepreneurship, technology/science/engineering, knowledge management, marketing and organization studies Baregheh et al. (2009) proposed following definition for innovation, which includes all the key attributes and characteristics commonly found in the literature: *"Innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete and differentiate themselves successfully in their marketplace."* Collaborative innovation is a concept within the broader category of open innovation, a term coined by Chesbrough (2006) to describe research, development, and innovation

activities conducted collectively. For the purposes of this study, we propose the following definition for collaborative innovation:

> *Collaborative innovation is a systematic, multi-stage process that involves internal and external partners working together towards a common goal, leveraging diverse expertise, resources, and perspectives to transform ideas into valuable offerings in an intellectual endeavor.*

Who are the collaborators in collaborative innovation?

Santonen (2021) used the Quadruple Helix innovation framework (Carayannis and Campbell, 2009) as a starting point to identify collaborative innovation-related concepts and methodologies. The Quadruple Helix model is a widely accepted concept that classifies collaborators into academia, public sector, industry, and civil society actors. Therefore, by incorporating different combinations of participating actors, it leads us to different scientific domains. For example, when public sector actors collaborate with citizens, it can refer to collaborative governance in which public agencies and non-state stakeholders have a collective decision-making process to make or implement public policy or manage public programs or assets (Ansell and Gash, 2008). In contrast, citizen science is an approach that describes collaborative research actions between professional researchers and the general public to gain research results (Eitzel et al., 2017).

In Santonen's (2021) study, 12 different actor groups were identified as being referred to in various collaborative innovation terms: community, public, citizen, crowd, civic, user, stakeholder, customer, maker, hacker, panel, and jury. Among these groups, the most popular terms were related to community, followed closely by terms related to public, citizen, and crowd. Therefore, it can be argued that collaborators comprise a diverse group of individuals, including those with common interests, belonging to social groups or organizations, living in specific places (such as by residence or nationality), buying or using specific products or services, or serving as advisors or decision makers.

3 Research design

3.1 Identification of collaborative innovation terms

The 97 collaborative innovation terms identified by Santonen (2021) formed the main keywords for the Google Trend searches. Furthermore, 22 additional collaborative innovation terms that were missing in the referred publication were also added using a similar methodology, resulting in a total of 118 keywords. Most of the newly added terms were adopted from Santonen's (2018) publication, which compared the popularity of the living lab term to its competing terms. The study presented various "lab" concepts, including change, city, design, desis, fab, government, impact, policy, reality, social, urban, and innovation lab. Other added terms were hackathon, collective innovation, collective intelligence, innovation center, innovation competition, innovation content, open innovation, open service innovation, and patient involvement.

3.2 Google Trend as data source

Google Trends is a website created by Google that analyzes the popularity of top search queries in Google Search across various regions and languages. This website can be considered as a big data source since it deals with large and complex datasets using a series of techniques (Ward and Barker, 2013). As the most popular search engine with over 90 percent market share, Google Trends can be considered a reliable indicator of general public behavior. Scholars have shown an increasing interest in Google Trends over the last decade, with hundreds of studies covering various thematic areas such as IT, communications, health, business, and economics in order to evaluate market and human behavior at different levels in society (e.g. Jun et al. 2018, Choi and Varian, 2012, Preis et al. 2013). However, only a few studies have utilized Google Trends to evaluate the evolution of scientific terms or for innovation management study purposes. Duwe et al. (2018) used Google Trends to forecast the diffusion of product and technology innovations, while Kliuiev (2021) identified interest in innovation in Ukraine.

Google Trends data is anonymized and aggregated, which allows for the evaluation of public interest in a particular topic from around the globe or down to city-level geography. In this study, global level data from the years 2004-2021 was used. Google Trends analysis normalizes search data, and the resulting numbers are then scaled on a range of 0 to 100 based on a topic's proportion to all searches on all topics included in the search query (Google Support, 2021). However, only five terms can be compared at the same time, making popularity comparison between all terms difficult. Therefore, this study focuses only on evaluating the progress of trends over time and excludes popularity analysis among the general public.

A Google Trends search for the identified 118 collaborative innovation terms provided results for 105 terms (89.0 percent). For the following 13 keywords, there was not enough data to show trend results, and thus these keywords were excluded: citizen-centric design, citizen participatory activity, citizen participatory budgeting, citizen participatory community design, citizen participatory design, citizen participatory journalism, citizen participatory noise sensing, citizen participatory processes, citizen participatory transdisciplinary research, co-ideation, desis lab, and participatory procedure. Most of the excluded terms are citizen participatory combination terms that include additional specifications relating to the activity. However, citizen participatory and citizen participation terms were included, which will provide an overview of the base term trend evolution.

3.3 Trend analysis

Kendall rank correlation coefficients were calculated to detect upward, downward, and horizontal trends since the Google Trend data did not follow a normal distribution. Monthly time series data are more subject to seasonality than quarterly and annual time series data. Therefore, the original monthly time series data was combined into quarterly and yearly time series data to evaluate the robustness of the trend results and control the effect of monthly variation. The following criteria were used for interpreting the correlation coefficients: a correlation coefficient of 0.7 or over indicates strong positive correlation, a coefficient of 0.5 or over but less than 0.7 indicates medium positive correlation, and a coefficient of 0.3 or over indicates weak positive correlation. The same threshold values

were used for negative correlations. Trends with a correlation coefficient higher than -0.3 but below 0.3 were excluded from the results reporting.

4 Results

4.1 Results overview

Table 1 presents the overview of the Kendall rank correlation coefficient results. In the case of yearly data 27 positive and 41 negative trends were identified. The number of positive trends remained almost the same for quarterly (28) and monthly (27) data, while in the case of quarterly data only 18 trends and in the case of monthly data 16 trends were negative. Respectively, the number of poorly correlated or none corelated keywords increase to 59 in quarterly data and to 62 in monthly data. As a result, the upward, downward, and horizontal trend results (i.e. poor or no correlation) varied depending on whether monthly, quarterly, or yearly data was used in the analysis.

Table 1 Overview of the Kendall rank correlation coefficient results

Correlation	*Yearly data*	*Quarterly data*	*Monthly data*
Positive ALL	27	28	27
Strong - Positive	10	6	5
Medium- Positive	9	9	8
Weak – Positive	8	13	14
Poor or no correlation	37	59	62
Weak – Negative	18	6	7
Medium- Negative	10	5	7
Strong – Negative	13	7	2
Negative ALL	41	18	16

Strong 0.7 or over, Medium: 0.5 but < 0.7, Weak: 0.3 but <0.5

4.2 Identification of upward trends

Appendix Table 2 presents search terms classification according to strength of positive correlation when all times series analyses are counted. As a result, a total of 24 terms are confirmed to have a positive trend (i.e. there is positive correlation in all time series). However, as the table indicates correlation strength varies between the time series. In all times series data stakeholder engagement, design thinking, community engagement, customer based and hackathon terms had strong positive trend. Impact lab, social lab, citizen science, change lab, and living lab terms were having strong to moderate correlation. Makerspace, Innovation lab and Citizen based terms had moderate correlation. Co-creation, Policy lab, Public sentiment, Customer driven and Public engagement terms correlation varied between moderate and weak. In the case of Collective innovation, Civic based, User based, Citizen engagement, Design lab, Citizen centric and Innovation

competition at least one time series correlation result was below the weak threshold and therefore conclusion regarding upward trend is ambiguous.

4.3 Identification of downward trends

Appendix Table 3 presents the classification of search terms according to the strength of negative correlation. As a result, a total of 16 terms have been confirmed to have a negative trend in all timeseries analysis, but the correlation strength results varied between the time series. Co-operation and co-development terms had a strong negative correlation in all analyses. Strong to moderate negative correlation was detected in the case of co-design, collaborative research, co-production, community involvement, collaborative design, and participatory research terms. The citizen schools term correlated moderately, while the correlation for public involvement ranged from moderately to weak, and the correlation for patient involvement was weak. More mixed results were detected regarding collaborative learning, collaborative development, and deliberative democracy, with correlations varying between strong, moderate, and weak. Participatory action research and testbed results were also mixed, with strong and weak correlations being detected.

4.4 Detailed Upward and Downward trends analysis

The following section will present a detailed analysis of the upward and downward trends for the 24 positive and 16 negative correlations that were verified in all time series analysis (month, quarter and year). However, the visualizations are based on monthly data. Figure 1 presents an analysis of the upward and downward trends based on correlation and Web of Science topic count. In the figure, the size of each bubble represents the mean value of Google Trend data, which was calculated based on monthly data. The horizontal axis of the figure uses a logarithmic scale, as the number of publications among the terms varied significantly.

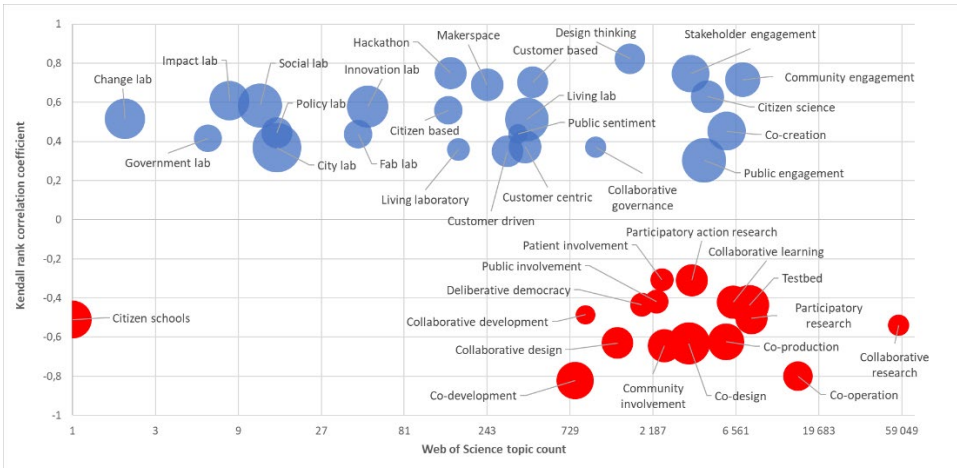

Figure 1 Upward and downward trends analysis based on correlation and Web of Science topic count.

The visualization in Figure 1 reveals that many of the "lab"-based terms (i.e. Change, Government, Impact, Social, Policy, City, Fab, Innovation) have gained very little interest

among scholars but are clearly showing an upward trend. Terms that have an upward trend but have modest interest among scholars include hackathon, makerspace, living laboratory, living lab, public sentiment, and customer-associated terms, including customer-driven, based, and centric. Terms that have over one thousand Web of Science topic counts and have a positive trend are collaborative governance, design thinking, citizen science, co-creation, public engagement, community engagement, and stakeholder engagement. Citizen school's popularity appears to be nonexistent among the scholars since only one publication was identified. Furthermore, collaborative and co-development are the only terms with citizen school having a Web of Science count of less than 1000 publications. All the remaining downward trend terms had clearly over 1000 publications.

Figure 2 presents a similar upward and downward trend analysis, but instead of using Web of Science title count results in the horizontal axis. In our opinion this figure reveals popularity differences better than the figure using topic count.

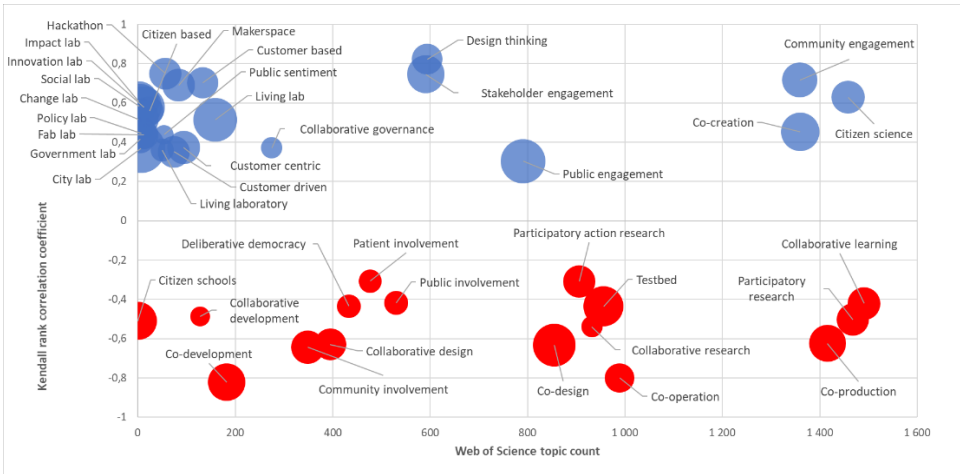

Figure 2 Upward and downward trends analysis based on correlation and Web of Science title count

Figure 2 clearly reveals that among the scholars' community, community engagement, citizen science, and co-creation are the most popular terms and have a clearly positive trend among the general public. The terms that are popular among scholars but have a downward trend based on Google Trends data are collaborative learning, participatory research, and co-production. The classification between low and moderately performing terms based on Web of Science title count becomes clearer. All lab-based terms, as well as citizen/customer-based, customer-driven/centric, makerspace, and public sentiment, which are experiencing upward trends, belong to the low-performing group along with the following downward trends: citizen schools, collaborative development, and co-development. Moderately performing upward terms consist of design thinking and stakeholder/public engagement. The upper tier of downward terms includes participatory action research, testbed, collaborative research, co-operation, and co-design, while the lower tier of downward terms covers public involvement, collaborative design, community involvement, and deliberative democracy.

4.4 Horizontal and trends

The table 4 presents the remaining terms, which did not have clear upward or downward trend (a.k.a. at least one of the correlation results when using monthly, quarterly or yearly data remained between threshold level a.k.a. higher than -0.3 but below 0.3).

Table 1 Overview of the Kendall rank correlation coefficient results

Term	*Combined with*	*Term*	*Combined with*
Adaptive governance		Innovation *	center, competition, contents
Citizen *	activism, centric, deliberation, driven, engagement, evaluation, involvement, juries, oriented, panels, participation, participatory or sensing.	Open *	innovation, service innovation
Civic *	based, centric, driven, engagement, involvement, participation, volunteerism.	Participatory *	budgeting, democracy, governance, innovation, modelling, sensing
Co decision		political participation	
Collaborative *	decision making, innovation, mapping, modelling	Public deliberation	
Collective *	innovation, intelligence	Public hearing	
Community *	based participatory research, concepts, of practice, participation, volunteerism	Public participation	
Crowdsourcing		Reality lab	
Customer *	oriented, oriented design	Service design	
Deliberative public		Stakeholder participation	
Design lab		Urban lab	
Hackerspace		User *	based, centric, centric design, driven, driven design, oriented, oriented design

* is indicating that word is a prefix e.g. Citizen activism

The more detailed data analysis reveals that a few of the terms were following a U-curve (collective innovation, open service innovation, hackerspace, and civic participation) or an inverted U-curve (citizen-oriented). The COVID-19 pandemic also had an impact on some trends. In the case of citizen activism, a clear drop starting in March/April 2020 was detected in the trend line. COVID-19 also affected the popularity of terms such as

customer-based, social lab, and living lab, although they were still able to maintain an upward positive trend regardless of the pandemic.

5 Conclusion

Several collaborative innovation-related terms have been presented, whose popularity among scholars varies significantly. However, it is not clear to what extent the general public is interested in these terms. An altmetrics research approach, based on Google Trends data, was utilized to evaluate the adoption of collaborative innovation terms among the general public. Specifically, this study aimed to determine which terms were following an upward, downward, horizontal or some other trend.

The study findings indicate that the interpretation of the upward, downward, and horizontal trend was dependent on the frequency of the time series data used for the analysis. A total of 24 collaborative innovation terms exhibited a positive trend, while 16 terms showed a negative trend, regardless of the frequency of the data used for the analysis. The analysis also revealed that a few terms followed a U-curve or an inverted U-curve. The COVID-19 pandemic also affected some trends, with a significant drop in popularity detected soon after the quarantine period and/or movement restrictions began. The study provides insight into which collaborative innovation terms are likely to gain more interest among the general public in the future and which ones, regardless of their popularity among scholars, are facing reduced interest. Additionally, the extended list of collaborative innovation terms can serve as a guide for researchers seeking new knowledge on different collaboration innovation approaches.

Due to limitations in the Google Trends user interface – only five terms could be analyzed at the same time – prevents detailed popularity analysis among the general public. Therefore, the study findings cannot make any assumptions regarding the popularity of different terms among the general public. However, by comparing terms in groups of five and always including the most popular term in the list, the future studies could provide an approximate indication of the differences in popularity among the terms.

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Appendix

Table 2 Positive Kendall rank correlation coefficient reliability test results regarding timeseries impact on results

Strong	*Strong to moderate*	*Moderate*	*Moderate to weak*	*Weak*	*Weak to poor*	*Mixed**
1. Stakeholder engagement 2. Design thinking 3. Community engagement 4. Customer based 5.Hackathon	1. Impact lab 2. Social lab 3. Citizen science 4. Change lab 5. Living lab	1. Makerspace 2. Innovation lab 3. Citizen based	1. Co-creation 2. Policy lab 3. Public sentiment 4. Customer driven 5. Public engagement	1. Fab lab 2. Government lab 3. City lab 4. Customer centric 5. Living laboratory 6. Collaborative governance	1. Collective innovation 2. Civic based 3. User based 4. Citizen engagement 5. Design lab 6. Citizen centric	*Moderate, weak and poor* 1. Innovation competition

Strong 0.7 or over, Medium: 0.5 but < 0.7, Weak: 0.3 but <0.5. *

Table 3 Negative Kendall rank correlation coefficient reliability test results regarding timeseries impact on results

Strong	*Strong to moderate*	*Moderate*	*Moderate to weak*	*Weak*	*Weak to poor*	*Mixed**
1. Co-operation	1. Co design	1. Citizen schools	1. Public involvement	1. Patient involvement	1. Community concepts	*Strong, moderate and weak*
2. Co-development	2. Collaborative research				2. Public participation	1. Collaborative learning
	3. Co production				3. Citizen activism	2. Collaborative development
	4. Community involvement				4. User centric design	3. Deliberative democracy
	5. Collaborative design				5. Civic driven	*Strong and weak*
	6. Participatory research				6. Citizen evaluation	1. Participatory action research
					7. Innovation contents	2. Testbed
					8. Citizen juries	*Moderate and poor*
					9. Deliberative public	1. Participatory modelling
					10. User oriented	2. Collaborative decision making
					11. Collaborative mapping	3. Citizen deliberation
					12. Public deliberation	4. Collaborative modelling
					13. Citizen panels	5. Participatory innovation
					14. Collective intelligence	6. Stakeholder participation
					15. Public hearing	7. Community based participatory research
					16. Community of practice	8. community volunteerism
					17. Participatory sensing	

Strong 0.7 or over, Medium: 0.5 but < 0.7, Weak: 0.3 but <0.5. *