Two new tools for science communication assessment: the community engagement index and communication effectiveness quadrants

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We present an integrated approach to the quantitative assessment of science communication activities of research projects. In particular, we introduce the community engagement index and the communication effectiveness quadrants plot. The former is a metric integrating all communication activities into one single index and representing the engagement of a community with the project. The latter is a dynamic graph to monitor and improve the performance of communication products. Our methodology can be applied to research initiatives of different kinds and geographical scope. Indeed it has been tested on a diverse set of EU-funded projects on disparate thematic areas.

Context

Over the past decades, communication has become a strategic success factor in the implementation of research projects and initiatives [Trench et al., 2014; Trench and Bucchi, 2010; Gascoigne et al., 2010]. In particular, effective outgoing communication is key to enabling the dialogue with the target audiences in the quadruple and quintuple innovation helix framework [Peris-Ortiz et al., 2016] and, via said dialogue, to their engagement with the project.

Despite its still vague definition [Weingart et al., 2021], engagement can be regarded as the state in which stakeholders interact actively with the project itself and its outcomes [Dhanesh, 2017]. High engagement levels may pave the way to: (i) uptake and upscale of the project's results by peers; (ii) attraction of investments for the market entry of the results and their application to society; (iii) implementation of science-based policies favourable to the ecosystem in which the project is set; (iv) acceptance of the research project in particular, and of scientific endeavours in general, by the public and society at large [Holliman et al., 2009; Stocklmayer et al., 2001].

The ability to quantitatively assess the effectiveness of the communication and engagement strategies is therefore crucial [Ziegler et al., 2021; Jensen, 2014; Trench, 2014]. It allows communicators to set concrete and measurable objectives, monitor the progress and evolution of the activities implemented, elaborate corrective action and compare the effectiveness of alternative communication approaches.

To better compare the effectiveness of communication campaigns carried out by different projects, it would be beneficial to use a widely shared approach to quantitively assessing

communication strategies. One example is the ecosystem of EU-funded research projects [European Parliament, 2018].

The European Commission places much emphasis on the assessment of communication strategies in projects [European Commission, 2021]. The ambition and the scale of European science funding programmes set the boundaries of a major research playground on the effectiveness of science communication instruments, tools and strategies [European Commission, Directorate-General for Research and Innovation, 2021; European Commission, 2013]. However, to the best of our knowledge, this EU-funded project ecosystem lags behind what can be found in other ecosystems and markets in that there exists no common approach to assessing how effective such projects are in their communication. Thus, a quantitative estimate and comparison of the projects' communication performance in particular, and of the overall Framework Programmes in general, represents a core challenge in evaluating how projects perform.

Objective

We present a methodology for the quantitative assessment of science communication activities in research projects. The goal is to combine a set of widely used outreach and engagement indicators into an integrated approach. The methodology has been developed for EU-funded research projects but can be easily scaled and applied to research initiatives of diverse scientific scope, geographical area, size, duration and budget. A detailed description of our approach is provided in the next section. An example of application and a discussion of the methodology's strong points and possible future developments are available in the following sections.

The example of application is drawn from two of the 28 EU-funded projects in which we are or have been involved as communication leaders and to which we have applied our methodology[1]. The 28 projects cover a wide range of research topics, scientific ambitions, geographical areas of interest, organisations involved and target stakeholders. The successful application of our approach to all these research initiatives clearly indicates the methodology's flexibility. Moreover, the methodology has been applied repeatedly to each project to monitor communication actions. As communication evolves during the project, with new channels or formats being adopted for example, the repeated applications enabled additional tests of our approach.

[1] Twenty-five of these projects have received funding from the European Union's Horizon 2020 programme (grant agreement number between parentheses): ASTRABAT (875029), BAMBOO (820771), BioMonitor (773297), BuildHeat (680658), CORONADX (101003562), DRIVEMODE (769989), dRural (101017304), EFFECT (737301), EFFECT (817903), eNeuron (957779), eTEACHER (768738), FETFX (824753), HOUSEFUL (776708), MAtchUP (774477), POCITYF (864400), PROTON (699824), REMOURBAN (646511), SKIN (728055), SocialRES (837758), STARDUST (774094), TExTOUR (101004687), TIGON (957769), ULISES (899708), URBAN GreenUP (730426), WADI (689239). The three other projects are Allthings.bioPRO, B-Ferst and BioCannDo, which have received funding from the Bio Based Industries Joint Undertaking (JU) under grant agreement N° 887070, 837583 and 720732, respectively. The JU receives support from the European Union's Horizon 2020 Research and Innovation Programme and the bio Based Industries Consortium. Fondazione ICONS has participated in the following projects as member of the youris.com EEIG: BioCannDo, BuildHeat, EFFECT (737301), PROTON, REMOURBAN, SKIN, WADI.

Methods

Our methodology is based on continuous monitoring of: (i) the distribution of a project's content; and (ii) the engagement mechanisms of all project communication activities, across all the channels considered. This activity tracks the number of visualisations of and interactions with a project's content.
Visualisations and interactions are then used to define a number of dedicated outreach and engagement indicators, respectively:

- **Outreach indicators:** they assess the size of the audience reached by the content conveyed with the aim of strengthening target stakeholders' awareness. Outreach indicators are basic indices that on their own do not provide a complete picture of a project's communication effectiveness. They rather serve as a starting point for further analysis.
- **Engagement indicators:** they help understand how effective a project's content is in generating interest and boosting acceptance from target stakeholders. Engagement metrics measure if and how stakeholders engage with the content, via e. g. online interactions. They are a quite powerful tool for assessing the effectiveness of the communication campaigns performed.

We establish outreach and engagement indicators over the following complementary areas, see definitions in Table 1:

- project websites;
- project social media channels;
- communication products, such as press releases, articles, interviews, videos etc., hereafter generically referred to as "publications";
- events, such as webinars, workshops and conferences;
- other, covering contents or actions that cannot be categorised otherwise. Examples are printed materials such as flyers and brochures, project newsletters, participation in events not organised by the project etc.

Individually, outreach and engagement indicators are insufficient to draw robust conclusions on the effectiveness of the communication campaigns implemented. Outreach indicators only offer an estimate of the audience reached, with little or no information about actual interest in the content or action. At the same time, engagement indicators should be analysed in conjunction with outreach indicators to provide a more precise picture of the level of interest generated. For these reasons, a composite engagement index is defined for each area as the ratio between the corresponding engagement and outreach indicators. For example, the Website Engagement Index (WEI) is calculated as: $WEI = ew/ow$, where ow and ew are the website outreach and engagement indicators, respectively (see Table 1). The indices for the other areas — Social media Engagement Index (SEI), Publication Engagement Index (PEI), Event Engagement Index (EEI) and Other Engagement Index (OEI) — are defined in a similar fashion.

Table 1: Outreach and engagement indicators defined for the five areas covering typical communication activities carried out by research projects. Indicators are presented as aggregated quantities but can also be calculated for individual or a subset of websites, social media channels, publications, events etc. For the sake of simplicity, the notation adopted does not explicit the indicators' time dependence. As for the website engagement indicator, we considered a page view duration of more than one minute as indicative of the reader's engagement with the content. In the "Other" areas, ov_q and oi_q should be calculated with an ad-hoc approach based on the specific nature of the considered content or action q.

Area	Outreach indicator	Engagement indicator
Websites	$ow = \sum_{n=1}^{N} pv_n$	$ew = \sum_{n=1}^{N} pvm_n$
	Where: • N = number of websites managed by the project. • pv_n= total number of page views achieved by website n. • pvm_n= total number of page views which lasted at least 1 minute and were achieved by website n.	
Social media	$osm = \sum_{m=1}^{M} pim_m$	$esm = \sum_{m=1}^{M} pin_m$
	Where: • M = number of social media channels managed by the project. • pim_m = total number of impressions achieved by the posts on social media channel m. • pin_m = total number of interactions (profile following, clicks on link, comments, mentions, likes, sharing) achieved by the posts on social media channel m.	
Publications	$op = \sum_{k=1}^{K}\left(\sum_{n=1}^{N} pv_{n,k} + \sum_{m=1}^{M} pim_{m,k} + \sum_{i=1}^{I} pve_{i,k}\right)$	$ep = \sum_{k=1}^{K}\left(\sum_{n=1}^{N} pls_{n,k} + \sum_{m=1}^{M} pin_{m,k} + \sum_{i=1}^{I} pie_{i,k}\right)$
	Where: • K = number of publications released by the project. • N = number of websites managed by the project on which publications are published. • M = number of social media channels managed by the project on which publications are promoted. • I = number of external online platforms where publications are published	

<table>
<tr><td></td><td colspan="2">(e. g. news aggregators, online magazines…).
• $pv_{n,k}$= page views achieved by publication k on website n (equal to 0 for those k not published on n).
• $pim_{m,k}$ = impressions achieved by all posts promoting publication k on the social media channel m (equal to 0 for those k not promoted on m).
• $pve_{i,k}$ = views achieved by publication k on the external online platform i (equal to 0 for those k not published on i).
• $pls_{n,k}$= page likes and social media shares achieved by publication k on website n (equal to 0 for those n not offering such features).
• $pin_{m,k}$= interactions (clicks on link, comments, external mentions, likes, sharing) achieved by posts promoting publication k on the social media channel m.
• $pie_{i,k}$= interactions achieved by publication k on the external platform i, including spontaneous uptakes or mentions. The types of interactions depend on the specific platform i.</td></tr>
<tr><td>Events</td><td>$eo = \sum_{p=1}^{P} evr_p$</td><td>$ee = \sum_{p=1}^{P} evp_p$
Where:
• P = number of events organised by the project.
• evr_p = number of individuals registered to event p.
• evp_p= number of actual participants to event p.</td></tr>
<tr><td>Other</td><td>$oo = \sum_{q=1}^{Q} ov_q$</td><td>$oe = \sum_{q=1}^{Q} oi_q$
Where:
• Q = number of communication contents or actions not covered by one of the previous areas.
• ov_q = number of views, impressions etc. achieved by content or action q.
• oi_q = number of interactions achieved by content or action q.</td></tr>
</table>

The engagement indices are expressed as percentage values, similarly to the penetration rates reported in market analyses. They can be segmented in multiple ways to estimate the communication effectiveness in specific areas, as needed. For example, the PEI can be calculated separately for each communication format to enable comparisons within the same area. Similarly, the SEI can be determined for specific subsets of the created social media posts (e. g. posts featuring publications or promoting project events) or for each social media channel (thus enabling a comparison of the project's performance on e. g. Twitter vs LinkedIn).

To integrate all communication activities into one single metric, we developed the Community Engagement Index CEI:

$$CEI = \frac{Total\ engagement}{Total\ outreach}$$

The total engagement (outreach) value is calculated by adding together the engagement (outreach) values computed for the individual indicators in Table 1. When calculating the CEI, the values of the addends must be corrected to avoid double counting. For example, op and ow overlap partially (see Table 1), as publications are also published on the project's websites. Hence, without due corrections, the publications visualised would be counted with the website page views as well.

The CEI represents the level of interest generated by the project considering its overall community and all areas and actions. It measures the engagement of a community with the content created and it can be used as a metric to compare the results achieved by different projects.

A target CEI value can be set at the beginning of the project. However, the true importance of the CEI mainly lies in the comparison with the CEI values calculated for other benchmark projects, rather than on the value obtained for a single, specific project. When focusing on the absolute performance of given project (hence, not its relative performance in comparison to other projects), the activity segmentation presented above in this section and the related metrics are the main tools of interest.

Example of application

We present the application of our methodology to the EFFECT and FETFX projects[2] together (hereafter: the project). The project aimed at enhancing the visibility and impact on society of EU-funded research on Future and Emerging Technologies (FET) [European Commission, Future and Emerging Technologies] and at stimulating collaboration among FET stakeholders. This was done via a number of actions, such as a rich production of communication materials featuring FET research projects, social media activity and organisation of events.

The following subsections provide a concise description of the analyses performed and the results achieved in four of the five areas shown in Table 1. Activities in the fifth area (Other) are not relevant for this example and are not discussed here. This is also due to the fact that this type of activity strongly depends upon the nature of the project in question. However, by following the examples that we provide for the other areas, the development of ad-hoc outreach and engagement indicators for such activities should be straightforward to the interested reader.

[2] EFFECT and FETFX received funding from the European Union's Horizon 2020 FET Programme under grant agreement No. 737301 and No. 824753, respectively. EFFECT ran from January 2017 to December 2018. FETFX is the continuation of EFFECT and ran from January 2019 to June 2021. For more information, visit fetfx.eu/about-fetfx-project.

Data set and data retrieval

The project's website is fetfx.eu, where, for example, publications were posted and events promoted. The project had a Twitter profile, a LinkedIn company page and a YouTube channel. We also used the Twitter, Facebook and YouTube profiles of the youris.com media agency for additional promotion of the project's journalistic articles and for some of the audiovisual production.

The subset of the project's publications considered for this paper consists of 30 journalistic articles, 67 press releases, 3 written interviews, 17 video-interviews, 3 video news releases (VNR), 4 web videos and 2 multimedia storytelling publications. For further visibility, publications are distributed to a network of international news aggregators and media outlets (hereafter: news aggregators). The news aggregators considered were: youris.com, AlphaGalileo, Science X, CORDIS and EU Agenda. The project organised 4 webinars and 3 other events, including workshops.

The data used to calculate the outreach and engagement indicators was collected in November 2021 with the tools in Table 2. This table refers to channels directly managed by the project. For external channels, an ad-hoc approach is followed. Outreach and engagement data from posts on project content created by users on external social media channels or platforms are retrieved via a dedicated real-time web-monitoring tool. Statistics from news aggregators are provided by the platforms themselves.

Website

The project website had been browsed by 40,891 users, who opened 60,458 sessions and visited $ow = 116{,}353$ pages. The number of pages visited for more than one minute is $ew = 59{,}039$. Hence, $WEI = 50.7\%$.

Social media

The project's Twitter and LinkedIn profiles were opened in February 2017 and April 2018, respectively. The project created 1,282 posts on Twitter and 214 on LinkedIn. These posts achieved 1,913,291 and 36,160 views, respectively. On Twitter, the project gained 1,549 followers, 2,363 mentions, 3,547 link clicks, 4,149 retweets, 7,421 likes and 188 replies, for a total engagement of 19,217. On LinkedIn, 539 followers, 803 clicks, 220 shares, 726 suggestions and 44 comments, for a total engagement of 2,332. As $osm = 1{,}949{,}451$ and $esm = 21{,}549$, $SEI = 1.1\%$.

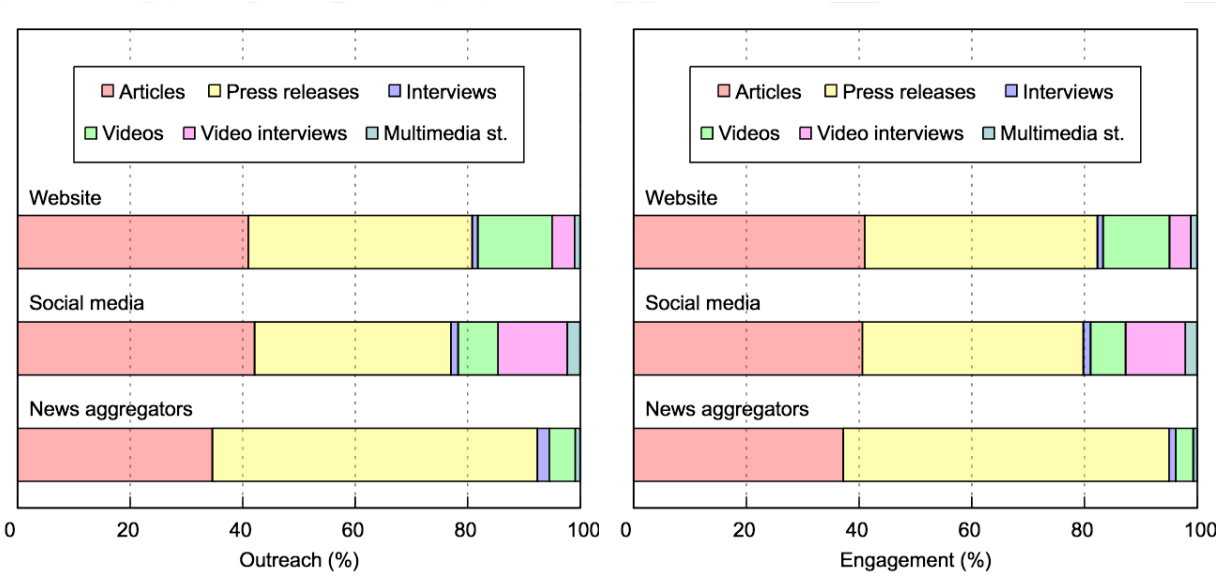
The project performance on the social media considered can be compared by calculating the SEI for each platform individually. This leads to a SEI value of 1.0% and 6.4% on Twitter and LinkedIn, respectively. The results indicate that the project achieved more visualisations on Twitter than on LinkedIn but that the latter saw a more engaged community.

Table 2: Tools used to collect outreach and engagement data for channels and actions directly managed by the project. The area on publications is not reported in the table as the same tools are considered for websites and social media alike. See text for the case of channels not directly managed by the project. For the sake of simplicity, YouTube is listed here among the social media channels. However, for its different nature compared to Twitter and LinkedIn, outreach and engagement data are only used for the area related to publications.

Area	Channel		Outreach tool	Engagement tool
Website	http://www.fetfx.eu/		Google Analytics	
Social media	FETFX	Twitter: @FETFX_EU LinkedIn: company/fetfx YouTube channel: UC3ARjRJE8A02w-YA3jEJV9g	Twitter analytics LinkedIn analytics Facebook analytics YouTube counter	
	youris.com	Twitter: @YourIS_com Facebook: youriscom YouTube: user/youriscom		
Events	Webinars	AdobeConnect GoToWebinar	Analytics from the platform used to manage the event	
	Physical events	n. a.	Registration form	Manual count

Table 3: Aggregated outreach and engagement data retrieved for each format and channel considered for the project's publications. Video interviews have not been distributed to news aggregators and thus achieved no outreach and engagement on such channels.

Format	Channel					
	Website		Social media		News aggregators	
	Outreach	Engagement	Outreach	Engagement	Outreach	Engagement
Articles	11,434	1,216	212,283	4,025	84,932	3,998
Press releases	11,107	1,224	176,085	3,892	142,051	6,223
Interviews	296	31	6,304	130	5,202	129
Videos	3,691	349	36,097	618	11,242	333
Video interviews	1,112	113	61,844	1,045	-	-
Multimedia storytelling	274	33	11,596	212	2,158	77



(a) (b)

Figure 1: Outreach (a) and engagement (b) data collected by the project's publications. The data is aggregated in terms of formats and channels. Video interviews have not been distributed to news aggregators and thus achieved no outreach and engagement on such channels.

Publications

Project publications enable a multi-dimensional analysis of the communication effectiveness. In particular, it is possible to perform investigations as a function of formats and channels.

Table 3 reports the aggregated outreach and engagement data collected by publications for each format and via each communication channel. For the sake of simplicity, we combined web videos and VNRs into the single format "video". A visual representation of the results in Table 3 is available in Figure 1. Here, the data is expressed as percentage values to account for the different number of publications per format.

Table 3 and Figure 1 indicate that, across the channels considered, articles achieved most of their outreach and engagement on the website and social media. On the other hand, press releases achieved better results on news aggregators. This performance variation of a given format across multiple channels underlines how beneficial a multi-channel communication strategy could be for a given project.

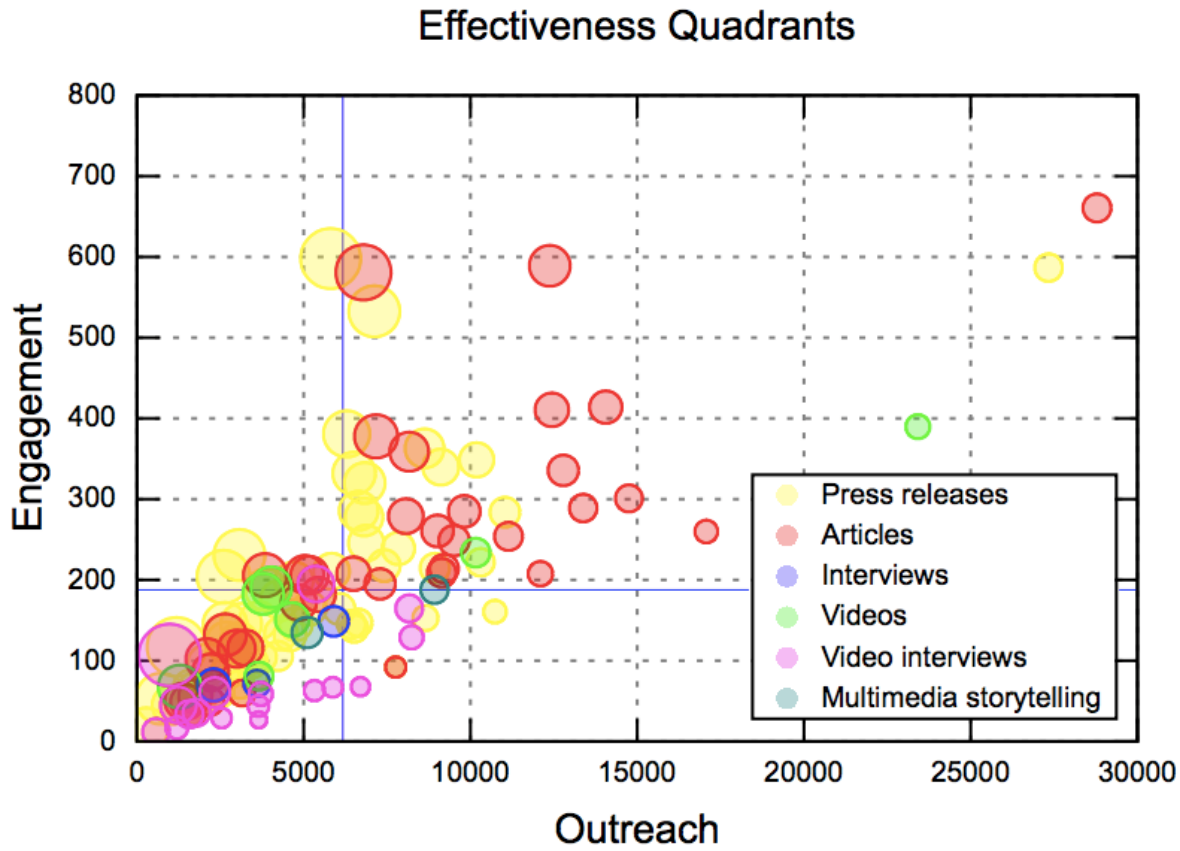


Figure 2: Effectiveness quadrants applied to the analysis of the project's publications. Each bubble corresponds to one publication and is centred at the publication's outreach and engagement values across all channels. The colour of the bubble indicates the format of the corresponding publication. The bubble area is the publication's PEI value. The horizontal and vertical solid lines indicate the distribution's average outreach and engagement values. For the sake of clarity, the plot does not show the distribution outlier — an article with outreach and engagement values of 37,339 and 1,025, respectively.

Communication effectiveness quadrants

In this subsection we introduce the communication effectiveness quadrants. These have been developed by the authors and represent a crucial component of our methodology. The quadrants are a visual, dynamic tool integrating information on outreach, engagement and PEI. Not only do they capture the project performance at a given stage of the project, but also: (i) allow to easily monitor the time evolution of the performance, and (ii) provide indications on possible corrective actions aimed at improving said performance.

We present the quadrants as part of the analysis of publications. However, they can be used to investigate other areas of the project's communication strategy, such as social media posts and events.

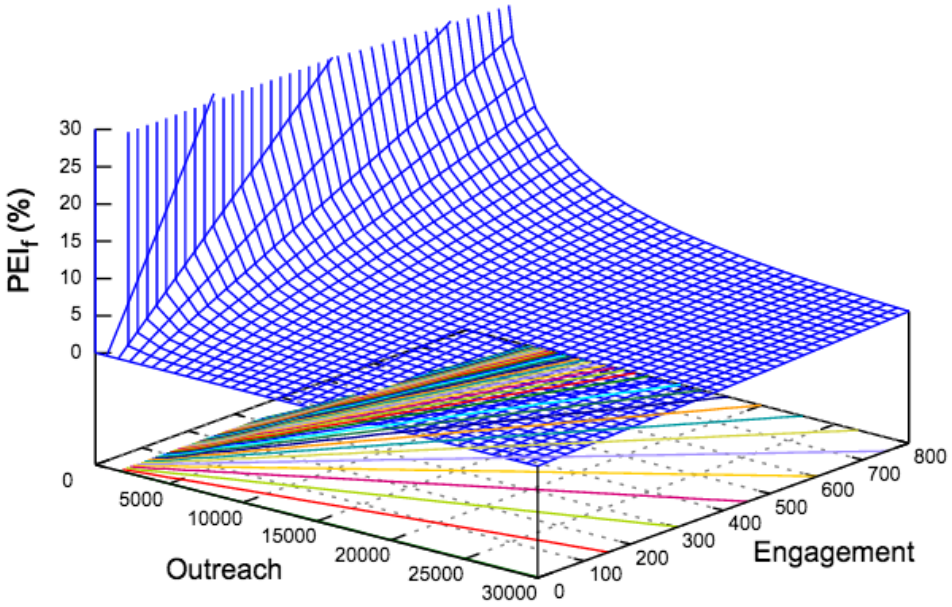


Figure 3: Representation with a 3D grid of the function PEI_f over the subset of its domain on the "outreach vs engagement" plane relevant for the present analysis. The continuous lines on the "outreach vs engagement" plane indicate a set of iso-PEI profiles. Publications distributed on the same iso-PEI profile share an equal bubble size if represented in a plot as in Figure 2. Since PEI_f is defined as the ratio between the engagement and outreach values, the iso-PEI values define straight lines.

The communication effectiveness quadrants established for our methodology are shown in Figure 2. The figure offers a visual representation of the distribution of the publications as a function of their total outreach and engagement. Each product is represented by a bubble. The bubble's colour and area correspond to the publication's format and PEI value, respectively. The plot highlights the publications which achieved the highest outreach and engagement values.

Figure 2 includes all publications considered for this paper. Depending on the analysis needs, it can also be drawn with just specific subsets of the publications (for example, with only some of the formats considered or with the publications posted in a specific time window).

The area of each bubble (i.e., the PEI value) is determined by the coordinates of the corresponding product on the "outreach vs engagement" plane. It is thus useful to define on such a plane the continuous function PEI_f of two real variables as the ratio between the engagement and outreach values. PEI_f helps visualise the variation of the PEI across the "outreach vs engagement" plane, see Figure 3. Note that the definitions of PEI and PEI_f are formally identical. However, the former is calculated on the integer outreach and engagement values retrieved for the project's publications, whereas the latter is a

mathematical object calculated from real and continuous values and which we introduced for illustrative purposes.

The solid vertical and horizontal lines in Figure 2 indicate the distribution's average outreach and engagement values (equal to 6,172 and 188, respectively). The two lines identify the following four quadrants:

1. Above average outreach, above average engagement: "effective" products;
2. Above average outreach, below average engagement: "reaching" products;
3. Below average outreach, above average engagement: "engaging" products;
4. Below average outreach and engagement: "neutral" products.

As the two lines cross at the average outreach and engagement values, all quadrants are populated by some elements of the distribution. In particular, recently posted publications tend to populate the "neutral" quadrant. This is due to the shorter time since posting and the consequently lower (compared to the rest of the distribution) outreach and engagement values.

In Figure 2, the "effective", "engaging", "reaching" and "neutral" quadrants are populated by 40, 11, 10 and 65 products, respectively. As for the "effective" products, 22 are articles, 16 are press releases and 2 are videos. Articles and press releases correspond to 24% and 53% of all publications. Hence, the result indicates that articles tended to achieve higher outreach and engagement values than press releases. However, as shown in Figure 2, the format is not the only aspect determining the quadrant a given publication belongs to. Other factors may play an important role, such as the publication's topic, the writing style and the timing. For a given publication of interest, the quadrants may provide valuable indications as to the factors possibly at play.

Alternatively, the two lines identifying the quadrants can be drawn in correspondence with the median (rather than the average) values of the outreach and engagement distributions. This approach can be considered when possible outliers of the distribution lead to ill-representative quadrants.

The calculation of standard deviations and quartiles of the outreach and engagement values can be considered for a more detailed analysis of the distributions. In our case, the standard deviations are equal to approximately $\sigma_O = 5{,}476$ and $\sigma_E = 153$, respectively. We calculate the standard deviation as $\sigma = \sqrt{\sum_{n=1}^{N}(x_i - \bar{x})^2 / N}$, where N is the number of data samples x_i and $\bar{x}$ denotes the mean of the x_i values.

The length of the outreach and engagement intervals over which the publications are distributed are equal to $L_O = 37{,}058$ and $L_E = 1{,}013$. We calculate the length of an interval over which a population is distributed as $L = x_{max} - x_{min}$, where x_{max} and x_{min} are the population's maximum and minimum values. Hence, the length of the outreach (engagement) interval discussed in the text is given by the difference between the highest and lowest outreach (engagement) values collected by the publications considered. As

$\sigma_O/L_O \sim 15\%$ and $\sigma_E/L_E \sim 15\%$, the outreach and engagement distributions share comparable compactness across the publications and formats.

The plot in Figure 2 does not represent the effectiveness of the project's publications compared to other projects. It rather compares and evaluates the effectiveness of the publications within the project itself. Each publication's outreach and engagement values increase over time and at different rates compared to the other elements in the distribution. Hence, over the course of the project, the bubbles move upwards and to the right on the plane, making the whole distribution dynamic.

The effectiveness quadrants enable the analysis of the evolution of the distribution over time. It suffices to draw the plot with updated outreach and engagement data periodically during the project and to compare the said "snapshots". In particular, the analysis of how the distribution evolves over time enables the assessment of those corrective actions (such as dedicated promotional campaigns on social media) that may have been implemented to boost the outreach and engagement values of under-performing publications.

The lines identifying the average outreach and engagement values (and thus the quadrants) also vary over time. However, they do not necessarily drift upwards and to the right on the plane. This is because new publications may be continuously posted. The initially low outreach and engagement values of the new publications introduce a competing effect that tends to decrease the distribution's averages. To a certain extent, which depends on the nature and frequency of the production of new publications, the competition between the two effects limits the drifting of the four quadrants on the "outreach vs engagement" plane over the course of the project. This sort of "stability" of the quadrants facilitates the assessment of the project's performance over time. In fact, a more "stable" configuration of the four quadrants helps compare the distributions of the publications at different project stages.

The population-based analysis we have outlined so far can be deepened further. However, as stated earlier, publications are posted at different times over the course of the project. Consequently, at the time of the analysis, recently posted publications have had less time to achieve visualisations and engagement compared to earlier publications. An approach to compare the publications' performances by accounting for their time inhomogeneity is offered by the PEI calculated for each single product. Table 4 lists the ten publications with the highest PEI values at the time of the present analysis. Three of them populate the "effective" quadrant and eight are press releases. The result indicates that quadrant-driven and PEI-driven comparisons of the publications should be performed together, as they provide complementary insights into the distribution.

Table 5 and Table 6 summarise the performance of the publications in terms of channels and formats. The total values in the two tables are equal and provide an overall PEI value of 3.0%. A visual representation of the results in the tables is available in Figure 4. The analysis highlights the dominant role played by news aggregators (press releases) among the channels (formats) considered for the project's communication.

Table 4: List of the project's ten publications with the highest PEI values at the time of writing. The publications are all available on the project's website fetfx.eu.

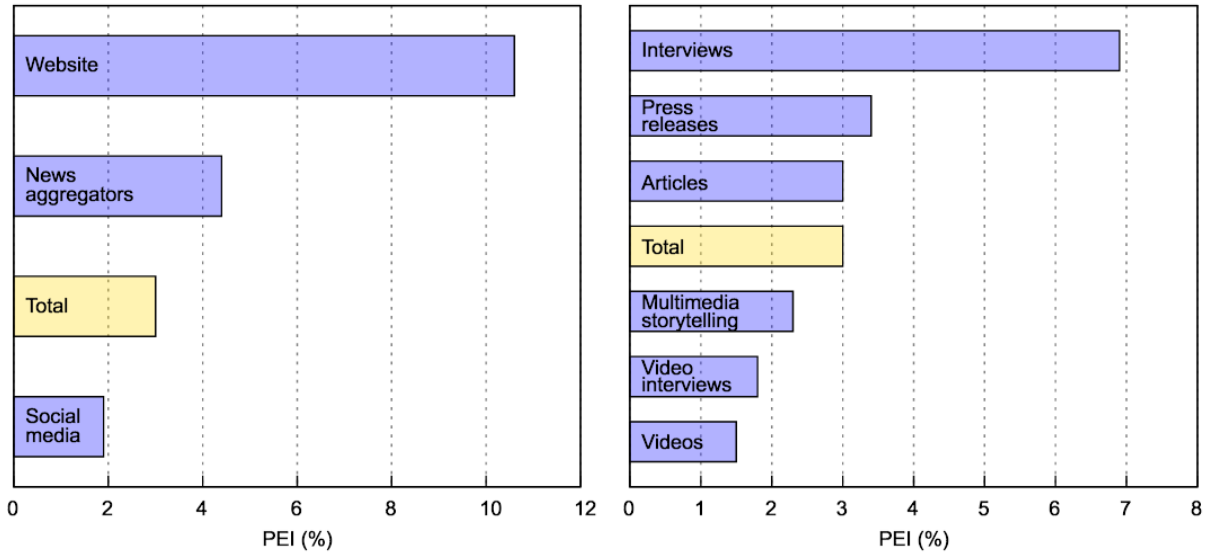
Title	Format	Outreach	Engagement	PEI
FETFX Journalist-in-the-Lab presents: Braincom	Video interview	985	107	10.9%
Processing power beyond Moore's Law	Press release	5,816	598	10.3%
New "quantum sorter" provides information on demand at the atomic scale	Press release	1,192	117	9.8%
Science-based civic projects	Article	6,793	581	8.5%
Creating longer lasting batteries by using Jenga	Press release	2,597	204	7.9%
How to create a virtual world without even trying	Press release	3,082	231	7.5%
Harnessing the power of swarms	Press release	7,122	533	7.5%
A robo-vegetal hybrid society is rising	Press release	729	53	7.3%
Metamaterials lead the way to treatments by travelling through 'innerspace'	Press release	6,290	381	6.1%
Thinking like Peter Parker	Press release	2,646	145	5.5%

Table 5: Aggregated outreach, engagement and PEI values calculated for the project's publications as a function of channels.

Channel	Outreach	Engagement	PEI
Website	27,914	2,967	10.6%
Social media	504,209	9,922	2.0%
News aggregators	245,586	10,760	4.4%
Total	777,708	23,649	3.0%

Table 6*:* Aggregated outreach, engagement and PEI values calculated for the project's publications as a function of formats.

Format	Outreach	Engagement	PEI
Articles	308,649	9,239	3.0%
Press releases	329,243	11,339	3.4%
Interviews	11,802	816	6.9%
Videos	51,030	774	1.5%
Video interviews	62,956	1,158	1.8%
Multimedia storytelling	14,028	322	2.3%
Total	777,708	23,649	3.0%



(a) (b)

Figure 4: PEI values calculated for the project's publications as a function of channels (a) and formats (b). The total value was calculated by using the total outreach and engagement values achieved across all channels and formats.

Events

Total outreach and engagement data for the events organised by the project are available in Table 7. In the table, events are split into two groups: webinars (held online) and workshops and other events (held physically). This separation is due to the fact that online and physical events tend to differ significantly in their scope, organisation and structure. Such differences may strongly affect their outreach and engagement. Thus, it is useful to introduce a specific engagement index for webinars: the Webinar Engagement Index ($WEEI$). This is calculated following the same approach as for the EEI and with the tools in Table 2.
Events in general can easily be assessed by calculating the EEI via the sum of the data of all events regardless of their types (see below in this section).

Areas comparison and CEI calculation

Table 8 compares the outreach, engagement and engagement indices values calculated for the five areas in which the project's communication activities were conducted. The values for the project website and social media differ from those in the previous sections as they have been corrected to avoid double counting with the publications. The table only presents combined event statistics, making no distinction between online and physical events. The table indicates the areas which contributed the most to the project's total outreach and engagement. In particular, it enables the CEI calculation, which quantifies the project's ability to engage its community. The project CEI is equal to 4.1%.

Table 7: Engagement indices calculated for webinars, workshops and other events organised by the project. Webinars were held online, whereas the events in the second row were held physically. For each event type, the total outreach (engagement) is calculated as the sum of the individuals who registered to (attended) the events. The corresponding engagement index is then given by the ratio between total engagement and total outreach.

Type	Number of events	Total outreach	Total engagement	Engagement index
Webinar	4	241	159	66.0% ($WEEI$)
Workshops and other events	3	494	240	48.6% (EEI)

Table 8: Aggregated outreach, engagement and engagement indices calculated on the project's communication activities as a function of the action area. As for events, no distinction was made between online and physical events and combined values are reported.

Area	Outreach	Engagement	Index
Website	94,237	59,039	62.6% (WEI)
Social media	1,524,739	15,692	1.0% (SEI)
Publications	777,708	23,649	3.0% (PEI)
Events	735	399	54% (EEI)
Total	2,397,419	98,779	4.1% (CEI)

Discussion

Our methodology's applicability depends on a number of aspects. A concise discussion of the most relevant factors is presented in this section. We have divided the discussion into three steps: (i) robustness of the adopted indices; (ii) main advantages offered by the methodology; (iii) hints for possible future development.

Robustness of the adopted indices

The methodology we presented is based on a number of indices. The robustness of the said statistics is crucial to enable a solid analysis of the outcomes of the communication strategies and to ensure a wide scope for our approach. Hence, the selection of the most suitable indices was also driven by their need to fulfil the main characteristics of good metrics [Sullivan et al., 2004]:

- Measurable: the metric can be represented numerically and analysed over time to identify trends, best practices and pitfalls.
- Easy-to-understand: the metric can be used by multiple actors, to ensure further use of the analysis results.

- Repeatable: the metric can be used and collected in a consistent way whenever it is needed.
- Available: sources are always accessible and available.
- Timely: the metric is made available whenever a new communication or engagement effort is undertaken.
- Reliable: the metric is drawn from trusted sources in the online analytics world.
- Insightful: the metric provides knowledge about the effectiveness of the communication and engagement effort.

The metrics adopted in this paper have all the above characteristics. However, metrics should also be controllable, i. e. measuring something which is under the control of the individual managing the campaign. In the case of communication and engagement, this is hardly possible. For example, the number of website visits, attendees at an event or social media interactions help assess the action carried out, yet they are not fully controllable. The number of articles written or events organised are controllable, but they are not good indicators of effective action. Possible measures to increase "controllability" include: (i) ensuring high-level quality of the publications and engagement efforts, (ii) analysing the statistical variance of the performed activities to identify best practices and pitfalls (authors, style, publication dates, content, events' features, etc.) and (iii) taking corrective action drawing on a series of communication effectiveness tools.
We also stress the importance of using a highly automated data retrieval process. This is crucial for: (i) reducing human errors in the data collection activity, and (ii) enabling the frequent repetition of the analysis with updated metrics values, which is necessary for monitoring the effectiveness of the communication campaigns and take timely corrective action.

Main advantages

Thanks to: (i) the characteristics of the adopted indices outlined in the previous subsection and (ii) the specific combination of such indices in the approach we described, our methodology presents the following advantages:

- Adoptable by EU-funded research projects: the sharing of a common set of indices would facilitate the quantitative comparison of the communication performances of different projects. Possible benchmarks for project comparisons are research field, funding call, geographical area, project size and budget.
- Flexibility: the methodology is applicable to a variety of fields and initiatives beyond EU-funded research projects. It encompasses typical communication activities and it is based on tools such as Google and social media analytics which are readily available to communicators. Moreover, the application examples we presented in the previous section are just some of the many possible analyses. The statistics can be combined in a variety of ways based on the specific analysis purpose. This is particularly relevant for publications, whose multi-format and multi-channel nature

offers numerous possible investigation approaches. Finally, the methodology can be easily expanded to incorporate additional engagement indices covering communication activities not included in our example of application.

- Integrated and bottom-up approach to the analysis of the collected data: it is possible to quantify the project performance both at an aggregated level (via the CEI) and by focusing on specific aspects (e. g. formats and channels) and actions (e. g. single publication, social media campaign or event organisation and promotion).
- Target setting and benchmarking of the results: communication efforts must align with the project's strategic objectives. The indicators on which our methodology is based can be used at the beginning of the project to set a number of communication targets in terms of outreach and engagement and for the various formats, channels and actions. Over the course of the project, continuous data monitoring and analysis will quantify the progress towards these targets. In particular, they will indicate the possible need for corrective action in the communication strategy (see next point).
- Project performance dashboard: the methodology offers a dynamic description of the project performance over time and a high level of controllability over communication activities, enabling project teams to identify corrective actions where and when required (e. g. via the effectiveness quadrants).

Hints for future development

At the time of writing, we have successfully applied the methodology presented in this paper to 28 European research projects in which we are or have been involved as communication leaders. However, the following aspects should be borne in mind:

- Our methodology focuses on the quantitative assessment of project activities, outputs and outcomes. It does not provide an estimate of a project's intended long-term benefits for society. Moreover, data isn't typically collected – nor therefore monitored – once a project has ended, as funding is no longer available. Hence, our methodology focuses on the communication activities carried out by ongoing projects, not on the long-term results following the project completion. In particular, there may be a correlation between high CEI values and large impacts as calculated in terms of the project strategic objectives, but we currently have no evidence to support this.
- The analysis is impacted by some technical limitations on data retrieval. For example, competing limitations lead to both an over- and underestimation of the outreach data for the case of publications:
    - The overestimation arises from the fact that, currently, website and social media analytics and news aggregators alike provide the amount of visualisation of a given content, but do not differentiate different users. The same users who encounter different content are counted multiple times.

Hence, outreach data is limited to content visualisations rather than audience size or number of users reached.

- The underestimation is due to the fact that not all news aggregators considered for the distribution of publications provide statistics on the visualisation of said products. Although attempts can be made to estimate the visualisations on such aggregators, caution should be exercised when including these estimates in the analysis.
- Another cause of underestimation is the difficulty in tracing project-related online content published by other users in languages different from the main project language (typically, English). Web-monitoring tools may fail to find them as they cannot identify the key words searched when used in other languages.

It is not possible to determine to what extent the competing effects cancel out. However, the adoption of the CEI as key reference statistics limits the impact of such uncertainty. Moreover, these kinds of limitations arise from the currently available technology or restrictions to data access, not from the methodology *per se*, and could be overcome in the future.

- The outreach and engagement indices defined in the previous sections can be further refined. Examples are:
  - Website outreach and engagement values can be differentiated based on page type and content (project description, project resources, news, event promotion…).
  - Our methodology mainly focuses on the calculation of quantitative metrics. Qualitative indicators may be considered as well, such as surveys and sentiment analyses of users' interactions. This would help assess those effects of communication campaigns that can hardly be captured by a fully quantitative approach, such as behavioural and perception changes across target audiences. In particular, capturing such changes could help estimate the long-term impacts of the project that the methodology cannot currently reach, as discussed above.
  - Event outreach and engagement values could be modified to include qualitative (e. g. participants feedback) or quantitative data (e. g. follow-up questions or download of event-related materials). In particular, outreach and engagement values could be re-defined as follows: the former, as the number of people who have come across the information of the event (e. g. by reading the related page on the website, posts on social media or via direct invitation); the latter as the sum of the number of actual attendees to the event and of the aforementioned follow-up questions and download of event-related materials. However, this approach cannot be considered when it is not possible to keep track of the individuals who have received a direct

invitation and to distinguish multiple users on Google and social media analytics.

Conclusions

We presented a methodology for the quantitative assessment of the effectiveness of communication campaigns. The methodology consists of an integrated analysis approach based on the combination of a number of widespread outreach and engagement indicators. The proposed methodology covers all typical areas of communication activities, such as websites, social media, publications and event organisation. In particular, the methodology offers a dynamic overview of the communication performance over time and thus the possibility to design and implement corrective action to boost the effectiveness of specific channels or activities. It draws on a metric and a graphic tool we introduced in this paper — the Community Engagement Index and the Effectiveness quadrants. The methodology we described can be refined further. However, our approach can already be easily taken up by projects, thus enabling the quantitative comparison of the effectiveness of the communication strategies of disparate research initiatives.

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