

# Rethinking altmetrics as process-based indicators: a conceptual framework for construct clarity

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**Abstract:** The Altmetrics Manifesto promised to broaden the notion of impact. However, reliance on citation theory has limited this promise, confining altmetrics to bibliometric principles by treating interactions with scholarly outputs that occur outside the norms and values that rule science through the same lens as citations. This study argues that this constitutes a form of ontological misalignment (*fallacy of reification*), whereby altmetrics are assigned entitative properties when they in fact capture processual aspects of engagement and use that may precede or contribute to societal impact. This misalignment is manifested as use of counts of social media and online interactions with scholarly outputs as direct indicators of societal impact. Aligning ontology and epistemology requires the redefinition of altmetrics as process-based indicators. We describe recent empirical developments applying interaction and networked approaches to translate this perspective into practice. We argue also that calls for production of socially relevant knowledge and increased interest in science communication represent a timely opportunity for use of altmetrics as process-oriented monitoring tools. To study societal impact, we suggest their use in a mixed-methods research design to identify engagement patterns that can be further explored using qualitative methods.

**Keywords:** Science-society interactions, ontological shift, societal impact, engagement, process-based indicators.

## 1. INTRODUCTION

Altmetrics emerged 15 years ago as promising web-based metrics for engagement, use, and impact. They were seen as expanding the scope of what can be measured systematically and what is worth measuring. Expectations about their ability to measure impact in a broader sense beyond journal-based scholarly publishing grew rapidly (Sugimoto et al., 2017). The aim of altmetrics<sup>1</sup> was to “value all research products” and “give a fuller picture of how research products have influenced conversation, thought and behavior” (Piwowar, 2013, p. 159). Although this ambition resonates with subsequent calls for reforms to research assessment<sup>2</sup>, which would acknowledge the diversity of the contributions in science and their impact (Rushforth & Hammarfelt, 2023), the initial promise and expectations surrounding altmetrics have yet to materialize (Wouters et al., 2019).

We argue that these unfulfilled expectations are not due merely to data issues such as heterogeneity, coverage, and persistence or to the absence of standards but rather stem from the lack of a conceptual grounding. As altmetrics accumulate at a rapid pace and broaden narrow indicators of scientific impact, researchers rapidly leap into data analyses translating citation theory to social media, resulting in inconsistent interpretations of its meaning (Haustein, 2016; Wouters et al., 2019). A growing number of recent studies is eschewing bibliometric-based models and their application to social media and advocating for interactive and network approaches to analyze altmetric data. Examples include development of methods to account for the circulation of research beyond academic boundaries (Alperin et al., 2024; Costas et al., 2021), differentiation between types and degrees of engagement (Fang et al., 2022; Haustein et al., 2016), mapping of scientists’ engagement patterns (Robinson-García et al., 2018; Walter et al., 2019) and communication practices (Hare et al., 2024; Mongeon, 2018), clustering users based

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<sup>1</sup> Following Wouters et al. (2019), we use “metrics” to denote both data and indicators.

<sup>2</sup> CoARA: [https://coara.eu/app/uploads/2022/09/2022\\_07\\_19\\_rra\\_agreement\\_final.pdf](https://coara.eu/app/uploads/2022/09/2022_07_19_rra_agreement_final.pdf)

on their social media behavior (Araujo, 2020; Díaz-Faes et al., 2019; Pearce et al., 2014; Yu et al., 2019), and tracing socially relevant topics and misinformation (Shao et al., 2018; Van Schalkwyk et al., 2020). However, despite the merits of such approaches, the conceptual discussion required to underpin any shift in focus is mostly lacking.

The present study aims to fill this gap by advocating for a shift in the conceptualization and application of altmetrics. We argue that a key obstacle to altmetrics realizing their initial promise is the absence of construct clarity, specifically the misalignment between what altmetrics capture (ontology) and how their meaning is interpreted and applied in research practice (epistemology). This arises because altmetrics remain grounded in bibliometric conventions and principles, and apply citation lens to interactions and exchanges that occur outside the norms and values that rule science. To improve construct clarity and position altmetrics as valuable tools to investigate science-society interactions<sup>3</sup>, we suggest they should be conceived as process-based indicators. We build on Thompson's (2011) framework to align ontology and epistemology to achieve construct clarity, and on Rescher's work on process philosophy (2006). Our work is informed also by Haustein et al. (2016), Robinson-García et al. (2018), and Díaz-Faes et al. (2019). The former work addresses the need for specific frameworks, models, and theories to support interpretation of altmetrics. The latter two call for an interactive approach to altmetrics.

Our paper is structured as follows: section 2 discusses the problems involved in applying a bibliometric model to societal impact, and shows that citation theory does not translate well to altmetrics. In this context, section 3 notes the importance of aligning ontology and epistemology and argues that altmetrics research suffers from a *fallacy of reification* (attributing entitative properties to processes). We argue that the shift towards a process view would make altmetrics more effective tools for studying science-society interactions. We also describe the empirical developments in the field in line with this view. Section 4 describes how the policy and evaluation

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<sup>3</sup> Costas et al. (2021) suggest that given the problems related to operationalizing 'society' as a well-bounded category, the distinctions science and non-science could be used as alternatives.

contexts create an opportunity space for use of altmetrics as process-oriented metrics. Section 5 presents the main implications of this study.

## **2. THE NEED TO DEPART FROM CITATION THEORY**

Citations have been discussed in the context of different competing and coexisting theories, mainly normative and constructivist (Moed, 2005). The normative view posits that citations are an institutionalized practice of science that requires scientists to acknowledge the sources and prior work on which they have built upon (Merton, 1973). Citations maintain “intellectual traditions and provide the peer recognition required for the effective working of science as a social activity” (Merton, 1988, p. 621). However, citation behavior is complex and cannot be described unidimensionally (Bornmann & Daniel, 2008; Brooks, 1986).

The constructivist view challenges the normative theory, arguing that citations function as rhetorical devices used to persuade — for example, to convince readers of the novelty or value of one’s findings (Gilbert, 1977) — rather than to reflect intellectual influence. However, as Zuckerman (1987) notes, Gilbert’s (1977, p. 116) notion that some papers are “important and correct”, and therefore used as authoritative references to support authors’ own arguments, is itself grounded in peer recognition and typically manifested in high citation rates, which in turn make those papers authoritative.

Empirical studies on the validity of both approaches to citation show that a normative account fits the data better than the persuasion model (Moed & Garfield, 2004; White, 2004). Besides theories, citing behavior can also be influenced by other factors, such as language biases, target audience, journal status, and the scope, format, or length of the paper (Cronin, 1981; MacRoberts & MacRoberts, 2018), although such biases tend to cancel out at aggregated levels (van Raan, 1998).

Despite the diverse motivations for citing and the presence of distorting factors<sup>4</sup>, it is generally agreed that citations reflect scholarly antecedents of work and serve as indicators of scientific impact (Aksnes et al., 2019; Martin & Irvine, 1983). Thus, one can assume that highly cited papers are generally scientifically relevant, and that citations can therefore be measured linearly and assumed to be positive (Bornmann & Daniel, 2008). However, such a convention cannot be applied to what altmetrics measure.

The altmetrics niche emerged based on the inadequacy of bibliometric indicators and peer review — the traditional filters. The Altmetrics Manifesto describes these indicators as slow, narrow, and closed compared to altmetrics' timeliness, diversity, and openness (Leckert, 2021). Citations have been criticized and described as: “counting measures [that] are useful, but not sufficient (...) influential work may remain uncited. These metrics are narrow; they neglect impact outside the academy and also ignore the context and reasons for citation” (Priem et al., 2010, p. 2). The Altmetrics Manifesto envisioned a change towards a more comprehensive understanding and assessment of science while in practice, the underlying logic does not represent any departure from the traditional filters. Altmetrics research rapidly became focused on counting<sup>5</sup> mentions, shares, and downloads of scholarly outputs in social media as if bibliometric conventions and the scientific ethos (the values and norms governing scientific activity) could be applied beyond the boundaries to academia. This can be seen clearly in the main topics addressed in altmetrics research.

Much of the research on altmetrics has focused on two lines of inquiry. The first examines the relationship between altmetrics and citations (Holmberg et al., 2019; Sugimoto et al., 2017) on the premise that two indicators of impact should be correlated. Since altmetrics accumulate

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<sup>4</sup> The fact that not all citations are critical, and that scientist's reason to cite can go beyond the merits of the work itself highlights the need for contextualized, multidimensional, and well-curated analyses.

<sup>5</sup> Data providers seized the opportunity to provide aggregated indicators such as the *Altmetric Attention Score* which lumps together diverse mentions and interactions not based on any clear criteria (Thelwall, 2021). Critiques of this method seem not to have prevented its application.

faster than citations, it was suggested that altmetrics could be used as predictors of future citations. This led to research that involved counting the number of times scholarly outputs were tweeted, shared on Facebook, or mentioned in blogs and news media to obtain direct indicators of impact. However, the evidence shows that altmetric counts of scholarly outputs are poor predictors of later citations (Costas et al., 2015). A second line explores the use of altmetrics to assess the societal impact of research. Yet, empirical studies show that high altmetric counts are not correlated with peer review assessment of societal impact<sup>6</sup> (Bornmann et al., 2019; Kassab et al., 2020; Ravenscroft et al., 2017). There are two reasons why these findings are not a surprise. First, there are no grounds for a straight relationship between citations and altmetrics since not all relevant scientific research (e.g. blue-sky research) will necessarily lead to societal impact. Second, attention and engagement with science do not necessarily translate into societal impact.

The qualitative assessment methods literature spells out the underlying reasons: the difficulty of linking specific scholarly outputs to observed societal impact (*attribution problem*), the often long time lag between research and its specific impact on society — *temporality issue* — (Spaapen & Van Drooge, 2011), and that societal impact encompasses social, cultural, environmental and economic aspects — *multiple dimensions* (Bornmann, 2013). Although the qualitative approaches to measuring societal impact are diverse and focus on different processes creating value, there is agreement about the need to move from attribution to contribution since societal impact is context-dependent and requires interactions between scientists and stakeholders (Smit & Hessels, 2021). Research with societal impact can take the form of a *product* (e.g. evidence, methods, technology, models), *knowledge use* (i.e. adoption of knowledge by stakeholders), or *benefits* based on its application and use (e.g. changes to practice, awareness, health, economic impact) (Bornmann, 2013; De Jong et al., 2014; Woolley & Molas-

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<sup>6</sup> The exception is Mendeley for which mild-medium correlations are found when compared with peer review scores from the UK Research Excellence Framework (Akella et al., 2021; Thelwall et al., 2023). Still, one can argue that this mainly reflect academic use.

Gallart, 2023). This stream of work offers a new lens allowing better use of altmetric data (Robinson-García et al., 2018).

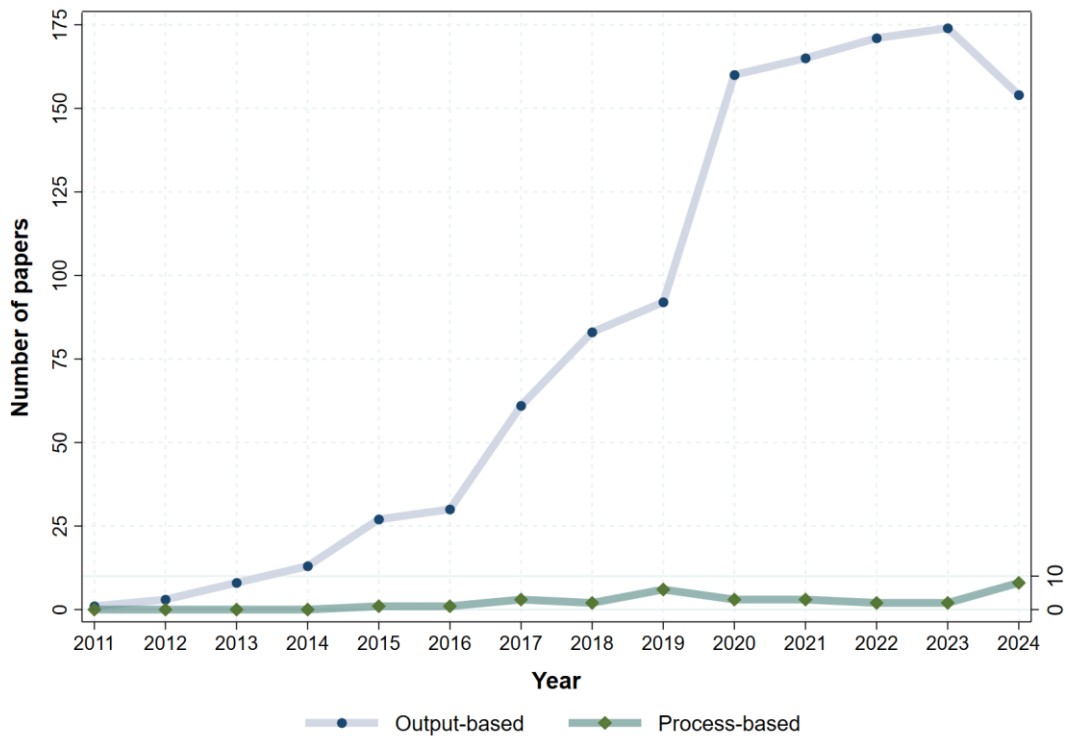
For instance, the SIAMPI approach (Spaapen & Van Drooge, 2011) defines interactions as productive if the knowledge produced is scientifically robust and socially relevant. The authors operationalize this by distinguishing between *direct* (people to people), *indirect* (interaction mediated through a carrier such as scholarly output), and *financial* (research contract, financial contribution) interactions. Another example is Morton's (2015) 'contributions approach' which defines a process view of societal impact based on the notion of *research uptake* (i.e. engagement with research), *research use* (e.g. discussion of, sharing, adaptations to, application of the research to inform policy or action), and *research impact* (research resulting in changes to knowledge, awareness, attitudes, or practice).

Despite the existence of empirical evidence and qualitative assessment methods that demonstrate the inadequacy of applying bibliometric conventions to altmetrics, most altmetrics research continues to do so. To assess the extent of this trend, we queried the Scopus database<sup>7</sup> and retrieved all Altmetric papers (articles and reviews) published between October 2010 — the year of the Altmetrics Manifesto — and 2024. We systematically screened the abstracts, methods, and results sections of each paper to check for any evidence of output or process-based approaches. This resulted in our classifying the studies into one of three groups: *output-based* (counting altmetric data on papers as direct indicators of impact, akin to citations), *process-based* (applying network and interaction approaches to examine patterns of engagement, dissemination, and use), and *other* (e.g. using altmetric data in fields such as digital marketing or education). Figure 1 shows that the vast majority of altmetrics research applies an output-based approach

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<sup>7</sup> (TITLE-ABS-KEY (altmetric\*) OR TITLE-ABS-KEY ("social media metric\*")) AND PUBYEAR > 2010 AND PUBYEAR < 2024 AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "re")) AND (LIMIT-TO (LANGUAGE, "English")). The search query retrieved 1,493 papers. After manual revision, 109 papers that were neither articles nor reviews were removed, resulting in a final sample of 1,392 papers.

(82%), while only 2% of papers adopt a process lens. The remaining 16% corresponds to the use of social media data unrelated to the scope of this study.



**Figure 1.** Time trends in altmetrics research by analytical approach

### 3. IMPROVING CONSTRUCT CLARITY IN ALTMETRICS

#### 3.1. Aligning ontology and epistemology

As explained above, there is no basis for applying bibliometric conventions and citation theory to capture a broader notion of impact. This mismatch is evidence of the need to rethink our understanding and use of altmetrics which demands a better clarification of altmetrics as a construct.

Constructs are conceptual abstractions adopted or invented for a specific scientific purpose (Venkatraman & Grant, 1986). As Suddaby (2010, p. 346) notes: “Clear constructs are simply robust categories that distill phenomena into sharp distinctions that are comprehensible to a community of researchers.” Because construct clarity provides a basis for theory and practice, we argue that it is crucial to align ontology and epistemology so that knowledge generated

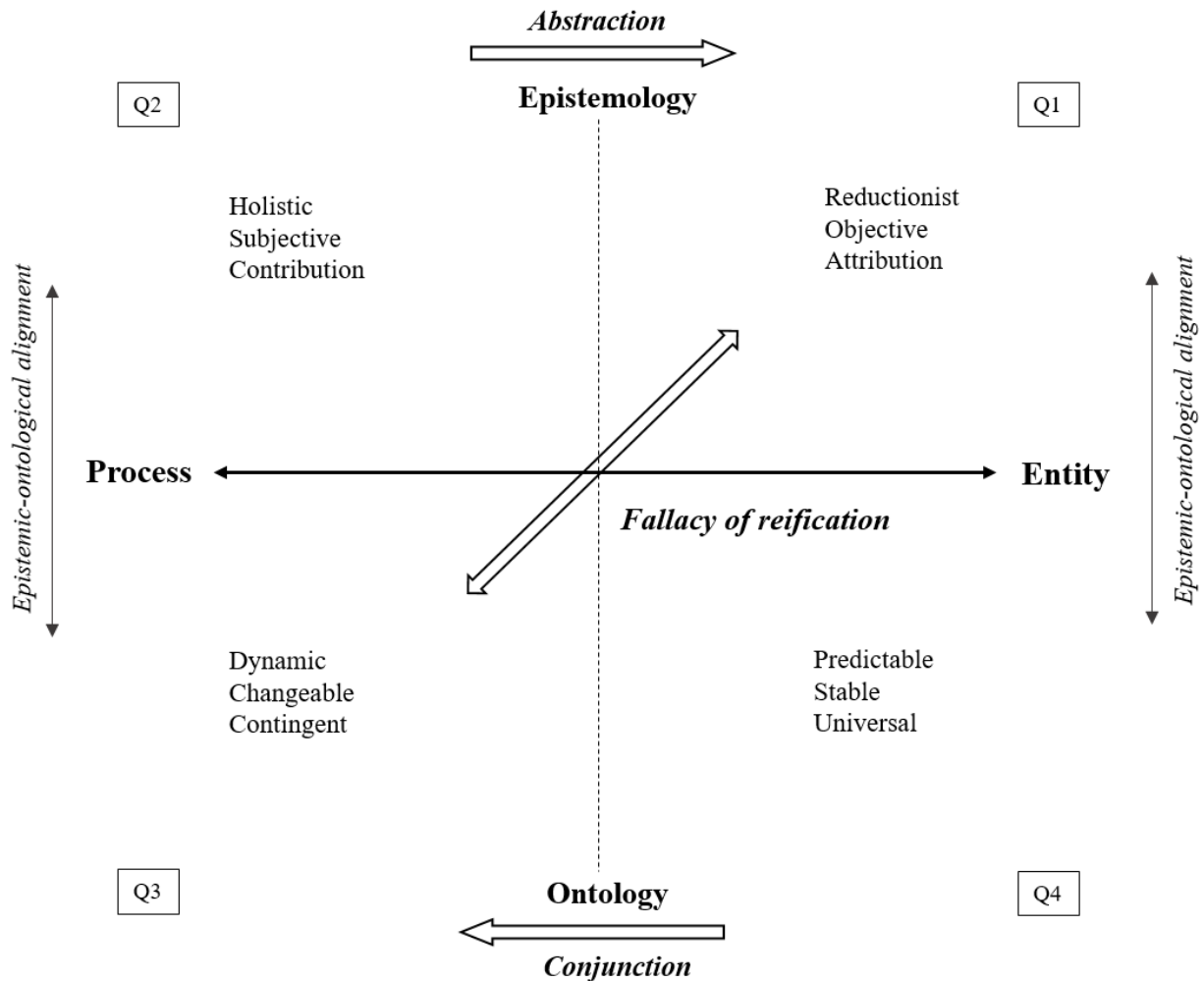


through altmetrics reflects the phenomena altmetrics seeks to observe. Ontology concerns the basic assumptions about the type of things that can exist, their conditions of existence and what counts as relevant objects, entities and processes in a given domain. Epistemology, however, deals with how valid knowledge about these objects, entities and processes can be accessed and generated (Chalmers, 1999; Kilduff et al., 2011).

Our proposed shift from a bibliometric model to a process view draws on Thompson's (2011) framework to provide construct clarity and contrast the classical perspectives that perceive reality as an entity or as a process. An entity lens views reality (in our case altmetrics) as comprising objects with stable properties whose meaning does not change across multiple situations. This applies to how citations are seen in bibliometrics and their consideration as direct indicators of scientific impact. However, a process lens emphasizes that reality is dynamic, emergent, and evolving and that interactions constitute rather than simply modifying reality (Rescher, 2006). Rather than considering *things* (numbers of mentions, shares, or comments to scholarly outputs) as meaningful and indicative by themselves, altmetrics should be about understanding *happenings* (the interaction, engagement with, and use of).

Figure 2 depicts how the misalignment between ontology (top half) and epistemology (bottom half) in altmetrics research leads to ontological drift, specifically the *fallacy of reification*. This fallacy attributes entitative properties to a construct that is more adequately understood as a process (quadrants 1 and 3). Grounded in an entity perspective borrowed from citation theory, altmetrics research treats diverse forms of online engagement and interactions with scholarly outputs as direct indicators of the broader impact of research. That is, there is an assumption that some specific societal impact can be attributed to mentions, comments, shares, downloads, or other forms of engagement and interactions with scholarly outputs. This ontological drift is manifested in the assumption that online engagement with science by diverse stakeholders is mediated by shared norms, values, and epistemic conventions similar to

researchers' citations to scientific work. Thus, it is a form of ontological drift since what altmetrics capture has drifted out of alignment with the appropriate epistemological lens.



- **Fallacy of reification:** an entity view of altmetrics translates citation theory to interactions and exchanges that occur outside the norms and values that rule science
- **Ontological shift (conjunction):** shifting from an entity to a process view of altmetrics to align what altmetrics capture with how their meaning is interpreted and applied in research practice

**Figure 2.** Aligning ontology and epistemology in altmetrics research for construct clarity.

Adapted from Thompson (2011)

Aligning ontology and epistemology becomes feasible if we acknowledge that altmetrics can be more accurately described as metrics that capture the complex processes of interactions between science and society. Following Thompson's (2011) scheme, improving construct clarity in altmetrics research requires an ontological shift, more precisely a *conjunction* that entails shifting from an entity to a more processual understanding of altmetrics as a construct. That is,

addressing the current ontological drift between ontology and epistemology requires moving from quadrants 1 and 3 to quadrants 2 and 3 in order to achieve alignment between the two. In this view, altmetrics are measures of science-society interactions which hint at potential antecedents contributing to societal impact, traceable through exchanges and patterns of engagement on social media and other online platforms where much engagement with science occurs. This shift avoids determinism and acknowledges that societal impact is not a static and discrete event but rather a complex and long-term process requiring a bespoke epistemic lens.

To illustrate the implications of rethinking altmetrics from a process view, Table 1 compares altmetrics as an entity and as a process. This comparison highlights how shifting from a discrete, static, output-based approach to a relational, contextual, and evolving view better captures the complex nature of what altmetrics measure.

**Table 1.** Entity vs process view of altmetrics

	<b>Altmetrics from an entity view</b>	<b>Altmetrics from a process view (proposed shift for construct clarity)</b>
<b>Concept of impact</b>	Borrowed from bibliometrics. Static, discrete events akin to citations	Emerge from complex context-dependent interactions among diverse stakeholders
<b>Measurement focus</b>	Counting interactions with scholarly outputs (e.g., mentions, downloads, shares, commenting)	Science-society interactions: dynamics of engagement and use
<b>Stakeholder involvement</b>	Assumes that engagement holds similar meaning regardless of context and stakeholders	Recognizes that different stakeholders interact in varied, knowledge and context-specific ways
<b>Causality</b>	Linear and deterministic (attribution): counts reflect the societal impact of research and can predict future citations	Nonlinear and relational (contribution): interactions evolve through different pathways and may not lead to societal impact
<b>Criticism</b>	Fallacy of reification: attribution of entitative features to processes	Ambiguity of meaning

Note that we do not suggest the primacy of one view over the other. Rather, we follow and posit a weak priority for process over entity (Rescher, 1996). That is, entities depend on (they are produced and characterized by) processes, as opposed to primacy in which entities are constituted (reducible to) by processes. Thus, the systematic quantitative evidence altmetrics

gathers on interactions and engagement are valuable representations of potential antecedents of the societal impact of research. However, their nature is contingent, changeable, and difficult to attribute directly to specific research endeavors. It follows that the value of altmetrics emerges only if viewed as metrics of the dynamic processes underlying science-society interactions.

### **3.2. Translating a process view into practice**

The ontological shift towards altmetrics as process indicators improves construct clarity. However, construct clarity on its own is not enough; it must be accompanied by construct validity. That is, the empirical instruments need to be able to measure what the construct is supposed to measure (Venkatraman & Grant, 1986). Recent developments in the field that advocate for an interaction and network approach provide a blueprint for implementation of a process view of altmetrics. The intent is not to discuss construct validity in depth but rather to highlight some methodological insights. Table 2 presents three core papers from this perspective to illustrate how the proposed shift would translate into practice. All three understand altmetrics as inherently process-based.

First, Haustein et al. (2016) propose a framework for interpreting altmetrics beyond platform limitations where the unit of analysis is the interactions among actors (individuals, groups, entities) and scholarly outputs. Haustein and colleagues categorize these interactions into three levels of engagement: *access*, *appraisal*, and *application*. Access includes events such as viewing, downloading, and storing an article or scholarly profile; appraisal involves deeper engagement such as commenting on social media or citing a work in a policy document; application is the highest level of engagement and involves use, adaptation, or transformation of scholarly outputs (e.g. applying theory or methods from a scientific article, exploiting a scholarly output for commercial purposes, or a collaboration among stakeholders to create something new). Second, Costas et al. (2021) extend the existing bibliographic coupling and co-citation models to the online environment to trace the network structure of a broad range of science-society

interactions. They propose multiple ways to define nodes and ties based on co-occurrence of events. Third, inspired by qualitative assessment methods (Smit & Hessels, 2021), Robinson-García et al. (2018) suggest that altmetrics should adopt a case study approach. Using a network approach, they contend altmetrics can be used to map “the context in which engagement among researchers and stakeholders take place” (Robinson-García et al., 2018, p. 821) and provide information on the potential contributions to societal impact.

**Table 2.** Empirical developments aligned to a process view of altmetrics

Method		Alignment with altmetrics as process metrics
Haustein et al. (2016)	Tracing research objects events: scholarly outputs for which stakeholder engagement can be traced (various stages: access, appraise, apply)	Altmetrics as online events to account for engagement patterns
Costas et al. (2021)	“Heterogeneous couplings”: measurement of the science-society interactions in multiple relational directions	Altmetrics capture the fluid couplings between scientific and societal entities
Robinson-García et al. (2018)	Case study approach: network analysis to examine the context in which engagement occur	Altmetrics to map dynamic, processual networks of engagement

It follows that more contextualized and tailored research designs are needed. Framing altmetrics as case studies as suggested by Robinson-García et al. (2018) is consistent with Haustein (2019, p. 740) claim that altmetrics hold potential beyond “counts and correlations, offering insights into *what, how, when, where*, and by *whom* scholarly outputs are shared and used”. Case studies can be approached from a *critical, interpretative, or positivist* perspective (Crowe et al., 2011). The critical and interpretative perspectives are a better fit with a process view of altmetrics. Critical case studies would examine the assumptions underlying the impact, uptake, and use of science while an interpretative lens would examine the context of the interactions and engagement, and the perceived meanings of the interactions<sup>8</sup>. A positivist approach aimed at generalizable inferences is not aligned to a process view of altmetrics.

<sup>8</sup> Liberatore et al. (2018) distinguish among 5 levels of social media engagement (core, active, occasional, peripheral, transactional) to assess participation in citizen science programs.

To study societal impact, we call for the integration of altmetrics as process measures within mixed-methods research designs where altmetrics critical and interpretative case studies can be used to identify potential antecedents of societal impact that can be examined in more depth using qualitative methods to identify their true meaning. This type of research design requires highly curated datasets and rich contextual information to account for context-specific characteristics of the platform (affordances), the topic (general vs. specific), and stakeholders' characteristics (e.g. predominant types of users, sociodemographic distribution). The ecosystem is wide and ranges from social networking sites, blogs, and wikis, to social news aggregators, and online photo and video sharing<sup>9</sup> platforms. The empirical developments discussed are not exhaustive, but they offer useful guidance for future endeavors. While altmetrics as process indicators inevitably make replicability more challenging, they also mitigate concerns about the heterogeneity of altmetrics and the trivial nature of many interactions with science (Haustein, 2016; Robinson-Garcia et al., 2017). They emphasize that the interest lies in identifying relevant patterns rather than assuming that all interactions carry the same meaning. In other words, the heterogeneity of altmetrics and the differences in meaning are intrinsic features, not problems that need to be solved.

Similar logic applies to scientists' interactions on social media. The fact that such interactions may often include self-promotion or limited engagement beyond peers (Peng et al., 2025) takes on a different significance under a process view. Research designs where altmetrics are integrated within critical and interpretative case studies allows for a more nuanced understanding in users' identity performances and self-presentation (Goffman, 1959). Bowman (2018) analyses of U.S. faculty shows that academics use Twitter in diverse ways — professional, personal or hybrid — illustrating that scientists adopt different roles depending on audience and context.

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<sup>9</sup> See Orduña-Malea & Lopezosa (2024) to exploit Twitch for the study of science-society interactions.

## **4. THE OPPORTUNITY SPACE: ALTMETRICS AS PROCESS METRICS**

Aligning ontology and epistemology should provide more robust foundations and a clear direction for future altmetrics research. However, beyond construct clarity and construct validity we must consider whether the context support the proposed shift (Thompson, 2011). This would seem to question whether framing altmetrics as process metrics fits the policy and evaluation contexts. This section discusses two changes in science that create an opportunity space for altmetrics, reconstituted as process metrics, to contribute. These changes include the call for production of socially relevant knowledge, and the evolution of the science communication model.

### **4.1. Calls for socially relevant knowledge**

The development of scientific knowledge used to be the exclusive domain of highly specialized scientists, based on the premise that expanding the knowledge frontier would inherently benefit society (Kilduff et al., 2011). However, the perspective on how to ensure benefits to society has changed (Aagaard et al., 2022; Bornmann, 2013) and increasingly funding bodies are requiring transdisciplinary research and research conducted in the context of its application (Gibbons et al., 1994), involvement of stakeholders and beneficiaries (Beck et al., 2022; Norström et al., 2020), and a focus on tackling pressing societal problems (Larrue, 2021). This has a clear implication for research evaluation and requires estimation of how stakeholders interact, value, and use knowledge to assess the relevance of the knowledge produced (Morton, 2015; Woolley & Molas-Gallart, 2023).

Social media and collaborative science platforms have further accelerated concerns about the production of socially relevant knowledge, and have increased visibility and engagement with research among diverse societal stakeholders from policymakers to the public (Bornmann, 2014). Similar to how in the wake of the institutionalization of research evaluation in the 1990s, bibliometric indicators became tools to support peer review (Rinia et al., 1998); the monitoring

of socially relevant knowledge requires new tools to measure broader notions of impact<sup>10</sup> (European Commission et al., 2017; Rafols et al., 2024). Since many activities and interactions with science are digital, altmetrics research adopting a process view can provide information on interactions, exchanges, dialogues, and the ways that different stakeholders engage with and use research knowledge.

Note also that the greater openness rhetoric which underpins claims of production of socially relevant knowledge triggers some important challenges (Mirowski, 2018). For instance, preprints make scientific work available faster and foster critique and uptake of new ideas but also facilitate the diffusion of unverified and methodologically flawed research (see Caulfield et al., 2021 for the COVID-19 case). Also, current open access is more a profitable business for a few commercial publishers than a way to provide societal access to science (Butler et al., 2023). Use of altmetrics as process indicators allows us to examine whether open access is achieving its goals or reinforcing inequalities and hampering diversity.

#### **4.2. The science communication model(s)**

Besides the greater expectations about scientific work bringing value to society, scientists are increasingly being encouraged by funders and their institutions to take a more active role in communicating science and establishing a dialogue with public audiences (NASEM, 2017; Weingart, 2017). As a result of digitalization, open access, and the rise of social media, science communication can no longer be understood as a linear and top-down process (deficit model) in which scientists generate new knowledge, science journalists operate as brokers, and the public passively consumes the information (Bucchi, 2017; Scheufele, 2014). This transformation of the science-society interface has democratized content creation and dissemination and paved the way

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<sup>10</sup> Concern over the “gamification” of societal impact measures as has happened with citations is well-founded (Holmberg et al., 2019). However, these arguments are related more to reform of the science reward system, research culture, and responsible use of indicators than total avoidance of quantitative data (Balboa et al., 2024). Peer review as a quality control mechanism is subject to bias (Horrobin, 1990), and qualitative assessments can lack objectivity and be hindered by time and resource constraints (Bornmann, 2013).



to dialogue, participatory, and co-creation models (Trench, 2008). However, it raises questions about how general audiences can identify reliable scientific information and how science communication can foster a shared understanding of scientific findings and support a dialogue to enact societal change. Robust socially relevant knowledge does not arise simply from scientific evidence but is spawned by continual interaction and conversation between fact-finding and meaning-making (Jasanoff, 2010).

Although the science, technology and innovation community has so far paid little attention to science communication, recent studies show, for example, the utility of a network perspective and content analysis for unraveling the communities involved in anti-vaccine movements (Van Schalkwyk et al., 2020), and scientists' engagement in the climate change debate (Walter et al., 2019). Likewise, science communication outputs — press releases, news items — are being analyzed quantitatively and becoming relevant to understanding online science communication (Groves et al., 2015; Orduña-Malea & Costas, 2023). Thus, altmetrics have the potential to monitor aspects related to the science communication processes. They can be relevant for policy to foster more informed and meaningful online interactions with science (i.e. diminish the effects of misinformation, fake news, and uncritical use of sources) (Díaz-Faes, 2023).

## **5. CONCLUDING REMARKS**

This study contributes to overcoming the seclusion of data-driven research in quantitative science studies (Rafols, 2019) by addressing the need for a conceptual framework in altmetrics research. Since construct clarity is crucial for theory and practice (Suddaby, 2010), we examine the misalignment between what altmetrics measure and how their meaning is interpreted and applied in practice. We also discuss construct validity to provide a basis for translating a shift towards viewing altmetrics as process-based metrics into research practice.

The Altmetrics Manifesto promised a change by expanding the notion of impact. However, the conceptual lens underpinning altmetrics research has remained grounded in the principles of

bibliometrics. We argue that altmetrics research uncritically borrowed citation theory, treating interactions and exchanges on social media and online platforms as if they were similar to those mediated by the norms and values ruling scientific work. This leads to the underlying assumption that scientific and societal impact are somehow equivalent, despite the fact that the latter is context dependent and difficult to attribute to specific scholarly outputs. This has resulted in a form of ontological misalignment (fallacy of reification) in which altmetrics are assigned entitative properties as if they directly indicate societal impact, rather than recognizing that they capture processual aspects of engagement that may precede or contribute to societal impact. We have suggested that aligning ontology and epistemology requires a redefinition of altmetrics as process indicators.

This shift is supported by the policy and evaluation context which needs quantitative evidence to provide information on the complex and pluralistic interactions and exchanges related to the potential antecedents of societal impact and science communication dynamics (Rushforth & Hammarfelt, 2023; Science Europe, 2022). Bornmann & Leydesdorff (2014) note that altmetrics are in a similar emerging state to that of bibliometric indicators in the 1970s. It could be argued that as a field, we are still navigating the development of a toolbox of methods for altmetrics while having embarked on this phase with no consensus on altmetrics as a construct. In developing altmetrics as process-based indicators to support assessment of societal impact, we suggest a mixed-method approach, in which process altmetrics adapt to and account for each platform's specific characteristics and affordances in order to hint at relevant science-society interactions and engagement patterns that can be explored further qualitatively.

### **Author contributions**

AADF: Conceptualization, Data curation, Investigation, Formal Analysis, Methodology, Visualization, Funding acquisition, Writing-original draft, Writing-review & editing

ZH: Investigation, Data curation, Formal analysis, Writing-review & editing

## Competing interests

The authors have no competing interests to disclose.

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