1 **"As-you-go" instead of "after-the-fact": A network**

2 **approach to scholarly communication and evaluation**

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12 **Abstract:** Scholarly research faces threats to its sustainability on multiple domains (access,
13 incentives, reproducibility, inclusivity). We argue that "after-the-fact" research papers do not
14 help and actually cause some of these threats because the chronology of the research cycle is
15 lost in a research paper. We propose to give up the academic paper and propose a digitally
16 native "as-you-go" alternative. In this design, modules of research outputs are communicated
17 along the way and are directly linked to each other to form a network of outputs that can
18 facilitate research evaluation. This embeds chronology in the design of scholarly
19 communication and facilitates recognition of more diverse outputs that go beyond the paper
20 (e.g., code, materials). Moreover, using network analysis to investigate the relations between
21 linked outputs could help align evaluation tools with evaluation questions. We illustrate how
22 such a modular "as-you-go" design of scholarly communication could be structured and how
23 network indicators could be computed to assist in the evaluation process, with specific use
24 cases for funders, universities, and individual researchers.
25
26 **Keywords:** evaluation; network; communication; paper; metaresearch; decentralization;
27 decentralisation; publishing
28

1. Introduction

30   Scholarly research faces threats to its sustainability and has been said to face a
31 reproducibility crisis [1] amongst other pernicious problems such as access and exclusivity.
32 The underlying cause might be the way we have collectively designed the reporting and
33 rewarding of research (implicitly or explicitly). The current scholarly communication system
34 is primarily organized around researchers who publish static (digital) research papers in
35 scholarly journals. Many of these journals have artificial page limits (in the digital age),
36 which leads to artificial scarcity and subsequently increases the perceived prestige of such a
37 journal due to high rejection rates (71% on average for APA journals in 2016;
38 perma.cc/Q7AT-RN5C). Furthermore, scholarly communication has become highly
39 centralized, where over 50% of all papers are published by as little as five publishers (over
40 70% for social sciences) [2]. Centralization has introduced knowledge discrimination, as
41 publishers are able to influence who can access scholarly knowledge, what gets published,
42 and allows for other single points of failure to arise with their own consequences (e.g.,
43 censorship; perma.cc/HDX8-DJ8F). In order to have a sustainable scholarly research system,
44 we consider it necessary to implement changes that provide progress on multiple of these
45 threats at once instead of addressing them individually.
46   Systems design directly affects what the system and the people who use it can do;
47 scholarly communication still retains an analog based design affecting the effectivity of the
48 spread and production of knowledge dissemination (see also [3]). Researchers and
49 institutions are evaluated on where and how much papers they publish (as a form of prestige).
50 For example, an oft-used measure of quality is the Journal Impact Factor (JIF) [4]. The JIF
51 is also frequently used to evaluate the 'quality' of individual papers under the assumption

52 that a high impact factor predicts the success of individual papers (this assumption has been
53 debunked many times) [5–7]. Many other performance indicators in the current system (e.g.,
54 citation counts and h-indices) resort to generic bean counting. Inadequate evaluation
55 measures leave universities, individual researchers, and funders (amongst others) in the dark
56 with respect to the substantive questions they might have about the produced scholarly
57 knowledge. Additionally, work that is not aptly captured by the authorship of papers is likely
58 to receive less recognition (e.g., writing software code) due to reward systems counting
59 publications instead of contributions (see also perma.cc/MUH7-VCA9). It is unfeasible that
60 a paper-based approach to scholarly communication can escape the consequences of paper's
61 limitations.

62   A scholarly communication system is supposed to serve five functions, but can do so
63 in a narrow sense as it currently does, or in a wider sense. These functions of the scholarly
64 communication system are (1) registration-, (2) certification-, (3) awareness-, and (4)
65 archival [8], and (5) incentives [9]. A narrow fulfillment of for example the registration
66 function would mean that findings that are published are registered, but not all findings are
67 registered (e.g., due to selective publication; [10]). Similarly, certification is supposed to
68 occur through peer review, but peer review can exacerbate human biases in the assessment
69 of quality (e.g., statistical significance increasing the perceived quality of methods; [11]).

70   We propose an alternative design for scholarly communication based on modular
71 research outputs with direct links between subsequent modules, forming a network. Whereas
72 a paper-based approach communicates after a whole research cycle is completed, modular
73 communication was proposed two decades ago [9,12–16]. These modules could be similar
74 to sections of a research paper, but extend to modular research outputs such as software or
75 materials. We propose to implement this modular communication on an "as-you-go" basis
76 and include direct links to indicate provenance. This respects the chronological nature of
77 research cycles and decreases the possibility for pernicious problems such as selective
78 publication and making predictions after results are known (HARKing) [17].

79   With a network structure between modules of knowledge, we can go beyond citations
80 and facilitate different questions about single- or collectives of knowledge. For example, how
81 central is a single module in the larger network? Or: How densely interconnected is this
82 collective of knowledge modules? A network could facilitate question-driven evaluation
83 where an indicator needs to be operationalized per question, instead of indicators that have
84 become a goal in themselves and become invalidated by clear cheating behaviors [18,19]. As
85 such, we propose to make evaluation of research its own research process with question
86 formulation, operationalizations, and data collection (i.e., constructing the network of
87 interest).

88 **2. Network structure**
89   Research outputs are typically research papers, which report on at least one research
90 cycle after it has occurred. The communicative design of papers embeds hindsight and its
91 biases in the reporting of results by being inherently reconstructive. Moreover, this design

92   eliminates the verification of the chronology within a paper. On the other hand, the paper
93   encompasses so much that citations to other papers can indicate a tangent or a crucial link.
94   Additionally, the paper is a bottleneck for what is communicated: It cannot properly deal
95   with code, data, materials, etc.
96   When stages of research are communicated separately and as they occur, it changes
97   the communicative design to eliminate hindsight and allows more types of outputs to be
98   communicated as separate modules. For example, a theory can be communicated first and
99   hypotheses communicated second, as a direct descendant of the theory. Subsequently, a study
100 design can be linked as a direct descendant of the hypotheses, materials as a direct descendant
101 of the design, and so on. This would allow for the incorporation of materials, data, and
102 analysis code (amongst others). In this structure, many modules could link to a single module
103 (e.g., replication causes many data modules to connect to the same hypotheses module) but
104 one module can also link to many other modules (e.g., when hypotheses follow from multiple
105 theories or when a meta-analytic module is linked to many results modules).

106   Figure 1 shows two simple examples of how these different modular research outputs
107 (i.e., modules) would directly connect to each other. The connection between these modules
108 only shows the direct descendance and could still include citations to other pieces of
109 information. For example, a discussion module could be a direct descendant of a results
110 module and could still include citations to other relevant findings. When one research cycle
111 ends, a new one can link to the last module, continuing the chain of descendance.
112 Incorporating the direct descendancy of these knowledge modules builds a different kind of
113 network than citation and authorship networks. As such, this network would be an addition
114 to these already existing citation and authorship networks; it does not seek to replace them.
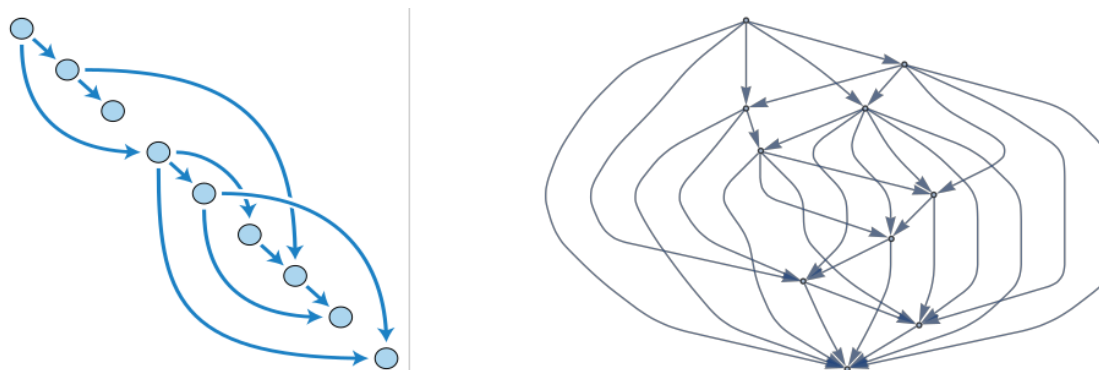

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Figure 1. Two Directed Acyclic Graphs (DAGs) of connected research stages. The ordering
is chronological (top-bottom) and therefore modules that are situated below one another
cannot refer upwards. Panel A shows a less complex network of modules; Panel B shows a
more extensive network of modules.

120   Given that these modular outputs would be communicated as they occur, chronology
121 is directly embedded in the communication process with many added benefits. For example,
122 preregistration of hypotheses tries to ensure that predictions precede observations, which
123 would be embedded with modular communication where predictions are communicated

124   when they are made [20]. Moreover, if modular outputs are communicated as they are
125   produced, selective reporting (i.e., publication bias) is reduced by having already
126   communicated the data before results are generated.

127   With immutable append-only registers, the chronology and content integrity of these
128   outputs can be ensured and preserved over time. This can occur efficiently and elegantly with
129   the Dat protocol (without a blockchain; perma.cc/GC8X-VQ4K). In short, the Dat protocol
130   is a peer-to-peer protocol (i.e., decentralized and openly accessible) that provides non-
131   adjustable timestamps to each change that occurs within a folder, which is given a permanent
132   unique address on the peer-to-peer Web (36^64 addresses possible) [21]. The full details,
133   implications, and potential implementations of this protocol for scholarly communication fall
134   outside of the scope of this paper (an extended technical explanation of the application of the
135   Dat protocol can be found here https://dat-com-chris.hashbase.io).

136   A continuous and network based communication system could take a wider
137   interpretation of the scholarly functions it is supposed to serve [8,9]. Registration would
138   become more complete, because selective publication based on results is preempted by
139   embedding communication before any results are known. Certification is improved by
140   embedding the chronology of a research cycle into the communication of research, ensuring
141   that predictions precede results [20]. Awareness is improved by using open by design
142   principles, whereas awareness is now limited by financial means to access scholarly papers
143   [22]. Archival would not only be simplified with peer-to-peer protocols, but also allows
144   anyone to create a copy and could result in excessive redundancy under the Lots Of Copies
145   Keeps Stuff Safe principle [23]. In the next sections, we extend on how incentives could be
146   adjusted in such a network structure, to facilitate both the evaluation of research(ers) and the
147   planning of research.

148   **3. Indicators**
149   With a chronological ordering of various modular research outputs and their parent relations,
150   a directional adjacency matrix can be extracted for network analysis. Table 1 shows the
151   directional adjacency matrix for Figure 1. Parent modules (i.e., modules) must precede the
152   child modules in time, therefore only $\frac{J(J-1)}{2}$ of cells of the adjacency matrix are filled in,
153   where J is the number of research modules.
154

155 **Table 1.** Directional adjacency matrix for Figure 1. modules are ordered according to time
156 (top-bottom in Figure 1). Rows indicate the source module, columns indicate the target
157 module.

	node01	node02	node03	node04	node05	node06	node07	node08	node09
node01	-	1	0	1	0	0	0	0	0
node02	-	-	1	0	0	0	1	0	0
node03	-	-	-	0	0	0	0	0	0
node04	-	-	-	-	1	1	0	0	1
node05	-	-	-	-	-	0	0	1	1
node06	-	-	-	-	-	-	1	0	0
node07	-	-	-	-	-	-	-	1	0
node08	-	-	-	-	-	-	-	-	0
node09	-	-	-	-	-	-	-	-	-

158

159 With a directional adjacency matrix, countless network indicators can be calculated
160 that could be useful in research evaluation depending on the questions asked. However, not
161 all network indicators are directly applicable because a time based component is included in
162 the network (i.e., new outputs cannot refer to even newer outputs). Below, we propose some
163 basic network indicators for evaluating past and future research outputs.

164 Networks indicators could be used to evaluate the network as it exists now or how it
165 developed in the past (i.e., backward-looking evaluation). For example, in-degree centrality
166 could be used to identify highly interconnected modules of information. This measure
167 indicates how many child modules are spawned by a parent module and indicates how much
168 new work a researcher's output stimulates (e.g., module04 in Table 1 would have an in-
169 degree centrality of three). To contextualize this, a data module could spawn four results
170 modules, hence has an in-degree centrality of four. This measure would look only at one-
171 generation of child modules, but other measures extend this to incorporate multiple
172 generations of child modules. Katz centrality extends this and computes the centrality over
173 N generations of child modules [24] whereas traditional in-degree centrality calculates
174 centrality for $N = 1$ generations. For example, two data modules that each spawn five results
175 modules would have the same in-degree centrality, but could have different Katz centrality
176 if only one of those two networks has a third-generation of modules included. If multi-
177 generation indicators are relevant, Katz centrality measures could provide operationalizations
178 of such measures.

179 Another set of network indicators could be used to evaluate how the network would
180 change when new modules are added in the future (i.e., forward-looking evaluation). For
181 example, a researcher who is looking for ways to increase the density in their own network,
182 could ask the question "If I would add one module that has k parents, which addition would
183 increase the density the most?" Subsequently, the researcher could inspect the identified

184 connections for inspiration and feasibility. Complexity of the new module could be increased
185 by increasing the number of parent modules to connect (k in the question; e.g., five instead
186 of two). Potentially, this could facilitate creative thinking, where k is gradually increased
187 over time to increase the complexity of the issue from a network perspective.

188 The indicators we highlighted here are simple proposals. Other indicators from
189 network analysis and graph theory could be applied to the study of knowledge development
190 when a network structure is available and we hope to see suggestions to answer questions
191 about the network. These kinds of analyses are already done within citation networks (e.g.,
192 [25]) and authorship networks (e.g., [26]), but we cannot do so with the provenance or
193 planning of knowledge generation in the current scholarly communication system.

194 **4. Use cases**

195 We describe three use cases of network based evaluation to contextualize the ideas
196 proposed above. For each use case, we first provide a general and non-exhaustive overview
197 of the possibilities with network based evaluation. Subsequently, we specify a scenario for
198 that use case, how an evaluation question flows from that scenario, how an indicator to
199 answer that question could be operationalized, and how that indicator could inform the
200 evaluation process. With these use cases we hope to illustrate that network based evaluation
201 could align better with the implicit evaluation criteria already present in common research
202 evaluation scenarios.

203 *3.1 Funders*

204 Funders of scholarly research often have specific aims when distributing their
205 financial resources amongst researchers. Funders often use generic "one size fits all"
206 indicators to evaluate the quality of researchers and research (e.g., JIF, h-index, citation
207 counts). Given that funding calls often have specific aims, these funding calls could be used
208 as the basis of research evaluation if we move beyond these generic measures.
209 A scenario could exist where a funding agency wants to fund researchers to extend an existing
210 and interconnected research line. This is not an implausible scenario, where funding agencies
211 aim to fund several million dollars (or similar in other currencies) in order to increase follow
212 through in research lines. A specific example might be the Dutch national funding agency
213 "Vici" funding scheme, which aims to fund "senior researchers who have successfully
214 demonstrated the ability to develop their own innovative lines of research"
215 (https://perma.cc/GB83-RE4J).

216 Whether researchers who submitted proposals actually built a connected research line
217 could be evaluated by looking at how interconnected each researcher's personal network of
218 modules is. Let us assume that a research line here would mean that new research efforts
219 interconnect with previous efforts by that same researcher (i.e., building on previous work).
220 Additionally, we could assume that building a research line means that the research line
221 becomes more present in the network over the years. Building a research line thus could be
222 reformulated into questions about the network of directly linked output and its development
223 over time.

224   Operationalizing the concept 'research line' as increased interconnectedness of
225   modules over time, we could compute the network density per year. One way of computing
226   density would be to tally the number of links and divide them by the number of possible
227   links. By taking snapshots of the network of outputs of that researcher in for example the last
228   five years on January 1st, we could compute an indicator to inform us about the development
229   of the researcher's network of outputs.

230   The development of network density over time could help inform the evaluation, but
231   one measure could hardly be deemed the only decision criterion. As such, it only provides an
232   indication as to whether an applicant aligns with the aim of the funding agency. Other
233   questions would still need to be answered by the evaluation committee. For example, is the
234   project feasible or does the proposal extend the previous research line? Some of these other
235   questions could also be seen as questions about the future development of the network and
236   serve as their own questions to investigate the applicant on.

237   *3.2 Universities*
238   Universities can use research evaluation for the internal allocation of resources and
239   to hire new scientists. As such, a research group within a university could apply network
240   analysis to assess how (dis)connected a group's modules are or how their group compares to
241   similar groups at other institutions. Using network indicators, it could become possible to
242   assess whether a job applicant fulfills certain criteria, such as whether their modules connect
243   to existing modules of a group. If a university wants to stimulate more diversity in research
244   background, network analysis could also be used to identify those who are further removed
245   from the current researchers at the institution. Considering that universities are often
246   evaluated on the same generic indicators as individual researchers (e.g., JIF) in the rankings,
247   such new and more precise evaluation tools might also help specify university goals.
248   Extending the scenario above, imagine a research group that is looking to hire an assistant
249   professor with the aim of increasing connectivity between the group's members. The head of
250   the research group made this her personal goal in order to facilitate more information
251   exchange and collaborative potential within the group. By making increasing connectivity
252   within the group an explicit aim of the hiring process, it can be incorporated into the
253   evaluation process.

254   In order to achieve the increased connectivity within the research group, the head of
255   the research group wants to evaluate applicants relatively but also with an absolute standard.
256   Relative evaluation could facilitate applicant selection, but absolute evaluation could
257   facilitate insight into whether any applicant is sufficient to begin with. In other words, relative
258   evaluation here asks which is the best applicant, whereas absolute evaluation asks whether
259   the best applicant is good enough. These decision criteria could be preregistered in order to
260   ensure a fair selection process.

261   Increased connectivity could be computed as a difference measure of the research
262   group's network density with and without the applicant. In order to take into account the
263   number of produced modules, the computed density could take into account the number of

264 modules of an applicant. Moreover, the head stipulates that the minimum increase in network
265 density needs to be five percentage points. To evaluate applicants, each gets a score that is
266 made up of the difference between the current network density and the network density if
267 they were hired. For example, baseline connectivity within a group might be 60%, hence, the
268 network density has to be at least 65% for one of the applicants to pass the evaluation
269 criterium.

270 If the head of the research group relied purely on the increase in network density as
271 an indicator without further evaluation, a hire that decreases morale in the research group
272 could easily be made. For example, it is reasonable to assume that critics of a research group
273 often link research outputs in a criticism of their work. If such a person would apply for a job
274 within that group, the density within the network might be increased but subsequently result
275 in a more hostile work climate. Without evaluating the content of the applicant that increases
276 the network density, it would be difficult to assess whether they would actually increase
277 information exchange and collaborative potential instead of stifling it.

278 *3.3 Individuals*
279 Individual researchers could use networks to better understand their research outputs
280 and plan new research efforts. For example, simply visualizing a network of outputs could
281 prove a useful tool for researchers to view relationships between their outputs from a different
282 perspective. Researchers looking for new research opportunities could also use network
283 analysis to identify their strengths, by comparing whether specific sets of outputs are more
284 central than others in a larger network. For example, a researcher who writes software for
285 their research might find that their software is more central in a larger network than their
286 theoretical work, which could indicate a fruitful specialization.
287 One scenario where network evaluation tools could be valuable for individual researchers is
288 resource allocation needs to be optimized. A researcher might want to revisit previous work
289 and conduct a replication, but only has funds for one such replication. Imagine a researcher
290 wants to identify an effect that they previously studied and which has been central to their
291 new research efforts. Identifying which effect to replicate is intended by this researcher as a
292 safeguard mechanism to prevent further investment in new studies, if a fundamental finding
293 proves to not be replicable.

294 In this resource allocation scenario, the researcher aims to identify the most central
295 finding in a network. The researcher has conducted many studies throughout their career and
296 does not want to identify the most central finding in the entire network of outputs over the
297 years, but only of the most recent domain they've been working in. As such, the researcher
298 takes the latest output and traces all the preceding outputs automatically to five generations,
299 to create a subset of the full network and to incorporate potential work not done by
300 themselves.

301 Subsequently, by computing the Katz centrality of the resulting subnetwork, the
302 researcher can compute the number of outputs generated by a finding and how many outputs
303 those outputs generated in return. By assigning this value to each module in the network, the

304 researcher can identify the most central modules. However, these modules need to be
305 investigated subsequently in order to see whether they are findings or something else (e.g.,
306 theory; we assume an agnostic infrastructure that does not classify modules).

307 Katz centrality can be a useful measure to identify which finding to replicate in a
308 multi-generational network, but would fail to take into account what replications have already
309 been conducted. When taking the most recent output and looking at its parent(s),
310 grandparent(s), etc., this only looks at the lineage of the finding. However, the children of all
311 these parents are not taken into account in such a trace. As such, the researcher in our scenario
312 might identify an important piece of research to replicate, but neglect that it has already been
313 replicated. Without further inspection of the network for already available replications,
314 resource allocation might be suboptimal after all.

315 **4. Discussion**

316 We propose to communicate research in modular "as-you-go" outputs (e.g., theory
317 followed by hypotheses, etc.) instead of large "after-the-fact" papers. Modular
318 communication opens up the possibility of a network of knowledge to come into existence
319 when these pieces are linked (e.g., results descend from data). This network of knowledge
320 would be supplementary to traditional citation networks and could facilitate new evaluation
321 tools that are based in the question of interest rather than generic "one size fits all" indicators
322 (e.g., Journal Impact Factor, citation counts, number of publications). Given the countless
323 questions and operationalizations possible to evaluate research in a network of knowledge,
324 we hope this would increase the focus on indicators as a tool in the evaluation process instead
325 of indicators being the evaluation process itself [27,28].

326 We highlighted a few use cases and potential indicators for funders, research
327 collectives, and individuals, but recognize that we are merely scratching the surface of
328 possible use cases and implementations of network analysis in research evaluation. The use
329 cases presented for the various target groups (e.g., universities) can readily be transferred to
330 suit other target groups (e.g., individuals). Award committees might use critical path analysis
331 or network stability analysis to identify key hubs in a network to recognize. Moreover,
332 services could be built to harness the information available in a network to identify people
333 who could be approached for collaborations or to facilitate the ease with which such network
334 analyses can be conducted. Future work could investigate more use cases, qualitatively
335 identify what researchers (or others) would like to know from such networks, and how
336 existing network analysis methods could be harnessed to evaluate research and better
337 understand its development over time. Despite our enthusiasm for network based evaluation,
338 we also recognize the need for exploring the potential negative sides of this approach.
339 Proximity effects might increase bias towards people already embedded in a network and
340 might exacerbate inequalities already present. Researchers might also find ways to game
341 these indicators, which warrants further investigation.

342 Communicating scholarly research in modular "as-you-go" outputs might also
343 address other threats to research sustainability. In modular "as-you-go" communication,

344 selective publication based on results would be reduced because data would be
345 communicated before results are known. Similarly, adjusting predictions after results are
346 known would be reduced because predictions would be communicated before data are
347 available (i.e., preregistration by design). Replications (or reanalyses) would be encouraged
348 both for the replicated (the replicated module gets more child modules, increasing its
349 centrality) and the replicator (time investment is lower due to only having to add a data
350 module that is linked to the materials module of the replicated). Self-plagiarism could be
351 reduced by not forcing researchers to rehash the same theory across papers that spawn various
352 predictions and studies. These various issues (amongst other out of scope issues) could be
353 addressed jointly instead of each issue vying for importance for researchers, funders, or
354 policy makers (amongst others).

355   To encourage culture- and behavioral change, "after-the-fact" papers and modular
356 "as-you-go" outputs could co-exist (initially) and would not require researchers to make a
357 zero-sum decision. Copyright is often transferred to publishers upon publication (resulting in
358 pay-to-access), but only after a legal contract is signed. Hence, preprints cannot legally be
359 restricted by publishers when they precede a copyright transfer agreement. However,
360 preprints face institutional and social opposition [29], where preprinting could exclude a
361 manuscript for publication depending on editorial policies or due to fears of non-publication
362 or scooping (itself a result of hypercompetition). In recent years, preprints have become more
363 widely accepted and less likely to exclude manuscript publication (e.g., Science accepts
364 preprinted manuscripts) [30]. Similarly, sharing modular "as-you-go" outputs could not
365 legally be restricted by publishers and can ride the wave of preprint acceptance, but might
366 also face institutional or social counterchange similar to preprints. Researchers could
367 communicate "as-they-go" and compile "after-the-fact" papers, facilitating co-existence and
368 minimizing negative effects on career opportunities. Additionally, "as-you-go" modules
369 could be used in any scholarly field where the provenance of information is important to
370 findings and is not restricted to empirical and hypothesis driven research per se.

371   As far as we know, modular "as-you-go" scholarly communication infrastructure that
372 includes direct links between modules has not yet been available to researchers in a
373 sustainable way. One of the few thought styles that has facilitated "as-you-go" reporting in
374 the past decade is that of Open Notebook Science (ONS) [31], where researchers share their
375 day-to-day notes and thoughts. However, ONS has remained on the fringes of the Open
376 Science thought style and has not matured, limiting its usefulness and uptake. For example,
377 ONS increases user control because communication occurs on personal domains, but does
378 not have a mechanism of preserving the content. Considering reference rot occurs in seven
379 out of ten scholarly papers containing Weblinks [32], concern for sustainable ONS is
380 warranted without further development of content integrity. Moreover, ONS increases
381 information output without providing more possibilities of discovering that content.

382   Digital infrastructure that facilitates "as-you-go" scholarly communication is now
383 feasible and sustainable. Feasible because the peer-to-peer protocol Dat provides stable

addresses for versioned content and it ensures content integrity across those versions. Sustainable because preservation in a peer-to-peer network is relatively trivial (inherent redundancy, anyone can rehost information and libraries could be persistent hosters) and removes (or at least reduces) the need for centralized services in scholarly communication. Consequently, this decreases the need for inefficient server farms of centralized services [33] by decentralizing services. However, preservation is a social process that requires commitment. Hence, a peer-to-peer infrastructure would require committed and persistent peers (e.g., libraries) to make sure content is preserved. Another form of sustainability is knowledge inclusion, which is facilitated by a decentralized network protocol that is openly accessible.

Finally, we would like to note that communication was not instantly revolutionized by the printing press but changed society over the centuries that followed. The Web has only been around since 1991 and its effect on society is already pervasive, but far from over. We hope that individuals who want change do not despair by feelings of inertia in scholarly communication throughout recent years and further entrenching of positions and interests. We remain optimistic for substantial change to occur within scholarly communication that improves the way we communicate research and hope these ideas contribute in working towards that.

5. Conclusion

The current scholarly communication system based on research papers is "after-the-fact" and can be supplemented by a modular "as-you-go" based communication system. By doing so, the functions of a scholarly communication system can be interpreted more widely, making registration complete, certification part of the process instead of just the judgment of peers, access to everything for everyone based on peer-to-peer protocols, simplify archival, and facilitate incentive structures that could align researcher's interests with that of scholarly research.

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