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Scientific publication process and its impact on growth of science

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Scientific publications are important for researchers to learn about earlier research in an area and also communicate their own research work. It helps the scholar and the publisher to achieve greater visibility to their research and to the reader to learn about an author's work. This paper reports the scientific publication process and reviews the existing literature on scholarly communication and evaluation. The concept of "*stakeholders circle methodology*" has been adopted to draw a generalised approach for visualising research impact. In this study, scientific publication process has been divided into two stages: pre-and post-publication. Both these stages have significant impact on the publication process, from communication to dissemination. In the pre-publication stage, various components such as creation (for novelty and integrity), evaluation (for generality and quality), and publishing (for copyright and cost) are discussed. In the post-publication stage, the outcomes (publications, patents and citations) hold significance, particularly in measuring research impact for greater visibility, promotion, rank and reputation.

Keywords: *Research publication; Publication process; Creativity; Evaluation; Publication; Impact*

Introduction

Scientific research is a systematic approach to reporting of advanced knowledge. In the 17th century, scientists circulated their research ideas, observations and experiments among peers through personal letters, anagram (which functioned as a sort of interim publication), etc. to staking out priority of discovery while retaining sole use[1]. In the mid-17th century, Henry Oldenburg, the First Secretary of the Royal Society proposed to verify and disseminate discoveries in science under the auspices of the Royal Society of England. As a result, the *Philosophical Transactions of Royal Society*, world's first scientific journal came into existence in 1665 with four fundamental principles: registration, verification, dissemination and archiving[2]. This was a truly decisive moment in the history of publication. It paved the way for a formal model of journal publication. "Since then, the structure of scientific work has respected the basic paradigms of introduction, methods, results and discussion"[3].

In the 19th century, leading universities of Europe, mainly in Britain and Germany, along with teaching, began to give equal weightage to scientific research[4]. Today, institutions around the world are promoting superior research ecosystems by setting up new labs, new incubation and innovation hubs, attracting fresh talent and providing freedom to their scientists to share scholarly research. Thus, scientific publication has been recognised as an indicator of achievement of the scientists and researchers for sharing their research work and promotion of novel ideas[5]. Scientific publication holds a stamp of validity. It helps in building reputation of scientists and their institutions. It is further evaluated for originality, authenticity, integrity and quality. As a result, scientific publications impact individual and institutional visibility and reputation.

This study reviews the structure of scientific publication process. Primarily, the structure of the publication process is designed to make input-output acts impact scientific research[6]. There are three versions (preprint, postprint and published) seen in the publication process[7]. In this process, pre-and post-publication actions also perform key roles to bring out value-based research inflow and outcome. In this study, pre-publication stage covers preprint to post-print, and further on to publication components like creation depicting novelty and integrity, evaluation for originality and quality, and publishing for copyright and cost. In the post-publication process, research outputs (publications, patents and their citations) become principal indicators of scientific impact, helpful for measuring visibility, recognition and reputation[8].

Review of literature

Research is crucial to survival in the academia[9]. It is an expression of creativity, publication in journals being a vehicle for that expression. Publications report new results which help scholars and institutions to be cited, ranked and to create reputation for themselves. Over a span of 350 years, scholarly journals have been serving the research community to disseminate and verify discoveries in science[10]. Scientific curiosity promotes creative thinking, supersedes rote learning and leads to writing, communication and publication of research papers[11]. A research publication is a product of research outcome and involves many dimensions.

Several studies have focused on the techniques and methodology of writing and publishing scientific research papers[12-13]. Scholars are constantly reading research papers of reputed journals, but they do not necessarily publish in the same journals. Scientific misconduct is one of the issues, in most cases, it is related to the nature of the respective science, scientist and the publication[14]. Young researchers commit scientific fraud mainly for two reasons: inadequate knowledge of internal policies of the respective institutions, and aspiration for early professional reputation[15]. Plenty of literature exists on scientific and economic conduct that involves high academic and ethical standards, making allowance for honest errors and correcting them for posterity[16-17]. However, adherence to norms, rules, policies and procedures promotes science and provides a promising foundation for building character with scientific integrity[18].

It is now universally accepted that a fair evaluation is the most important part of research publication process; it is an important filter for validating the content for all generality, quality and reliability. Such fair evaluation is carried out by a process of peer-review, which has been practiced as an unbiased method of evaluation. Peer-review process has many versions, starting with Galen's primordial form, followed by several structured forms developed mostly in the 18th century. For instance, the editor of *Physical Review* had shown Einstein's paper to another specialist before printing it[19-20]. There have been instances of peer-review scams[21]; still, the double-blind review process is being followed by many reputable journals.

Advanced techniques involving modern computing tools, including Artificial intelligence (AI) help the editors to track manuscripts, identify and communicate with authors and reviewers, and reduce the duration of peer-review process by almost 30% without increasing the pool of reviewers[22]. As a result, the review process has become more objective, thoughtful, open, transparent and collaborative, validating research outcomes, even after publication[23].

Scientific publications are considered to be standardised and creative, qualifying as copyrightable works[24]. A study entitled, "Whose copy? Whose rights?" describes the process and licenses of Creative Commons (CC) in agreements reached among authors and publishers[25]. Open access (OA) has grown in prominence[26]. Today, a good volume of scientific literature is available on OA platforms. The OA is realised easily, when authors retain copyright to most of their research, granting journal publishers only a non-exclusive license to publish. Further, the OA is playing a very significant role in decision-making for economic incentives, appointments, promotions, and award of grants[27]. Very often, publishers cover publishing costs, which is broadly categorised under two models: 'reader-pays model' and 'author-side pays model'[28]. In OA publishing process, Article Processing Charge (APC) has become experimental and confrontational in publishing industry[29].

Scientific impact is another metric which is central to the publication process. It is calculated through research, production and citations using various metrics, including bibliometrics and article-level-metrics[30]. Several studies[31-32] have elucidated the history, merits and drawbacks of the system of journal impact factor (JIF). In spite of several controversies, impact factors have immensely helped in quantifying and promoting research impact and visibility. Research funding is another factor governing the formulation of research policies and increasing research productivity of both individuals and institutions[33]. It is also helping them gain visibility, rank and reputation.

Stakeholders in the publication process

Research methodology refers to the underlying logic of any research. It is closely linked to the research structure and its process of implementation. In this study, a concept of 'stakeholders circle methodology'[34] is adopted to draw an extrapolated approach relating to scholarly publication process[35]. Stakeholders (scholars-content creators, publishers-content producers, and readers-content consumers) constitute the foundation of any publication process and hold dependent relationships with each other[36].

"Stakeholders are identified as individuals or institutions who are impacted by or can impact the work or its outcomes"[37]. Based on this methodology, the stakeholders and their relationships in the publication process are developed and is shown in Figure 1.

Publication structure and its impact

The publication process has three versions: preprint, postprint and the published version. The preprint and postprint versions are considered as input versions and the published version is the final output of the research article:

- Preprint (author's initial version): a manuscript submitted to the editor to consider for publication.
- Postprint (author's final version): a manuscript accepted for publication.
- Published (published version): a manuscript published in the publisher's format.

Components of publication structure

The publication structure has three components: creation, evaluation and publishing.

Creation: novelty and integrity

Creativity is an art of producing a new set of knowledge. It constitutes the essence of research[38]. Scientific writing is one of the scholastic abilities, whereby scholars communicate their research ideas, knowledge, skill and concepts in the form of scientific publications. While writing and communicating research, absolute novelty with integrity is expected from the scholars communicating an article. It becomes a challenging task for editors of journals and scientific peers to carefully examine all potential publications and stamp out scientific misconduct in scholarly works[39].

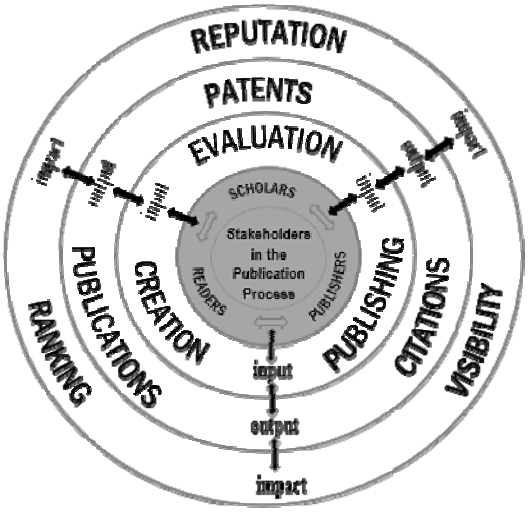

Fig. 1 – Stakeholders' Relationship in the Publication Process

A study done by Okonta and Rossouw (2014) found that scientists in developing countries were more prone to scientific misconduct[40] compared to their counterparts in developed economies. The phrase "publish or perish" coined by Coolidge in 1932, became very popular among academics[41], put tremendous pressure on young academics, often leading to misconduct. Many scholars, though capable, avoided producing a few high-quality papers in favour of subdividing their work to create many papers of lower quality[42].

In scholarly publication process, retraction is a relatively rare, but is essential for correcting the literature and maintaining trust within the scientific community[43]. During the past 10 years the number of articles retracted by journals has increased 10-fold, from 44 in 1997 to 488 in 2016[44]. Sometimes scientific misconduct attracts lawsuits against falsification of data in applications and reports at both individual and institutional levels. Unlike retractions, corrections (as evidence of scientific integrity) to the literature in post-publication stage do not affect the publication, do not hurt the career of the scholar, nor disgrace him or her in public eye[45]. Rising volume of fraudulent research corrupts scientific literature and ultimately harms the society[46]. Thus, honesty in research is essential and provides filtration, retraction and insulation from unauthorised works like fabrication, falsification, plagiarism, bias etc.

In order to promote academic and research creativity and integrity, a global policy framework is essential. All scientists across the world have strongly supported the adoption of the San Francisco Declaration on Research Assessment (DORA) of 2012 to promote best practices in the realm of research and development[47]. In India, the University Grants commission (UGC) regulations 2018 on dealing with plagiarism has put in place guidelines and fair punishment on fraudulent academics. Thus, inclusion of academic and scientific creativity (uniqueness) and integrity (ethics) in scholarly works enhances individual and institutional reputation.

Evaluation— originality and quality

In the publishing industry, assessment of scholastic standard is an important step in bringing out originality, aptness and quality in research output. A scholarly publication goes through several stages of evaluation, particularly in the editorial process.

Preliminary assessment is done in terms of general style, structure, language, scope, etc., before it is taken up for the next level of assessment. This includes ethical concerns related to checking of references, conflict of interest, detection of plagiarism, and redundancies[48]. Advanced technologies help editorial staff to track manuscripts, and to assess reliability, quality and inventiveness.

In the evaluation process, reviewing is crucial. According to Hartling *et al* (2017), reviews can be principally of two types: rapid and systematic. Rapid reviews are "literature reviews that use methods to accelerate or streamline traditional systematic review processes"[49]. They are comprehensive and long. Normally, it is hard for most manuscripts to be accepted in high-impact, peer-reviewed journals, and rejection rate of manuscripts is quite high. For instance, *Science*, one of the highest impact factor (IF) journals worldwide now accepts less than 7% of original manuscripts submitted to it, and about 80% of submitted manuscripts are rejected during the initial screening stage[50].

Peer-review process is widely accepted to maintain standards in spite of criticism like bias, fraud, conflict of interest, reducing trust and professional connections. Waiting time before publication widely varies by discipline, social science journals being notoriously slow[51]. In the recent past, China has cracked down on fake peer-reviews; funding agencies have also announced stronger policing efforts and harsh penalties on scientists found guilty[52]. A new concept called "post-publication peer-review' is gaining increasing importance in efforts towards improving quality of research through community interactions. It involves steps like finding out flaws, appraisal, comments and feedback on public websites such as PubPeer, PubMed common etc. "It is an explicit judgement which asks whether the research addresses a relevant study and is significant in its field of study and whether it can advance or positively impact science"[53]. In journal evaluation process, increased revisions of manuscripts, not rejections, can improve citation and publication quality[54]. Further, the reviewers' assessment reports constitute valid tools for maintaining quality[55].

Publishing— copyright and cost

Publishing deals with the steps of acceptance of the manuscript, signing of copyright agreement and meeting the cost of publication. Soon after acceptance of the manuscript, the authors are asked either to transfer or to license the copyright of their article. Copyright is a process of safeguarding the rights of the author and allows the publisher only to publish a reprint of his/her work[56]. Scholars sign and submit the copyright agreement to the publishers in exchange of the privilege of getting their works published. Both copyright and license agreements ensure protection against breaches by unscrupulous individuals. In recent years, authors are getting a choice of publishing their articles under Creative Commons (CC), a system conceived by Lawrence Lessig of Harvard Law School[57]. CC is just a license (as a legal tool), granting rights out of copyright. These are issued rather freely, give more freedom to creators of knowledge and ensure better use of resources among stakeholders. The CC-BY license is the most open license available and is considered as the industry's 'gold standard' for OA. Many funding authorities prefer this licensing method[58].

In the scholastic domain, accumulating knowledge is eventual for economic growth[59]. At present, the publishing industry is highly competitive and costly to sustain. The cost associated with publishing involves proofreading, typesetting, IPR protection, discovery, metrics, posting, archiving, migration, etc. Publishers need to carefully and legitimately plan their activities - publishing, customising, disseminating, promoting content, sales and payments. Kurien *et al* (2019) have highlighted that about 75% of published science articles are locked behind paywalls[60]. According to *Science* (2013), one fourth the publications are made available publicly soon after publication, while three fourth are available publicly only after 12 months of embargo[61].

To maximise creation and dissemination of scientific knowledge, open access is helpful. Started in the 1990s, OA is one of the viable options for permanently removing publication obstacles - financial, legal, technical, accessing, sharing and reusing scholarly research output[60]. There are two types of OA publishing routes: gold and green. Gold OA means that articles are published directly in OA journals, while green OA articles are deposited in a repository through self-archiving. In recent past, the majority of commercial publishers, including Elsevier, Springer, Sage, PLOS, Biomed Central, etc. have supported OA journal publishing. As on January 05, 2021, the Directory of Open Access Journals (DOAJ) has listed 15,682 OA journals[62].

In the competitive world, a couple of economic models govern all operations of scientific publication process from subscription to OA. These are: 'reader-pays model' (subscription model) and 'author-pays

model' (APC model). In the reader-pays model, scientific publishing receives well over A$4 billion of revenue a year through subscription, mainly from institutions and Government[63]. Publishers generate nearly three-fourth of their revenue (68-75%) from libraries alone[64]. They retain the copyrights, but provide the right to authors to share their articles for personal/institutional/academic/research purposes. In the 'author-pays model', adopted mainly by OA journals, publishing costs are borne by authors directly or by their funders/institutions on their behalf.

The majority of OA publishers disclose APC up to $5,000 on their websites. For instance, *Cell Reports* charges US$ 5,000 for an article to be published; similarly *PLoS One* receives $1,350 and *PeerJ* $299 for unlimited submissions[65-66]. In the APC model, authors hold the copyright, but exclusive license is given to the publishers to publish and distribute the articles. However, the 'author-pays model' needs increased experimentation to standardise the global framework. An exception to APC is possible by waiver of charges, reimbursement and credit on a case-by-case basis. Further, the mushrooming of predatory journals (also called fast-track, pseudo and fake) has placed academic and scientific research in a quandary. Retraction Watch (2015) has reported that "the number of articles published by predatory journals spiked from 53,000 in 2010 to around 420,000 in 2014, appearing in 8000 active journals charging an average APC fee of $178[67].

Post-publication activities

The post-publication process represents the output of research that is being produced, marketed and demonstrated publicly. A report published in the journal *Science* in 2013 stated that a new paper is produced every 20 seconds, and more than 50% of new research is now made available free online[61]. It has also noted that "28,000 journal publishers published 2.5 million articles and 5 million drafts submissions in a year globally"[68]. Visibility and reputation of researchers depend on their productivity (publications, patent and citations) who in turn rely on infrastructure and resource facilitation, mentoring, policies, funding etc. of an institutional research ecosystem.

Intellectual impact— visibility, recognition and reputation

Scientific impact is the central tenet in the success of evaluation of research. A number of pragmatic reasons may justify this such as: 'worth reporting', 'progress in scientific thought', 'reaching a wider audience' or 'increased chance of promotion to impact research' etc.[69]. The criteria for selection and publication of manuscript is, in most cases, the Journal Impact Factor. It was developed by Eugene Garfield in 1955 to measure research output and to rank journals[70]. A good number of scholars consider this method crude and misleading[71].

Traditionally, scholars have been looking for a bibliometric method to measure the quality of journals and books etc. In recent years, other indicators of quality of research, such as h-index (author-level), i10-index (quality of author's work) and Egghe's G index (quality and quantity of author's work with more emphasis on quality), are gaining popularity[72]. Another indicator named Altmetrics (alternative to citations) was introduced in 2010 to supplement traditional methods. Thus there came a heterogeneous set of metrics covering all social media activities, news, policy documents, etc. However, it is observed that "citation-based metrics and readership counts are significantly more related to quality than tweets"[73]. Wagner (2015) has found that "80% of national research quality is measured by citations"[74]. Probable factors such as field, time, fund, collaboration, social media, etc. also influence citations[75]. Nowadays, many publishers are using altmetrics like PlumX metrics, impactStory (open-source tool), InCites, CitedIn etc. to find, analyse and visualise research outputs online. These metrics are also helpful in making crucial decisions while appointing for academic posts and promotions, giving grants and incentives, and in rankings, etc.

Scholars are popularising science through their publications, and the vast majority of them are involved in scholarly publishing as reviewers and editors etc. without expecting any monetary benefits. However, several studies have indicated that reward systems for publishing research papers in peer-reviewed journals have played key role in creating reputation of scholars, institutions, and even nations. For example, in Indonesia, the Government has started rewarding scientists for publishing in high-impact scientific journals with hard cash, and in Thailand private universities provide incentives to their faculties for publishing the research in peer-reviewed journals[76]. Similarly, institutions across several countries, including India offer incentives to scholars for publishing papers high impact journals like *Science* or *Nature*[77]. In Vietnam, scientists receive no monetary reward, but international

publications earn 'points' which contributes to their career progression.

It is obvious that both productivity and impact are two important aspects of research quality. Therefore, research publications and their citations are the most widely used inputs to measure national and world ranking. "The impact of an article is defined as the number of lead authors that have been influenced by it. However, it is only fair to quantify scientific output, not only with measures that favoured productivity"[78]. In USA scientists of the National Academy of Sciences are evaluated based on the impact of their work rather than the number of publications[79]. Similarly, UK's Research Excellence Framework (REF) has accepted "impact" as the criterion for rewarding scientists in their work. The French Academy of Sciences (FAS) has been concerned with current evaluation practices for individual scientific performance[75].

It is also seen that various metrics associated with research progress significantly correlate to university reputation[80]. Prestige, speed of publication and visibility influence scholars' choice of journals for publishing their most important works[81]. OA publishing is another key avenue for scholars to enhance their scientific impact and visibility, and to enter into international collaborations[82]. Research inclusivity also raises visibility and reputation which eventually generate funds for the scientists and their institutions.

Conclusion

Scientific publication has been an important tool to report, record and validate scientific knowledge. Since the 17th century, valid scientific results are enabling stakeholders to assess observations, repeat experiments and evaluate intellectual processes[83]. Stakeholders in the publication process hold independent relationships with each other for the creation, production and dissemination of scientific knowledge. In the pre-publishing phase, the scientist's creativity and responsibility not only lie in introducing new knowledge in scholarly works, but also in doing so ethically. In the evaluation process, peer-review is a key process, bringing out accuracy, originality and quality in research. Nowadays, peer-review has become more liberal, open, transparent and collaborative. Publishers often invest in scientific knowledge (peer-review) to maximise their services as well as their returns. Publication expands readership and attracts revenue. Acquiring author's rights as part of the publication process by the publisher benefits both parties - the author for authenticity and the publisher for exclusivity. The OA publishing model (author-pays) is a rather new normal and needs increased experimentation to standardise the process globally. Thus, scientific impact has become an outcome of research in the form of visibility, recognition and reputation, drawn through publications, patents and citations.

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