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Digital Transformation and Hybrid Model inEngineering Education

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Abstract - Digitalisation is also transforming research in ways that are common to other domains of social interaction but are very pronounced since the scientific community is highly interconnected globally. The survey show that the use of digital productivity and collaborationtools is more intense within Higher education institutions and small economies, and it is associated with higher rates of personal scientific collaboration and productivity. Online identity is important for UG, PG and researchers because a significant but incomplete part of their science- related activities leave a digital trace. In turn, this digital footprint supports the production of metrics that researchers use to inform decisions that impact on their teaching and learning careers, such as hiring and promotion decisions in universities.

Keywords – Digitalization of Engineering Science, for Scientific and Technological Policy (CSTP), Organization for Economic Co-operation and Development (OECD), Information Systems Security Association (ISSA).

***JEET Category*—Practice**

I. INTRODUCTION

In general, challenges faced by faculty and students of engineering education in the digital era concernprincipally access to data and infrastructure, including basic Internet connectivity. The perception of this challenge increases with the relevance of data for research. This paper finds evidence of a marked digital divide across gender and age groups. The teachers are likely to report engagement in activities contributing totheir digital online identity and communication.

II. DIGITALISATION DIVIDES IN SCIENCE AND IMPLICATIONS

Youngengineers exhibit higher digitalisation scores across the various dimensions identified. There is no evidence of an earnings premium from using advanced digital toolsor engaging in data sharing, whereas a more intensive use of digital tools seems to be correlated to a greater involvement in activities beyond core research. For instance, scientists with a more intense use of advanceddigital tools are more likely to be involved in business /managerial activity (e.g., start-ups) or to apply or register for IPR protection. However, a major driver of reported incomes is the lifetime average prestige of the journals where scientific students have published, more so than the average normalised citation record. This is a poignant reminder of the value that the scientific marketassigns to the decisions made by editorial boards in journals over and above their actual citation influence, and it points to entrenched patterns explaining the incentives facing by researchers at different points in their careers when considering potential policy reforms, for example, around open science practices. Overall, faculty and students seem to have a positive view of the impact of digitalisation in science, and especially on theefficiency of research work and collaboration across national borders. Young engineers are more sceptical about its effects on research valuation and rewarding systems.

III. DIGITALIZATION OF SCIENCE CONCEPTS

The development and adoption of digital technologies is transforming science through all stages of the scientific process, from agenda setting and experimentation to research output communication and evaluation. Severalstudies and practical evidence suggest that scientific activity has not only been transformed – like all other areas of economic activity – by the uptake of productivity and collaborative ICT tools but has also become increasingly data-intensive. Indeed, IT infrastructures and software tools are allowing the collection and use of large amounts of data in scientificresearch. The use of ICTs is also enabling a deeper andmore efficient analysis of the data permitting the investigation of new and more complex research questions as well as the adoption of new, data-driven research methods. This has led some observers to arguethat the techniques and technologies for such data- intensive science are so fundamentally different that a "fourth paradigm" for scientific exploration, distinct from empirical, theoretical, and computational approaches to sciences, has emerged (Hey et al., 2009).This new paradigm raises both opportunities and challenges for the established processes by which hypotheses are developed and scientific facts are established.

The use of digital tools in science has co-evolved with the emergence of digitally native journals, repositories, pre-print servers as well as new tools for metadata and publications of intermediate research outputs and pieces of information with important implications on differentaspects of science. In many instances, scientific publications and underlying data are becoming freely and openly available, as part of a drive towards "open science" paradigm to make the entire scientific process more open and inclusive to all relevant actors (OECD, 2015b). Digital tools facilitate data reuse, generating anexpectation of increased research efficiency and reproducibility, but also represent a challenge for traditional appropriation mechanisms and may call for the design of new institutions that incentivise research and its translation into workable solutions.

IV. MEASURING THE DIGITALISATION OF SCIENCE: THE ISSA STUDY

The Organization for Economic Co-operation and Development (OECD) developed the Information Systems Security Association (ISSA) survey with the intention to contribute to the OECD Going Digital project, a horizontal OECD effort to build a coherent and comprehensive policy approach on the societal andeconomy-wide process of digital transformation. This work was carried out in line with the priorities set out inthe Programme of work of the OECD Committee for Scientific and Technological Policy (CSTP), as well as the OECD Blue Sky Agenda (OECD, 2018) adopted bythe CSTP's Working Party of National Experts in Science and Technology (NESTI). Interested readers can find a full technical description of the study in a separate technical paper (Bello and Galindo-Rueda, 2020). The ISSA study targeted the corresponding authors of scientific publications whose contact information is available in a bibliographic database. This approach builds on the model of a first pilot carriedout in 2016 (ISSA1), which focused on the relationship between scientific publishing and open access. In the 2018 ISSA edition, a sample of scientific authors listedas the document's corresponding authors were invited to participate in an online survey conducted directly by theOECD in the last quarter of 2018 and were asked to report on their use of a broad range of digital tools and related practices, in addition to another key demographic and career information. The ISSA final dataset contains data on approximately twelve thousand scientific authors worldwide.

V. MULTIDIMENSIONAL APPROACH TO MEASURING THE DIGITALISATION OF SCIENCE.

This section describes the multifaceted transformation of science by examining the adoption of digital tools andrelated practices by scientists across the multiple stages of the scientific research process. It does so by covering the following aspects: (a) types of research methods adopted by scientific teachers and students; (b) the production of data and code and related sharing and curation practices; (c) use of a broad range of digital tools; (d) online presence of scientific authors and communication of scientific work; and (e) main digitalisation dynamics in science.

A. Research paradigms - methods adopted by scientific engineers.

The ISSA survey collected information on the involvement of scientists in a range of substantive functional types of research activities associated to different science paradigms. The survey questionnaire is available online. This includes gathering or curating information, formulating theories, and studying their properties and predictions; using computation modelling and simulation methods; formulating and testing hypotheses in experimental settings and formulating and testing hypotheses in empirical, nonexperimental settings. This information can helpidentify the main types of research methodologies usedacross different scientific domains and facilitatesinterpreting the role and nature of digitalisation.

B. Production and dissemination of publications, dataand code

Open access to publications an important feature of digitalisation is the considerable potential for facilitating access to scientific publications and implementing dissemination models that are more in tune with actual review and publication costs. The subject of open access was covered at length in this survey's previous edition, investigating not only the extent and nature of open access but also the complex interaction between incentives and scientists'preferences that allowed to generate estimates of the economic value of open access.

ISSA results indicate that nearly 70 percent of scientific publications published in 2017 were available in late 2018 on an open access (OA) basis. Journal-based openaccess (gold-OA) seems to be more prevalent in Medicine and health professions as well as in Biochemistry, genetics, molecular biology, immunology and microbiology, whereas repository-based open access (green-OA) is more common in Mathematics and Earth and planetary sciences. Hybrid open-access publishing (subscription journals where thearticles is on open access basis) is most often found for documents featured in Multidisciplinary and Materials science journals.

C. Researchers use of digital tools and data

Research lifecycle online tools ISSA collects information on the use of a wide range of digital tools for purposes covering the entire scientific research cycle. Respondents were asked to indicate their use of digital tools for a battery of 28 research-related activities, which can be grouped under the following main dimensions: search of information and resources, project management and data analysis, writing, and dissemination of scientific outputs. The survey results present a multifaceted view of digitalisation of scientificactivity.

i. Use and development of big data and advanceddigital tools

In addition to the adoption of a broad range of productivity and collaborative tools, another key facet of science digitalisation concerns the development and use of advanced digital tools by scientists - not only within the computer sciences and ICT engineering domains - to gain knowledge about phenomena,evaluate models as well as formulate and test hypotheses. This includes the use of big data analytics, artificial intelligence, sensor-nets and the Internet of Things, whose high potential as general purpose technologies contribute to generate expectations of stepchanges in research quality and efficiency at a time in which there are concerns about a decline in research productivity. The use of cloud computing in science, forinstance, is allowing groups to host, process, and analyse large volumes of multidisciplinary data creating economies of scale, facilitating data sharing and collaboration, and enabling long-term data preservation, whereas AI is enabling to tackle complex computation problems, collect large-scale data, optimise experimental design, among others (OECD, 2019).

ii. Digital identity of scientific authors

ISSA also examines various aspects relating to digital identity, understood as the body of information about an individual or organisation that exists online. For scientists, digital identity can be a crucial reputation asset and vehicle of communication with their peers and society more broadly. Digital identity in science is important for the organisations for which scientists workas well as for third parties that need or may need to interact with them, for example publishers or funding agencies in search of reviewers, or firms in need of specialised scientific or technical services.

Use of identifiers and communication mechanisms Use of IDs to assert identity in digital environments is widespread across all fields. Only 15% of authors reportnot using them to claim authorship over their work and distinguish themselves from other researchers or individuals. The “Open Researcher and Contributor Identifier” (ORCID), promoted by the namesake international non-profit organisation, appears to have become the prevailing global standard as it is the most diffused type of identifier used by scientific authors worldwide (more than 60 percent), followed by other author IDs or personal profiles associated to citation indices. Organisational or country-specific IDs are widely reported but their lack of global reach restricts their overall level of uptake with localised exceptions.

iii. Measurement and assessment of science in thedigital age

Given the importance of metrics supported by online digital sources and tools for the assessment of impacts, ISSA enquires about how researchers perceive that theyare used in their work environments. The results demonstrate the pervasive use of traditional indicators based on measures of journal prestige, counts of outputssuch as number of peer reviewed papers and number of citations. Although rather novel, online usage metrics, which measure the numbers of views, downloads, etc., are already reported to be used in 20% of cases. These metrics, which in some cases provide insights into the usage of scientific outputs outside the population of scientific authors (for example, medical practitioners or policy makers who download scientific documents to keep to up to date with the literature and support their decisions) are beginning to be systematically provided by publishers.

iv. Patterns of digitalisation of scientific activity

The presentation of descriptive statistics corresponding to multiple and interrelated survey items helps introducea more exhaustive exploration of general patterns of digitalisation in scientific activity. The wealth of data collected, corresponding to a large number of variables, needs to be synthesised to identify core features and patterns. This further serves the purpose of facilitating the subsequent analysis of the drivers and impacts of digitalisation in its various facets. This article uses factor analysis as a dimensionality reducing technique to identify a reduced number of synthetic indicators capturing distinct and relevant patterns of science digitalisation.

The principal component factor method enables theextraction of a minimum number of factors that accounts for a maximum proportion of the variables’ total variance. The number of factors selected was restricted to four based on the analysis of the eigenvalues, screen plot and the variance accounted by each factor. To facilitate the factors’ interpretability, an orthogonal rotation generating mutually uncorrelatedfactors was applied to the factor loadings, i.e. the correlations between the factors and the underlying variables. The resulting rotated factor loadings are provided. The factors are interpreted and labelled basedon their loadings (associations) with the observed variables. These turned out to refer to four major facetsof the digital transformation of science:
• use of digital scientific collaboration and productivitytools
• development and management of digital access to dataand code
• use of advanced, computing oriented, digital tools (e.g.big data analytics)
digital identity in online environments and

communication of scientific work.

VI. FACTORS INFLUENCING DIGITALISATION OF SCIENCE

This section aims to explore the link between an author's characteristics such as gender, age, education, research methods, and his/her digital practices. Although a causal relationship between these indicatorscannot be assessed given the "snapshot" nature of the data collected, the results presented in this section can still provide important insights into the patterns of use of digital tools in science. The multivariate analyses presented seek to account for variation in digitalisation intensity across different groups of scientific authors keeping other characteristics constant.

VII. LINKS BETWEEN DIGITALISATION PATTERNS AND THE PROFILE OF SCIENTIFIC AUTHORS

Regression analysis examines the correlation between the use of digital tools and several teachers and students' characteristics, including gender, age, education, employment, place of birth, and research performance, while controlling for research field and country of residence.

A. The digital gender divide in science

Regression results point to significant digital divides between men and women even for a highly professionalgroup such as that of scientific corresponding authors. Female authors score significantly lower than their malecounterparts in the use of advanced tools. They are alsosignificantly less involved on average in data and code sharing practices. However, women score higher than men in the factor representing digital identity and communication of research work. For this reason, it is more appropriate to speak about gender divides than a single modality of gender differences around digitalisation. Concerning the use of digital productivityand collaboration tools, no significant differences are found.

B. Age and other digital divides in science

Age - An author's age appears to be strongly correlatedwith a lower score in all measures of digital intensity except for digital productivity and collaboration tools, where the estimated effect of age is also negative but notstatistically significant. A difference of 10 years of age drives on average a significant gap in the factor capturing the take up of advanced digital tools of 7% standard deviations.

C. Qualifications

These age effects are indeed robust to the inclusion of information on whether the authors graduated in an ICT subject. ICT graduates do not only score higher than their non ICT specialist counterparts in the use of advanced digital tools, but they do so also in relation to data and code dissemination activities. Interestingly,these authors with an ICT-related qualification exhibit low scores on the digital identity and communication factor.

D. Institutional sector of employment

Teachers in the Higher education sector score higher indigital productivity and collaboration as well as identity and communication factors, but significantly lower in relation to the adoption of more advanced digital practices, compared to authors in the Government sector, who represent the estimation baseline. Scientistsin the Private non profit sector achieve comparableresults in terms of digital identity and communication scores to those in the Higher education sector.

E. Links between digitalisation patterns and research methods

To complete the analysis of digitalisation patterns this subsection explores how the digitalisation factors relateto the fundamental research modes adopted by scientificauthors and their teams. The links depends on datagathering and curation, theory formulation, use of computational modelling, hypothesis testing in experimental settings, and hypothesis testing in empirical, non-experimental settings.

F. Drivers and impacts of digitalisation in science

Having mapped the multifaceted nature of digitalisation in science as well as its potential explanatory factors linked to the modes and features of scientific research, the main questions remaining to be addressed in this paper relate to the identification of the key drivers and impacts of digitalisation. Such questions are unpacked in three steps: identifying key barriers faced by scientists in their work; examining the link between digitalisation and measures of scientific impact andexploring authors' personal views on how they themselves view the impact of digitalisation in science.

G. Challenges faced by scientific authors in digital environments.

Directly following questions on their use of data and code, scientific authors were asked in ISSA to report onthe greatest challenge they face in their scientific work in digital environments. Researcher appear almost equally split across the three main options provided to them, namely skills, data, and infrastructure and tools. Infrastructure and tools are more important for scientists working in chemical engineering, material science and a number of life sciences. Access to data was consideredmost challenging in the fields of Economics and business, as well as in other social sciences. The fields to put the greater emphasis on skills, the least reported challenge on average, were those of Pharma and neurology, Mathematics, and Physics and astronomy. Digitalisation and the impact of research activity depends on the following factors.

i. Citation influence and journal prestige

The data collected allows to explore the extent to whichoften used measures of research influence, such as normalised citations or journal prestige, are associated with measures of digitalisation intensity. The results of the analysis suggest that both proxy measures of research quality are positively correlated with the use of digital productivity tools and data/code sharing. This might be suggestive of positive effects of collaboration and openness that may be enhanced by such digital practices. The propensities to use advanced digital tools and engage in digital identity and communication practices are negatively correlated with the measure of journal prestige while they are positively but not significantly correlated with the measure of citationimpact.

ii. influences of research

Since the impacts of research and related activity can extend beyond the immediate influence of publications on the scientific community, it is important to explore towhat extent digitalisation relates to broader measures ofpotential impact, as implied by activities potentially incurred by scientists. Analysis of ISSA data suggests that authors reporting a more intensive use of digital tools tend to engage in more activities that can result in broader impact mechanisms. Higher digitalisation scores on the use of advanced digital tools and digital identity and communication are associated with a higher probability of reporting the registration of IPRs, engagement in business management activity, provision of research services and consultancy work.

iii. Digitalisation and research careers

To provide evidence on the link between digitalisation patterns and authors' career performance, the coefficientof a regression analysis of the relationship between authors' annual income gross of tax and her digital profile and other personal characteristics, including the average number of hours worked. These estimates are therefore interpreted as indicative of the way in which the market rewards the competences and efforts of scientific authors or appears to penalise certain traits.

VIII. HYBRID MODEL IN ENGINEERING EDUCATION

What looked like a piece of cake initially in terms of working from home and having to just switch on a device, soon became a nightmare. Yes, the internet has been a real boon; without it, learning would have been completely lost this past year. However, it is a 'Hybrid Model' today that is the need of the hour—one that is ahealthy mix of printed material like books, pen and paper along with the digital content. Another thing that has become increasingly important today as has co-curricular classes like art and craft, physical education, etc. Shammi Manik, CEO of a large educational publishing house says, "It is imperative for both schoolsand parents to ensure that blended learning with printedbooks and stationery, along with the digital content is consumed by students to get the balance right; onewithout the other may cause serious issues.

The hybrid model is the way forward. 2020 has been both a challenge as well as a great learning curve for everyone across the globe, especially in the education space: for students to sit in front of a screen with little or no social interaction with friends, and for educators who have had to learn how to use many different tools for teaching, engaging as well as evaluating students.

There is no doubt that publishers too have gone that extra mile to help facilitate all kinds of online teaching- learning experience for all three stakeholders through: students, educators and parents. Dr Vinod 'Prasoon' Chauhan, who is associated with NCERT, CBSE and ICSE, and is a poet and author of bestselling Hindi serieslike Saarthak, Unmesh and Udgham for K-8 says, "TheCorona era has taught us a lot. If the technology had notsupported us at this time, the teaching-learning process would certainly have been greatly affected. Therefore, there is no doubt that online classes have reduced the loss of studies to a great extent during this disaster, but it is also true that online classes cannot be considered as an alternative to offline classes.

However, new methodology and tools like Hybrid Teaching, Blended Teaching are part of major discussions today and their imperative implementation are being appreciated in the changing era. Books equipped with authentic innovative measures, ideal teachers and their innovative uses, proper use of technical tools and an environment full of joy makes learning child-centered, comfortable, joyful andexperiential." Therefore, even though the online learning mode is being facilitated through tools like animations, test generators, online competitions, educational games and so on, there is no substitute for physical books and activities. Hybrid teaching-learningmethodology is the way forward to facilitate more than just learning for examinations; it aids in overall understanding and in-depth knowledge.

A new teaching-learning environment has now been created that facilitates learning anytime, anywhere and as per one's interest areas. Student-centric learning looks like they are slowly becoming a reality with digital systems information to learners at an affordable cost andacross boundaries, but to make it truly viable, the print material is important, making one's own notes is important and reading extensively is important. We stillhave a long way to go, but the best part is that with all that is available in terms of content—both online and offline by publishers—we can see a whole lot of innovation and usage in the education space for the session in 2021.

IX. Conclusion

This article has provided an overview of the key findings of the OECD ISSA study on the digitalisation of scientific research. The survey results provide a rich,global snapshot picture of the multi-faceted nature of science and digitalisation, providing a baseline for charting its digital transformation and the mechanisms through which it influences scientific research and its impacts on society. The evidence presented in this document shows that although digital activity is pervasive, the transformation has been uneven across fields and sectors, influenced by factors such as norms, experience, skills and data availability. The potential impacts of digitalisation have been explored, combiningdifferent indicators of research impact as well as examining subjective views about the state of play. Overall, scientists appear to be optimist about the possibilities brought about by digitalisation, and especially in relation to the efficiency of research and collaboration across national borders.

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