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2021 - 2022

RESEARCH CONTRIBUTION OF SAVITRIBAI PHULE PUNE UNIVERSITY (SPPU): A BIBLIOMETRIC ANALYSIS

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ABSTRACT -

The current study used bibliographic data to examine the research productivity of the Savitribai Phule Pune University (SPPU) in Maharashtra, India. The study's goal was to examine research productivity over 31 years (1990-2020). It covers publication format, the most prolific author, preferred source of publication, subject wise research productivity, author collaboration with national and worldwide, and the author with the highest H-Index. The bibliographic and citation data were sourced from the Web of Science (WoS) database. Bibliometric techniques were applied to analyse the data, and tools such as Bibexcel, Biblioshiny, Hiscite, and Ms-excel were used to analyse a total of 8602 records. The major findings reveal that the number of research publications and citations at the SPPU has increased over the last ten years. SPPU faculty members collaborate well both within India and with researchers around the world. Chemistry was discovered to be SPPU's dominant research area.

Keywords - Author Collaboration, Bibliometric, H-Index. Research Productivity, Web of Science

INTRODUCTION

In today's condition, it is common belief that developing countries may not have sustained growth if they lack of good quality educational and research institutes. Therefore, for developing countries, it is most important to have quality educational institutes, basic infrastructure and skilled human resources. In Maharashtra and in particular in Pune city, such reputed Institutions known for quality education and basic infrastructure required for this is available. Pune is one of the progressive cities from Western Maharashtra in India and Savitribai Phule Pune University (SPPU) is well recognized all over the world which has also earned reputation as Oxford of Eastern World. Savitribai Phule Pune University was earlier named as Pune University which was established in 1949. Since establishment, Pune University has become one of the important centres among Research and Educational Institutes of the Country. The 411 acres, peaceful and still equipped with all modern amenities, campus of Pune University in northern-eastern region of Pune city offers an ideal environment for numerous research students to pursue their research interest in various fields. Pune University has more than 40 departments that provide comprehensive educational programs. In very less time, Pune University has set very high standards in various areas of Research and Teaching and still continuing in pursuance of excellence.² In view of this, we studied in this paper the great emphasis Pune University has made in Research areas.

For this study, we have used bibliometric analysis as a tool in which we evaluated the scientific contributions published by all researchers in the Pune University. In Bibliometric analysis, only those articles which are published in English on Web of Science have been included. The major objective of this research paper is to analyze the research articles published by all the researchers in Savitribai Phule Pune University. For this, the papers published over a period of 31 years (i.e. from 1990 to 2020) and the citations received by these articles, collaborations and authorship patterns have been considered.

REVIEW OF LITERATURE

Bibliometric studies have been done by many researchers so far. In this, it seems to have shed light on the research work of a city as well as organizations as well as the productivity of the department, the range of studies and the research done over a specific period of time. We review some such references.

Pandita (2013) analyzed the research output and contribution made by 310 research articles published in the year during 2002-2012. Author identified the most of the authors (about 65%) published the research papers with co-authors. She also founds that the average of 17.11 references have been assigned to each article.³

Maharana (2013) in this analysis clears the research output of Sambalpur University's publications in IST Web of Science during the period of 2007 to 2011. He analyzed total 170 research papers. He found the most cited papers with self citations and without citations and H-index of authors. Also he found that the chemistry department was the most favored in area of research in Sambhalpur University. He has stated that the publication range of the university has an annual average growth rate of 30.53%.⁴

Nagarkar (2015) in her study focused on the seven life sciences department of Savitribai Phule Pune University, Pune (formally known as University of Pune). She collected data from WoS database during the period of 1999-2013. She found that total 690 papers published in 362 Journals and total 6210 citation received. She also examined the points of productivity of faculty members of life sciences, authorship patterns, collaborations with reputed institutes like Bhabha Atomic Research Centre (BARC), National Chemical Laboratory, Agharkar Research Institute etc.⁵

Khan (2015) studied the research productivity of Government Medical College, Jammu. In his

study, he studied around 18 departments and their research publications with the help of Scopus database. The results showed that the total 514 published publications were by various departments during the period of 1973 to 2011 and he founds that General Medicine, Pathology and Surgery Department achieved 1st rank for paper publication with 97 (18.87%) publications in the Government Medical College Jammu. The Majority of publications were published with coauthors and their percentage was 91.44. Pediatrics Departments publications was the highly cited in the Government Medical College Jammu.⁶

Lihitkar's (2019) study is based on Scientific Publications of Shivaji University, Kolhapur during the period of 1989 to 2018. For this study, authors used Web of Science for data collection. The finding of this study was, the Material Science is at the top of the list in research area of Shivaji University and achieved 30.44% of all the research output. The study shows 92% research papers published as research journal articles. The Local Citation score of Shivaji University was found 850 and Global Citation Score founds 65924.⁷

Garg (2020) examined the growth of articles published during the 28 years of 1992 to 2019 in block of four years each. For his study he analyzed total 910 research papers. By this study the DRDO-DESIDOC, New Delhi is the most prolific Institutions with the 128 research papers with 7.5%. In the most prolific authors he found S.M. Gupta topped the list. Lastly he advised that journals should take efforts to attract authors for working abroad for publications.⁸

For the present study, we looked at records published from 1990 to 2020, a period of thirtyone years from SPPU, Pune. From the Web of Science, a total of 8602 records were retrieved from this period published by SPPU. The details are as below:

OBJECTIVES OF THE STUDY

- To investigate the types of documents produced by SPPU faculties
- To measure the year wise research outcome of SPPU from 1990 to 2020
- To identify the journals preferred by SPPU faculties to publish their research
- To identify the most productive author of SPPU
- To study the subject wise research productivity of SPPU from 1990 to 2020
- To analyse the collaboration of SPPU faculty members with national and international authors for research publication.
- To find out the highest H-Index holder author among SPPU faculty

METHODOLOGY

The current study is based on a bibliometrics analysis of research publications from Savitribai Phule Pune University. For this, bibliographic data was taken from the Web of Science database (https://clarivate.com). The biblioshiny application(https://www.bibliometrix.org/Biblios hiny.html) was used to do the bibliometric analysis of the extracted data. Biblioshiny is a tool for drawing inferences from great bibliometric data. Bibexcel, Biblioshiny, Hiscite, and Ms-excel are some of the tools used to analyse bibliographic records.

| Sr. No. | Types of Documents | Num. of Documents | TGCS |
|---------|-----------------------|-------------------|--------|
| 1 | Article | 7618 | 149452 |
| 2 | Proceedings Paper | 312 | 3817 |
| 3 | Review | 289 | 15006 |
| 4 | Meeting Abstract | 118 | 13 |
| 5 | Editorial Material | 95 | 260 |
| 6 | Letter | 90 | 688 |
| 7 | Book Review | 32 | 1 |
| 8 | Article; Early Access | 20 | 25 |
| 9 | Biographical-Item | 11 | 0 |
| 10 | Book Chapter | 7 | 107 |
| 11 | News Item | 5 | 5 |
| 12 | Retracted Publication | 4 | 51 |
| 13 | Film Review | 1 | 1 |
| | Total | 8602 | |

Table No.1. Types of Documents

Table No.1 describes types of documents published by SPPU faculties. The above analysis shows that SPPU faculty published 7618 Research articles from 1990 to 2020. It means 90% of SPPU research published through Research articles in various journals. SPPU faculties also published their work in Conference proceedings (312), Review (289), Meeting abstract (118) and Editorial (95).

| Sr. No. | Publication Years | Total Document per year | Percentage | Average Citation Per year |
|---------|-------------------|-------------------------|------------|------------------------------|
| 1 | 1990 | 125 | 1.45% | 0.58 |
| 2 | 1991 | 156 | 1.81% | 0.6 |
| 3 | 1992 | 142 | 1.65% | 0.49 |
| 4 | 1993 | 124 | 1.44% | 0.66 |
| 5 | 1994 | 117 | 1.36% | 0.6 |
| 6 | 1995 | 113 | 1.31% | 0.54 |
| 7 | 1996 | 122 | 1.42% | 0.64 |
| 8 | 1997 | 132 | 1.54% | 0.79 |
| 9 | 1998 | 133 | 1.55% | 1.1 |
| 10 | 1999 | 131 | 1.52% | 1.05 |
| 11 | 2000 | 106 | 1.23% | 1.29 |
| 12 | 2001 | 126 | 1.47% | 1.12 |
| 13 | 2002 | 135 | 1.57% | 1.81 |
| 14 | 2003 | 136 | 1.58% | 2.46 |

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| 15 | 2004 | 150 | 1.74% | 1.82 |
|----|------|-----|-------|------|
| 16 | 2005 | 189 | 2.20% | 1.86 |
| 17 | 2006 | 250 | 2.91% | 2.16 |
| 18 | 2007 | 261 | 3.03% | 1.9 |
| 19 | 2008 | 288 | 3.35% | 1.98 |
| 20 | 2009 | 297 | 3.45% | 2.33 |
| 21 | 2010 | 348 | 4.05% | 2.61 |
| 22 | 2011 | 339 | 3.94% | 2.05 |
| 23 | 2012 | 355 | 4.13% | 2.18 |
| 24 | 2013 | 363 | 4.22% | 2.45 |
| 25 | 2014 | 393 | 4.57% | 3.01 |
| 26 | 2015 | 413 | 4.80% | 2.83 |
| 27 | 2016 | 600 | 6.98% | 6.1 |
| 28 | 2017 | 578 | 6.72% | 3.55 |
| 29 | 2018 | 564 | 6.56% | 5.36 |
| 30 | 2019 | 663 | 7.71% | 2.73 |
| 31 | 2020 | 643 | 7.48% | 3.75 |

Table No.2 reflects year wise publications with average citations of SPPU during 1990 to 2020. The research outcome of SPPU has been increased throughout the years. The table shows that in the year 2019 SPPU contributed 663 (7.71 %) highest numbers of publications and in the year 2020 SPPU got the highest (3.75 %) average citations. It is observed that research outcome of SPPU has been increased in last five years like 2020 (643), 2019 (663), 2018 (564), 2017 (578) and 2016 (600) as compared to early ninety i.e.1990 (125), 1991 (156), 1992 (142), 1993 (124) and 1994 (117).

| Sr. No. | Journal Title | Total Publicati on | H index | G index | M index | Total Citations |
|------------|---|--------------------------|------------|------------|------------|--------------------|
| 1 | Current Science | 190 | 19 | 38 | 0.87879 | 2946 |
| 2 | Monthly Notices of the Royal Astronomical Society | 150 | 25 | 37 | 0.60606 | 1109 |
| 3 | Journal of Applied Physics | 93 | 26 | 50 | 1.29032 | 12376 |
| 4 | RSC Advances | 93 | 22 | 30 | 0.51613 | 905 |
| 5 | Journal of Materials Science- Materials in Electronics | 91 | 19 | 33 | 0.57576 | 1771 |
| 6 | Astronomy & Astrophysics | 89 | 40 | 85 | 0.78788 | 2742 |
| 7 | Journal of physical chemistry a | 81 | 29 | 46 | 0.84849 | 2398 |
| 8 | Journal of the geological society of india | 77 | 14 | 19 | 0.73077 | 1284 |

Table No. 3. Top Twenty Journals preferred by SPPU faculties for Publication

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| 9 | Physical review b | 77 | 27 | 48 | 1.16 | 2424 |
|----|----------------------------------|----|----|----|---------|------|
| 10 | Applied physics letters | 70 | 29 | 53 | 0.4375 | 521 |
| 11 | Journal of chemical physics | 65 | 28 | 48 | 0.60606 | 1364 |
| 12 | Applied surface science | 61 | 20 | 30 | 0.78125 | 2115 |
| 13 | Nuclear instruments & methods | 59 | 14 | 20 | 0.45161 | 560 |
| | in physics research section b- | | | | | |
| | beam interactions with materials | | | | | |
| | and atoms | | | | | |
| 14 | Tetrahedron letters | 58 | 20 | 28 | 0.81818 | 2457 |
| 15 | Thin solid films | 57 | 16 | 36 | 0.62069 | 1138 |
| 16 | Materials letters | 55 | 20 | 35 | 1.25 | 1272 |
| 17 | Physical review e | 54 | 18 | 32 | 2.2 | 1359 |
| 18 | Plos one | 54 | 20 | 34 | 1.63636 | 932 |
| 19 | Scientific reports | 53 | 18 | 29 | 0.60606 | 1010 |
| 20 | Astrophysical journal | 52 | 16 | 28 | 0.48485 | 1420 |

TP-Total publication

Table No.3 reveals top twenty sources of publications preferred by SPPU faculty to publish their research work. The above analysis indicates that current science journal secured first rank in the table with 190 publications, H-Index 19 and total Citations 2946. It is observed that current science journal is most preferred journal among SPPU faculty to publisher their research. Along with current science journal SPPU faculty consistently publish their research work in Monthly Notices of The Royal Astronomical Society (TP.150), Journal of Applied Physics (TP.93) RSC Advances (TP.93) and Journal of Materials Science-Materials in Electronics

| Sr.No. | Authors | No.Publication | H Index | G | M Index | Total |
|--------|--------------|----------------|---------|-------|---------|----------|
| | | | | Index | | Citation |
| 1 | More MA | 195 | 34 | 52 | 1.133 | 3993 |
| 2 | Gadre SR | 158 | 44 | 71 | 1.333 | 5823 |
| 3 | Kulkarni SK | 158 | 41 | 78 | 1.242 | 6662 |
| 4 | Ogale SB | 158 | 31 | 53 | 0.939 | 3306 |
| 5 | Bhoraskar VN | 155 | 17 | 29 | 0.515 | 1460 |
| 6 | Padhye S | 141 | 36 | 61 | | 4317 |
| 7 | Bhoraskar SV | 140 | 26 | 47 | 0.788 | 2799 |
| 8 | Gejji SP | 140 | 20 | 35 | 0.8 | 1816 |
| 9 | Dhavale DD | 136 | 32 | 46 | | 3030 |
| 10 | Dhole SD | 134 | 17 | 31 | 0.548 | 1400 |
| 11 | Kanhere DG | 109 | 32 | 43 | 0.97 | 2475 |
| 12 | Gosavi SW | 104 | 26 | 46 | 1.04 | 2485 |
| 13 | Joag DS | 102 | 28 | 49 | 0.848 | 2797 |

| 14 | Mathe VL | 102 | 24 | 37 | 1.6 | 1739 |
|----|--------------|-----|----|----|-------|------|
| 15 | Aiyer RC | 97 | 23 | 43 | 0.697 | 2129 |
| 16 | Shouche YS | 94 | 27 | 44 | 1.08 | 2308 |
| 17 | Mahamuni S | 91 | 29 | 55 | 0.879 | 3284 |
| 18 | Late DJ | 84 | 28 | 49 | 1.556 | 2695 |
| 19 | Singh S | 83 | 20 | 38 | 0.645 | 1579 |
| 20 | PatwardhaN B | 81 | 28 | 54 | 0.875 | 3039 |

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Table No.4 reflects most productive authors in SPPU. It is observed that M.A. More got highest rank in table with 195 publications, H-Index-34 and 3993 total citations. In the table Prof. S.R.Gadre secure second rank with 158 publications in the table also he got large number of citations (5823) for his research publications.

As mentioned above in the table Prof. Kulkarni has 158 publications on his account but he got highest number of Citations 6662 for his research publication. From the table it clears that SPPU faculty produce quality research in their respective areas.

| Sr. No. | Prominent Area of Research | Number of Publication | Percentage |
|---------|------------------------------------|-----------------------|------------|
| 1 | Chemistry | 2228 | 25.901 |
| 2 | Physics | 2013 | 23.402 |
| 3 | Materials science | 1295 | 15.055 |
| 4 | Science technology other topics | 746 | 8.672 |
| 5 | Biochemistry molecular biology | 570 | 6.626 |
| 6 | Engineering | 564 | 6.557 |
| 7 | Astronomy astrophysics | 495 | 5.754 |
| 8 | Mathematics | 388 | 4.511 |
| 9 | Biotechnology applied microbiology | 367 | 4.266 |
| 10 | Pharmacology pharmacy | 292 | 3.395 |
| 11 | Environmental sciences ecology | 257 | 2.988 |
| 12 | Geology | 241 | 2.802 |
| 13 | Nuclear science technology | 210 | 2.441 |
| 14 | Plant sciences | 194 | 2.255 |
| 15 | Biophysics | 184 | 2.139 |
| 16 | Instruments instrumentation | 165 | 1.918 |
| 17 | Microbiology | 164 | 1.907 |
| 18 | Meteorology atmospheric sciences | 156 | 1.814 |
| 19 | Optics | 154 | 1.79 |
| 20 | Cell biology | 129 | 1.5 |

Table No.5 Subject wise Research contribution

It is clearly retrieved through Table No.5 that chemistry (2228) is most productive subject area of research in SPPU. Out of all the subjects or departments 25.9% of research publication published in Chemistry. Along with chemistry other subjects also have good number of research publications like physics (TP.2013, 23%), Material Science (TP.1295, 15.05%), Science technology and other topics (TP.746, 8.6%) and Biochemistry Molecular Biology (TP.570, 6.6%)

| Sr. | Country | Records | SCP | MCP | Total | Average Article |
|-----|----------------|---------|------|------|-----------|-----------------|
| No. | | | | | Citations | Citations |
| 1 | India | 7277 | 6204 | 1073 | 124961 | 17.17 |
| 2 | USA | 268 | 40 | 228 | 17160 | 64.03 |
| 3 | Germany | 76 | 2 | 74 | 2132 | 28.05 |
| 4 | United Kingdom | 71 | 4 | 67 | 7985 | 112.46 |
| 5 | Iran | 55 | 2 | 53 | 959 | 17.44 |
| 6 | Korea | 55 | 1 | 54 | 1105 | 20.09 |
| 7 | France | 43 | 2 | 41 | 3057 | 71.09 |
| 8 | China | 37 | 0 | 37 | 447 | 12.08 |
| 9 | Italy | 37 | 0 | 37 | 1612 | 43.57 |
| 10 | Canada | 35 | 9 | 26 | 708 | 20.23 |
| 11 | Australia | 34 | 1 | 33 | 631 | 18.56 |
| 12 | Sweden | 22 | 0 | 22 | 525 | 23.86 |
| 13 | Japan | 17 | 0 | 17 | 291 | 17.12 |
| 14 | Spain | 17 | 0 | 17 | 481 | 28.29 |
| 15 | Turkey | 16 | 0 | 16 | 474 | 29.62 |
| 16 | Netherlands | 13 | 0 | 13 | 592 | 45.54 |
| 17 | Switzerland | 9 | 0 | 9 | 35 | 3.89 |
| 18 | Finland | 8 | 0 | 8 | 136 | 17 |

 Table No.6 Collaboration with other countries

Table No.6 shows author collaboration with other countries. With the above analysis it is observed that SPPU faculties publish 7277 papers in collaboration with Indian authors and they got 124961 citations for their research publications.

SPPU faculties also publish their research with USA (TP. 268, TC.17160), Germany (TP.76, TC.2132,), United Kingdom (TP.71, TC.7985) and Iran (TP.55, TC.959)

| Sr. No. | H Index | Total Authors |
|---------|--------------|----------------------|
| 1 | more than 40 | 2 |
| 2 | 35 to 39 | 67 |
| 3 | 30 to 34 | 110 |
| 4 | 25 to 29 | 54 |

| 5 | 20 to 24 | 24 |
|---|----------|-------|
| 6 | 15 to 19 | 58 |
| 7 | 10 to 14 | 203 |
| 8 | 5 to 9 | 1651 |
| 9 | 0 to 4 | 17859 |

The H-index of the authors of SPPU is shown in the above table as per group. Only two authors have an H-index of more over 40, The top two authors as Gadre S.R. secured 1st rank with 44 H-Index and Kulkarni S.K. is second with 41 H-Index. There are 17859 authors with an H-Index of 0 to 4, and 110 authors with an H-Index of 30 to 34. In addition, 67 authors were ranked between 35 and 39.

MAJOR FINDINGS

- 90% of SPPU research is published in the form of a research article.
- It has been observed that the number of research publications has increased in the recent ten years when compared to the early 1990s. In addition, average number of citations has increased with the number of publications
- The current science journal is a prominent journal for research publication at the SPPU. The Current Science Journal published 190 research papers between 1990 to 2020.
- Prof. S.A. More is the most productive author among SPPU faculty. He has authored 195 research papers between 1990 to 2020, with an H-Index of 34. In addition, his research publications received 3993 citations.
- In SPPU, chemistry is the most prominent subject of research. Only chemistry has accounted for 25% of all research publications.

- As compared with the international level, the majority of SPPU faculty members work on research with Indian authors.
- There are only two SPPU authors with more than 40 h-index.

CONCLUSION

The present study evaluates the research contribution of Savitribai Phule Pune University from 1990 to 2020. Total 8602 bibliographical data has been extracted from the web of Science database. To analyse, present and evaluate bibliographical records Bibexcel, Biblioshiny, Hiscite, and Ms-excel applications were used. The study showed that the SPPU publication frequency in the last 10 years has increased. It is observed that in recent years, SPPU authors have produced quality research. It has been found that international SPPU collaboration is less than national collaboration. The SPPU contributes greatly to chemistry in research, but the University should promote other fields for research contribution.

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Conducting Polymers: A Versatile Material for Biomedical Applications

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Conducting polymers (CPs) are organic polymers with metallic conductivity or semiconducting properties which have drawn considerable attention globally. They are versatile materials because of their excellent environmental stability, electrical conductivity, economic importance as well as optical and electronic properties. CPs are interesting because they can be functionalized in several ways and the chemical properties are fine-tuned by incorporating new functionalities, making them more suitable in biomedical and other applications. They act as

1. Introduction

The new class of materials called conducting polymers (CP), discovered in 1977, has attracted increasing interest in various fields such as electronics, energy storage, tissue engineering, etextiles, hydrogel, etc.^[1] Greene and Street discovered the first inorganic conducting polymer, poly (Sulphur nitride), in 1975. Organic conducting polymers have drawn particular attention among researchers such as polyacetylene (PA), Polyaniline (PANI), and Polypyrrole (PPy). This is accounted to their prominent electrical conductivity, environmental stability, and economic importance, as well as their high mechanical, tunable electrical, and optical properties.^[2] The major development of conducting polymers was done by Alan MacDiarmid, Alan Heeger, and Hideki Shirakawa which led them to win Noble Prize in Chemistry in the year 2000.^[3] These polymers are in the range of semiconductor conductivity and have unique features such as lightweight, corrosion resistance, and flexibility. The conductivity of these materials can be influenced by the type of monomers, dopants, and the synthetic path to polymerization.^[4-6] The two most prevalent methods for synthesizing conjugated polymers are chemical and electrochemical redox polymerization. Electrochemical polymerization produces a fine polymeric layer, the thickness of which can be regulated by adjusting factors like current density and duration of electro polymerization. The polymerization is often oxidative, but reduction reactions could also be employed. During polymerization, factors such as the composition of the electrolyte and the applied current vs applied voltage, which can significantly influence the electrical and physical parameters of conducting polymers, must be properly addressed. These conducting polymers are also developed as nanocomposites or nanoparticles and find various applications in polymer chemistry.^[7-13] The most successful procedure for the preparation of polythiophene is chemical polymerization where CuCl₂ functions as an oxidizing agent and HCl and CuCl₂ are produced as byproducts. Polythiophene, a conducting polymer made of five-atom hetero aromatic rings is prepared by

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 E-mail: anitha.varghese@christuniversity.in appropriate mediums of biomolecules and can be employed to improve the speed, stability, and sensitivity of various biomedical devices. They can transit between conducting and semiconducting states and have the ability to change mechanical properties by regulated doping, chemical modifications, etc. In this paper, we review the potential biomedical uses of conducting polymers such as smart textiles, bioactuators, hydrogels, and the use of CPs in neural prosthetic devices.

polymerizing thiophene in the presence of an oxidizing agent AlCl₃ and in CS₂ solvent. Preparation conditions of polythiophene are confined because of its higher oxidation potential in comparison to pyrrole high molecular weight polyaniline was synthesized by oxidative polymerization at low temperature using (NH₄)₂S₂O₈ in acidic aqueous solutions. The reaction was performed at an optimum temperature of 35 °C. The lower molecular weight fraction could be formed by dimerization of cation radical of aniline and higher molecular weight species were formed by the integration of the oxidation mechanism. Catalytic chemical polymerization of aniline is carried with CuCl₂ or CuBr₂ which gives good yields compared to anilinium chloride. The catalytic activity of CuCl₂ is very much dependent on the solvents used for the polymerization. The acetonitrile-H₂O (1:1) medium gives the best yield, almost three times more than that given by acetonitrile. The succeeding polymerization reaction might be used for the polymerization of polyaniline. The first condition for a polymer to be conductive is bond conjugation. Trans-polyacetylene, which is also an electrically conductive polymer, is the most basic example of a conjugated double bond system. The conjugated backbone is conductive because the carbon atoms involved are sp² hybridized. A continuous π bond is formed since p orbitals of carbon atoms are parallel to each other, through which charge carriers move along the polymer chain.^[14] In the absence of charge carriers within the polymer, it is not conducive. To make a polymer conductive, bond conjugation alone is not sufficient. Apart from this, the polymer structure must be disrupted by removing or adding electrons into it (oxidation or reduction). This process is known as p doping and n doping. The doping process is a way of introducing charge carriers into conducting polymers. Doping causes the conduction band or valence band to be partially filled, or it causes polarons to be formed.^[15,16] The electronic properties of CPs are shown in Schemes 1 and 2.^[17,18] These diverse properties of CPs make them excellent in sensors, rechargeable batteries, supercapacitors, bio actuators, etc.

Numerous special properties of conducting polymers qualify them for integration with biological systems. Several applications in biomedical fields are observed in conducting polymers in medical diagnosis and treatment of damaged body parts. This includes easy functionalization with biomolecules, ionic and electrical conductivity, responsiveness, electrical stimuli, organic nature, low-cost processability, easy fabrication, etc.^[19] They have applications in batteries, light emitting diodes, antistatic coatings, chemical sensors etc. Biosensors which have

various biological sensing elements incorporated within can detect different biological materials. Conducting polymers are employed in the field of neural recording and stimulation. Electrical pulses are used to elicit precise responses in neurons via implantable electrodes. Artificial muscle and biological devices are both applications of conducting polymer-based actuators.^[20] Potential actuator materials include piezoelectric polymers and shape memory metals. The conducting polymers like PANI and PPy amongst the other CPs are appealing options in biomedical applications because of their rich redox chemistry, high cellular responsiveness, and ability to support the growth of a variety of cell types, which is an important feature of biocompatibility.^[21-24] Biocompatibility refers to a biomaterial's ability to perform medical tasks by eliciting a cellular response from a living host organism.^[25] The functional groups, chemical structures, morphology, and manufacturing processes affect the biocompatibility of conducting polymers. Conducting polymers are beneficial in biomedical applications



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2. Production of Electrically Conductive Textiles

Conductive textile materials have opened up a new world of opportunities by developing intrinsically conducting polymers (ICP). Conjugated polymers whose electrical conductivity in-



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Scheme 1. a) Polymerization of PEDOT doped with anion polymer b) Size dependence of conducting polymers due to dopant size c Polymerization of pyrrole.

smart

textiles'

creases by doping are termed intrinsically conducting polymers. Polythiophene, polypyrrole, polyaniline, polyester, and polyacetylene are some of the known conducting polymers of this type present today.^[26] Different varieties of ICPs can be made with different conductivity ranges. ICPs were developed for improved oxygen resistance and a robust, close-fitting structure, but one of the major drawbacks is low processability. Extrinsically conducting polymer composites are created by combining an insulating polymer matrix with filler materials that are conducting in a thermosetting plastic matrix. Intrinsically conductive polymers, on the other hand, are naturally conductive.^[16] Intrinsically conducting polymers such as metallic fibers are obtained from ferrous alloys, stainless steel, titanium, aluminium, and copper and are versatile in producing wearable electronic devices. Bundle drawing or shaving are the methods by which it can be manufactured. There are various ways by which electrically conducting textiles can be produced. Electrically conductive materials include conductive fibers,

performance.^[27] The simplest conducting polymer obtained by polymerization of acetylene is polyacetylene.[28] But other conducting polymers are intensively studied due to the instability of polyacetylene in the air. Inter-chain hopping of electrons and p-type conduction govern the conductivity in polypyrrole. The disorder in the polypyrrole backbone is the major limiting factor in the conductivity of PPy. Because of their nontoxicity, good electrical conductivity, and environmental stability, they are employed in smart textiles. Polyaniline appeals to people all around the world because of its thermal and chemical stability.^[29,30] It can be easily doped with organic and inorganic acids to get the conductive form. PANI is investigated primarily in the areas of drug delivery and tissue engineering.^[31] The most explored conducting polymer for smart textile application is PEDOT: PSS since it is readily available in water dispersion form.^[32]

yarns, fabrics, and final products, whose quality determines

durability, reusability, and

fibrous





Scheme 2. Polymerization mechanism of aniline.

3. The Role of Conducting Polymers in Fabric Treatment

Textile structures can be incorporated into smart materials by different methods such as embroidering, knitting, weaving, yarn spinning fiber, spinning, coating, plating, printing, etc.^[32,33] Manual application masking process, dip coating, or imprint are the methods employed in coating textiles. Coating uniformity is influenced by the coating material's viscosity and consistency, as well as the tension and permeability.^[34] Screen printing, gravure printing, and ink-jet printing are the printing procedures used to create highly conductive textile materials. One of the issues with printing conducting polymers is plate thickness. Screen printing, gravure printing, and ink-jet printing are the printing procedures used to create highly conductive textile materials. One of the issues with printing conducting polymers is plate thickness.^[35] Weremczuk et al. found that humidity sensors could be printed on textile materials using ink-jet printing technology. Another method to obtain conductive fabric is to bind a conductive structure to a basic form by embroidery techniques. This method enables machinecontrolled sewing and the use of yarns with various electric characteristics.^[26] Conductive yarns are inserted into textile fabric by weaving, knitting, or braided mechanism. Polypyrrole-coated textile fabric can be prepared by in situ polymerization of pyrrole onto the textile fabric (Figure 1). Here Ferric chloride is used as an oxidant, and the dopant used in this method is p-toluene sulphonic acid. Polyester fibers, cotton, wool, etc., can be coated by this method with polypyrrole. As alkaline pH increases, the resistance of the composite fabric increases.^[36] The SEM images of different fabrics coated with polypyrrole represented in Figure 1.

PEDOT: PSS (polyethylene dioxy thiophene: polystyrene sulphonic acid) is one of the most eminent conducting polymers in wearable smart textiles. Textiles can be treated with PEDOT: PSS by polymerization, spinning, coating/dyeing methods, the printing of PEDOT: PSS, etc. Ethylene dioxy thiophene monomer can be electrochemically coated on textile material after dispersing it in an aqueous medium by PSS. In the production of heated textiles, conductive textile materials are used. The polymerization was carried out in an electrolysis

| Table 1. Few conducting polymers and their biomedical applications along with limitations are listed. | | | | | | | |
|---|--|---|------|--|--|--|--|
| Polymers | Applications | Limitations | Ref | | | | |
| Polyaniline Polyaniline | Biosensors, neural Electrode coating | Hard to process, non-Biodegradable, limited solubility | [21] | | | | |
| +нй-<>-й-<>-й-<>-й-< | ∑=N-√n | | | | | | |
| Polypyrrole Polypyrrole | Artificial muscles and Actuators, Drug delivery | Rigid, brittle and insoluble | [22] | | | | |
| | f_{n} | | | | | | |
| Polyacetylene Polyacetylene | Actuators | Hard to process, Instability to air | [23] | | | | |
| ~\[~\] | ~ | | | | | | |
| PEDOT: PSS PEDOT: PSS | Neural probes, Biosensors, Drug delivery | Limited solubility | [21] | | | | |
| | D | | | | | | |
| Polythiophene | Biosensors, Food processing | Lack of solubility, limited processability | [23] | | | | |
| t s n | | | (22) | | | | |
| Polyfuran | secondary batteries, humidity sensors, | Low stability | [23] | | | | |
| t o h | photovoltaic cell. | | | | | | |
| Poly (p-phenylenes) Poly | Used in medicine for Sterilizable instruments made of plastic | Indefinable distribuition of molecular weight | [23] | | | | |
| (p-phenylene | s) | | | | | | |
| + | n | | | | | | |

cell containing stainless steel wires as working electrodes and cotton-based textile material. As reference and counter electrodes, Ag wires and Pt mesh were used, respectively. Adding 40micron thick steel wires to the weave enhanced the conductivity of the textile material. The cyclic voltammetry method was used to characterise the electrochemical properties of coated textile materials.^[37] PEDOT: PSS is available in water dispersed form, so roll to roll processing is suitable for textile processing applications. Textile sensors for health monitoring were developed using the roll-to-roll technique. During fibre

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Figure 1. In-situ chemical polymerization of polypyrrole into textile fabrics [Reproduced with permission from Ref. [36] © Hindawi 2015].

wet spinning or electrospinning rod, the textile is dipped in PEDOT: PSS dispersion with auxiliary chemicals. The functional group on the textile determines the uniformity and depth of coating. PEDOT: PSS is applied to the surface of the textile structure with some thickening agents to obtain a fine paste.

Sinha et al. established incorporation of screen printed PEDOT: PSS with ECG circuitry on textiles and recorded ECG signals.^[38] The formation of polyaniline [PANI] onto the fabric's surface can be done by treating the fabric with oxidant and dopant, which is then treated with aniline. Since it is a time-consuming process, in-situ polymerization on the surface of the fabric in the presence of ferric chloride as the oxidant and egyptol as the dopant at different pH values for 4 hours and 25 °C is studied.^[39] Acidic media is required for the polymerization of aniline. This method results in fabrics with distinct properties such as electrical current conduction and microbial growth resistance. This smart textile can be used for medical, biosensor, and electromagnetic shielding applications.

4. Biomedical Applications of Conducting Polymer

The use of conducting polymers in biomedical applications have seen a steep rise in the recent years. The advantage of using conducting polymer is that the structural properties could be tuned to get the desirable properties. The biomedical industry employs conducting polymers for the fabrication of several devices and biotechnology applications. The biomedical

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applications of conducting polymer includes smart textiles, tissue engineering, neural prosthetic devices, recording/stimulating devices, bioactuators and hydrogels (Figure 2).

4.1 Smart Textiles

The vital component in smart textile development is the use of conducting polymers which could be functionalized in a way to achieve the desired properties. Fabrics that can sense external conditions or stimuli such as thermal, electrical, mechanical, magnetic, etc., and intelligently respond to them are called smart textiles. Wearable instrumented garments that can record biomechanical variables have applications from medical fields and also leisure to sporting and artistic fields. They can be used for enemies' recognition or sensing of biochemical threats in the military. 'Biodegradable smart shirt' is a textile platform that uses data management-based information applications to examine vital signs or heartbeats for patients. Fashion articles have also been introduced to smart textile. Sensors that detect environmental changes or stimuli are integrated into functional smart textiles. Smart textiles are employed in clothing and accessories and are categorised as passive, active, or very smart textiles.^[40] The vibrant, smart textile can sense and react to the stimuli. They can move a part of its environment. Brilliant textiles can sense, respond and change according to stimuli. Textile is an interface between wearer and surroundings with a large surface contact, ideal for large-scale and long-term health monitoring. Power supply clothing as a headband for facial

Figure 2. Biomedical Applications of conducting polymer.

EMG, as a knee sleeve and flex sensor, or even as a pressure sensor that can provide relief from post-medical-operational health consequences.

Textile-based wearable devices were manufactured to record heart rate and ambulatory conditions in the clinic. Textrodes were developed to measure heart rate or even ECG. Textrodes have a knitted structure and are made of stainless steel fibers used in direct contact with the skin. Respibelt is a respiration rate monitor made of stainless steel yarn knitted into a belt.^[40] The Sensoria firm developed smart socks with textile sensors that can detect foot pressure. Conductive fibres in the socks transmit data to an anklet that connects to a smartphone app via Bluetooth. The Life Tech Jacket was a sophisticated new three-in-one jacket designed by Seymour Powell company for a sportswear brand that keeps users alive in difficult conditions. A smart fitness shirt was developed which absorbs the sweat from workout and uses it for power needed to display the person's vitals. Stretchable Conductive inks printed to textile fabric were launched by Dupont Microcircuit Materials (Figure 3).^[40] When a host of colored fabrics which were coated with PEDOT:PSS as electrodes for eletrochromic devices, it was found that brighter and more vibrant colours affected the experiential colours. This information was useful for the production of variety of wearable displays or stylish patterns with different colour combinations by employing different conductive fabrics and polymers.

A structural method based on Quality Function Deployment was used to design and produce smart shirts.^[41] Smart shirts were developed to oversee soldiers in battle in order to meet their needs, and the information was transferred wirelessly so that the person's movement was not disrupted. The most significant benefit of smart shirts is that they give an effective means of monitoring human vitals. The vital signs data collected by the sensors integrated into the garments is processed by the smart shirt controller before being sent to the relevant communication infrastructure. Following that, a data display and management system that receives this data in real time can deliver the appropriate response to the situation, based on the wearer's state. Another probable effect of smart shirt technology is the eventual eradication of regional or geographical restrictions for those seeking the greatest healthcare available anywhere in the world. Patients treated by regular family practitioners in remote locations can easily access healthcare specialists being in their own locality, lowering overall healthcare expenses. The data collecting capability of a smart shirt can be utilised to detect someone slipping off to diabetic shock or dozing off while driving. Smart shirts are also used to keep an eye on babies who are at risk of SIDS (sudden infant death syndrome). A sensor for monitoring

Figure 3. Application of smart textiles [Reproduced with permission from Ref. [40,43] © Emerald Group Publishing 2004 and SAGE Publications 2018]

oxygen levels or gaseous pollutants can be built into a smart shirt variant that can be worn by firefighters.^[42]

Textile fibres coated with polypyrrole exhibit good adhesion properties and environmental stability, suggesting application in the aircraft fuselage. Textile materials with antimicrobial and antibacterial properties are used in hospitals. Heating textiles, such as operating room blankets, are made with conductive textile materials. Through wearable technologies integrated into clothing, smart textile materials can be regarded an advantage in the interaction between medical staff and patients.^[4] They help in diagnosis and monitoring of vital signs, as well as enabling remote monitoring of patients via wireless communication technology. The real advantage is that the patient can access all hospital resources from their residence, where they are still monitored through telecommunication and medical professionals can interpret data. The concept of a smart house for the elderly could become a reality, allowing them to live independently while they are still being cared for.

Second skin, designers and makers of Lycra garments and splints, developed the Body Splint, an extensive splinting device. This garment is suitable for both children and adults who have been diagnosed with a neurological condition such as a traumatic brain injury or cerebral palsy. This is designed to address issues like pelvic, trunk, and shoulder postural stability, resulting in better arm and hand function. This can be worn for six to eight hours, allowing the wearer to carry out daily tasks in a modified manner.^[25]

4.2 Tissue Engineering

Tissue engineering is a branch of science that utilizes the principles of engineering and life sciences for the development of tissue scaffold.^[44] A scaffold is a structural feature that serves as a model for the regeneration of functioning tissues. The functions of scaffold include biocompatibility with tissues, acceptable biodegradable rate, non-toxic product formation and porosity for transportation of various substances.^[45-49] It

was first introduced by Barth in 1893. Basically, tissue engineering deals with the replacement of faulty, unhealthy or missing tissues or organs.^[50] The action potential produced at the synapse is the main component of neuronal communications in the body. The body-machine interface was made possible by electrically alert tissues including the brain, heart and skeletal muscle.^[51] Polymers are one of the commonly used scaffolding materials. Polymers, both natural and manmade, are used. Initially, pure CPs were employed as scaffolds enabling adhesion, propagation, and differentiation of various cell types.^[29,52] Later, to improve mechanical properties CPs are blended with degradable and more flexible polymers. Chitosan, gelatin, collage are the natural polymers and polylactide (PLA), polycaprolactone (PCL), polyurethane (PU) are the synthetic polymers in which they are used as biomaterials for tissue engineering.^[53-58] Conducting biomaterials have a wide range of applications in biosensor and bone tissue engineering due to their strong tensile strength and electrical conductivity.^[59-65]

CPs are a class of new generation organic materials that resembles metals and inorganic semiconductors in terms of their electrical and optical properties and also it can be easily synthesized.[15,66-68] Polyaniline (PANI), polypyrrole (Ppy) and polythiophene are the most attractive materials in CPs because of their physical and chemical properties. Electrically sensitive tissues such as cardiac muscles, nerve, skin and bones are frequently engineered with these materials.[69-71] Cell compatibility can be observed when current is applied to the CP but at the same time evidence of cytotoxicity was observed during prolonged exposure to current.^[72] The advantage of using CP is that the electrochemical synthesis enables polymer to be deposited on the electrode surface while protein molecules are trapped at the same time. But it has a major limitation in which the hydrophobicity of CPs prevents entrapping of proteins and maintaining their bioactivity.^[73] Conducting copolymer films are another form of modification that allows CPs to be employed in tissue engineering.^[34] As some CPs are not naturally biodegradable, their application in vivo can be minimal. This can be improved by combining aniline with CP to make a copolymer.^[74-76] PANI mixed with gelatin, which has an electrical conductivity of $4.2 \times 10^{-3} \,\text{S}\,\text{cm}^{-1}$, was employed for cardiac tissue engineering.^[77,78]

Let us consider PANI and Polypyrrole in the field of tissue engineering. PANI has wide range of application in tissue engineering because of its high environmental stability and its ability to undergo doping/dedoping process.^[79,80] PANI powders and films are biocompatible and can be implanted in the posterior region of the skin. By using covalent or physical adsorption processes, PANI thin films can be employed as substrates or coatings. This is the most desired characteristic to become a biomaterial since there is no change in bulk, only the surface modification takes place. This helps in improving biocompatibility with bioactive peptides.[81,82] The production of PCL(polycaprolactone)/PANI/Biosilicon scaffolds requires many phases of PANI film generation, and these composites display rapid calcification in simulated body fluid when electrical bias is applied cathodically to the scaffold. Polypyrrole is the most investigated CP for biological application due to its flexible method of preparation, ion exchange capacity, in vitro and in vivo biocompatibility, and helps in cell adhesion.^[24] Chemically prepared polypyrrole particles are used in immune system and in peritoneum cells that do not show any cytotoxic effect. PPy may bind to a variety of biomolecules to form biodopants, which can be employed to enhance cell development. It can trigger wound healing by changing biodopants. Both electrical and biological properties are affected by the biomolecular dopants on the resultant surface. For tissue engineering or drug delivery, some biomolecules can be encapsulated in PPy films.^[83,84] There is improved neuronal growth and neurite extension when there is PPy surface containing bioactive peptides.^[85]

There are several types of tissue engineering such as skeletal muscle, nerve, cardiac, bone and skin tissue engineering which is illustrated in Figure 4. Skeletal muscle tissue engineering deals with the differentiation and maturation of precursor cells on a scaffold in order to prefabricate muscle tissue.^[86,87] Skeletal muscles are highly organised structures made up of myofibers, blood arteries, and nerves that have the potential to regenerate, but loss of muscle function is unavoidable in extreme conditions such as trauma.[88,89] The basic structural unit of skeletal muscle is the myofiber. Because of their aligned shape, the scaffolds can imitate the anisotropic structure of elongated myofibers.^[90] Nerve tissue engineering deals with the making of conducting scaffolds with PPY and PANI for the growth and renewal of nerve tissue.^[91-93] According to studies, conductive scaffolds can keep cells actively proliferating and growing neurites, making them attractive for neural tissue engineering.^[94] For neuronal function and nerve regeneration, electrical stimulation is considered as an effective approach.^[95] The length of the neurite increases when electrical stimulation is applied to the aligned conductive sheath nanofiber, indicating its potential use in tissue engineering.^[96] Cardiac tissue engineering is concerned with conductive films that can increase the speed of calcium wave propagation and reduce the duration of calcium transients. Electrical signals propagated by cardiac cells generate the heart's excitation and contraction.^[97,98] Any destruction along the pathway of electrical signals to heart leads to cardiovascular diseases. Cardiac applications mainly focus on the mechanical properties of conducting polymer. Skin is the covering that protects human body from damage and microbial invasion. Any biomaterials that is developed for wound dressing comes under skin tissue engineering.^[99] Cellular activities like fibroblasts and keratinocytes are can be performed using conductive materials.^[49] When compared to alternative therapies, the conducting nanofibres utilised for dressing exhibited overall healing with increased collagen and granulation.^[87]

Tissue engineering is a promising field since its creation and led to the invention of various products ranging from artificial skin to bone and cartilage. This discourses the disparity that exist between patients who are awaiting donor tissue and the donors who are available. Also, there were several attempts been carried out which showed positive response, such as artery regeneration, nerve regeneration or tissue-engineered

Figure 4. Tissue engineering applications and function of conductive biomaterials [Reproduced with permission from Ref. [57,100–103] © American Chemical Society 2018, Springer Nature 2017, ScienceDirect 2018, Future Medicine 2011 and MDPI 2020].

bladder replacement. Although, there is a need of better control over mechanical and physicochemical properties. In most cases, when mechanical properties are suitable, the physico-chemical properties are insufficient due to the processing of biomaterial. At the same time, when physicochemical properties are suitable, the scaffolds may not show sufficient mechanical properties.^[104] Biomaterials are essential to the growth and advancement of tissue-engineered products. The use of tissue engineering technologies to improve connection and communication between implanted electrodes and local neurons in the neural prosthetic device is a promising approach. Many researchers have created novel neural prosthetic alterations with the goal of achieving flawless devicetissue integration.

4.3 Neural Prosthetic Devices

The necessity for high resolution and site-specific stimulation in brain prosthesis is driving microelectrode research to build smaller electrodes with extended lifetimes. Implantable neural prostheses have been widely used to improve or restore main functions of the nervous systems for patients with neural damage. Cochlear implant,^[105] spinal cord,^[106] and deep brain stimulators^[107] are some of the examples of common neural prostheses. Retinal prostheses and brain machine interfaces are new novel neural prostheses with high resolution that are actively investigated.^[108,109]

The demand for high-resolution stimulation in neural biomedical implants necessitated the development of micro-

electrodes with a high density and high-performance. Charge injection capacity is one of the most significant criteria for neural stimulation electrodes. In brain stimulation, current is sent via the electrode to supply charge, whereas in neural recording, the electrode is controlled by a high resisting amplifier with no current flowing through it. This makes maintaining lower resistance and biocompatibility challenging for neural stimulation electrodes. Stimulation electrodes serves as an interface between electronic devices and neural systems. Since high levels of charge inoculation and electric fields are administered to functional tissues and electrode materials, impairment to tissues or nerves, along with electrode materials, should be avoided.^[83,110] Functional stimulation and recording of the peripheral and central nervous systems are possible using micromachined neural prosthetic devices. When these devices are anchored to brain tissue for prolonged recording, they gradually lose electrical connection. To resolve this, the electrode locations' interfacial interaction with biological tissue must be improved. Surface modification should be carried out in order to improve signal transport at the electrode contact surface. Electrode sites consist of plain or slightly concave metal or iridium oxide pads that are placed on the surface of a silicon-based probe. It's ideal for bringing tissue and microelectrode sites closer together. To improve charge transmission, a high-efficiency interfacial region would be created. Neurons and neural processes are drawn to electrode sites by biological causes. PPy/CDPGYIGSR and PPy/CH₃COO were coated on a 4channel single-shank probe. The results of a three-day cultivation of the probe with human neuroblastoma cells along with the SEM images of PPy/ silk-like polymer having fibronectin fragments (SLPF)-coated electrode depositions at different charge passed shown in Figure 5. Neuroblastoma cells were planted preferentially onto and propagated beyond the CDPGYIGSR-containing electrode. Between two coated electrodes, a network was formed. The electrode that has the PPv/ CH₃COO coating, which is devoid of cell-binding species, did not show any symptoms of cell attraction. Researchers were able to construct a new form of microelectronic device by combining silicon-based microelectronic fabrication technique with electrochemical deposition of conducting polymer/biomolecule mixes. The surface of the device could be patterned with a variety of biochemical species, allowing for the distribution of cells that has high spatial resolution. Most importantly, cells gravitate toward electrode sites, which should facilitate communication between them. On such a device, it may be possible to build neural networks. The device might be implanted into living cells to act as a neural prosthetic system.^[24]

A variety of conducting polymers have recently been investigated as potential electrode materials for brain interfaces. They are becoming popular as neural stimulation materials because of their strong ionic conductivity and huge electroactive surface area, which allows for faster and higher charge delivery. The goal of neural prosthesis is to establish a functional link between the external environment and the neurological systems by recording or stimulating them. The grade of electrode materials determines how long neural devices last. CPs are qualified candidates who can provide an electrode-to-tissue interaction. By lowering the impedance and boosting the charge transfer density, CPs can improve the electrical performance of neural recording and stimulation.

The transport of ionic species in the tissue is required for electrical stimulation with a metal electrode. The two methods that can produce charge flow are the faradic and capacitive mechanisms.^[109] Metal electrodes are outperformed by conductive polymers. CPs are a class of organic substance that can conduct electricity. To enhance charge injection potential and bio-compatibility, the surface of a conducting polymer can be changed. So, conductive polymer coatings for neural stimulation electrodes are a promising option. Polythiophene, polypyrrole and related derivatives can be electrochemically polymerized and coated on the neural electrode from aqueous solutions.^[23] To encourage neuron development and binding to

Figure 5. Result of 3 day culture of probe with neuroblastoma cells of polypyrrole composite [Reproduced with permission from Ref. [24] © John Wiley & Sons, Inc.2001]

the electrodes, dopants such as bioactive molecules could be introduced into the polymer. $\ensuremath{^{[110]}}$

Conducting polymers are a popular alternative for nextgeneration neural interfaces, with applications ranging from stimulating and recording devices to tissue engineering for nerve and heart tissue regeneration. Certain doping agents can alter the chemical, physical and electrical characteristics of polypyrrole. PSS and sodium dodecyl benzene sulphonate are two examples. In neural scaffolds and neural electrode coating, PPy/PSS has a broad range of functions. Choi and Park found that polyaniline films made using the cyclic voltametric technique were finer and more compact than polypyrrole films. Charge injection boundaries have been observed for PEDOT coatings on neural electrodes, as well as electrochemical stability during long-term stimulation of charge densities. For greater stability, the majority of PEDOT polymers examined are p doped. Bioactive molecules can be incorporated into PEDOT films and can be polymerized in and around living neural tissue. The colour of electrochemically synthesized PEDOT films is determined by the plating condition and film thickness. Electrochemical polymerization allows control over thickness and morphology of the electrode surface well defined coating can be deposited over microelectrode. IrOx was activated on bare Ir sites, and PEDOT coatings were electrochemically deposited on microelectrode sites. The electrode was inserted into an electrically linked reservoir holding aqueous monomer solution comprising 0.001 M PEDOT in deionized water containing 2.5 mg/ml PSS. The CE is platinum foil, while the WE is the electrode position on the neural probe. Polymer was formed on electrode sites by galvanostatic electrodeposition using a current amplitude of 6nA. Over several voltametric scans, PEDOT with dopant PSS were proven to be electrochemically stable. The impedance modulus is reduced by two orders of magnitude when PEDOT/PSS coating is applied.^[111] PEDOT can be electrochemically deposited on thin film of Pt electrode of stimulation electrode arrays to evaluate its properties for chronic stimulation. Because of the large surface area and high ion conductivity all over the film, coated electrodes have lower impedance than thin film Pt. Overvoltage and linear voltage fluctuation can be seen on the coated electrode. PEDOT electrodes that were well coated remained stable under prolonged stimulation, indicating that PEDOT is a suitable candidate for long-term neural stimulation applications. Film shape, impedance, adhesive surface activity, and other parameters influence the grade of polymer coating. Other criterias include the temperature of the solution, the pH of the dopant, and the amount of doping. Uniform and compact morphology was achieved at ambient temperature during the deposition of Ppy/NaDBS coatings, whereas coarse and porous surface characteristics were formed at 4 °C.

4.4 Recording and Stimulating Devices

The focus of conducting polymer development has mostly been for neuro prosthetic electrode in the biomedical research area. This includes brain machine interfaces, considered as a recording application whereas retinal prostheses and cochlear implants being considered as primarily stimulating implants. Since the introduction of the first ECG in 1887, the recording and stimulation of tissue activity seems to have been fundamental in medical diagnosis and treatment of ailments. Implantable neural interfaces, such as neuro prosthetic devices, have provided exquisite regulation over cell recording. To study a neural response, several recording devices uses platinum or stainless-steel electrodes. Vision prosthesis, urinary pacemakers, and neuromuscular interfaces for restoration of limb function are among the devices that communicate with living organisms via implantable metallic electrodes. The relevance of CPs as recording electrodes has been studied in a lot of researches.^[111,112] CPs' long-term effectiveness is unknown due to the short time frame. The signal to noise ratio and the number of cell events are essential variables in recording electrodes.^[112] The CP coated electrodes enhance SNR and unit identification in multiple tests, however this benefit is lost when scar tissue encapsulation isolates devices. The main reason for using CPs on neurostimulating electrodes is to reduce electrode size without affecting the devices' effectiveness and security. Small electrodes on arrays are employed in stimulating devices, allowing for a greater number of stimulation areas and improved biological counter response resolution for implant receivers. In profoundly deaf guinea pig hearing perception, a combination of neural growth factor injected inside the PPy coating and electrical stimulation was claimed to improve implant efficiency.^[113]

4.5 Bioactuators

Natural muscles are electro-chemo-mechanical devices that convert chemical energy into mechanical and heat energy. The working involves the generation of an electric pulse from the brain that passes through the nervous system towards muscles.^[112] In this way, bio-actuators or artificial muscles work. Electroactive polymer actuators are commonly referred to as artificial muscles due to their muscle-like properties.^[114] When an external stimulus is applied, artificial muscles respond to changes in size and shape or produce any motion.[115] Biomedical actuators are usually made up of CP due to their change during oxidation and reduction reactions. It has a high young's modulus, high tensile strength, and requires only a very less amount of voltage compared with other materials.^[116] For bio actuator application, CP can function at room or physiological temperatures^[117] and has high resistance towards aqueous corrosive environment without any protection, such as blood.[118]

By controlling the applied voltage, volumetric expansion of CP can be maintained. The oxidised state is firmer than the reduced state due to the delocalization of electrons and the ionic crosslink at the polaron site.^[119] Several CP composites can function as actuators. Among them, PPy-PANI has the highest work per cycle. Firstly, bilayer CP actuators with one layer of CP and a non-conducting layer were created as a potential device for artificial muscle. On applying voltage, the CP (PPy) gets oxidized, and dimensional changes occur. But there is no change in the non-conducting layer (plastic layer), so the

bilayer bends. This is because of the development of a macroscopic movement at the bilayer free end. Later a triple layer CP actuator was fabricated, which consists of a two-layer of CP in which it has a third middle layer that is a non-conducting material.^[120] When current is applied on these layers, one gets oxidized, as shown in equation (1), and the other gets reduced, as shown in equation (2).^[121] The oxidized layer expands, which allows the inflow of dopant ions, and the reduced layer contracts, which makes the outflow of the dopant ions illustrated in Figure 6.

$$P^+ (A^-) + e^- \quad \leftrightarrow \quad P^0 + A^- \tag{1}$$

$$P^+$$
 $(A^-) + C^+ + e^- \leftrightarrow P^0$ (AC) (2)

where $P^+ =$ doped oxidized state of the polymer, $P^0 =$ undoped reduced state of the polymer, P^+ (A^-) = anion A^- incorporated in the polymer as the dopant ion, P^0 (AC) = a cation is inserted during reduction.

As a result, CP can mimic the sarcomere structure, which is an ideal molecular motor.^[122] Due to strong intramolecular interactions, CP chains form a compact coiled structure in their neutral state. The rate of the oxidation process determines the change in structure, which is controlled by the applied current.^[123]

Since oxidation and reduction take place simultaneously, they get translated into mechanical force, which in turn acts like muscles in the biological system.^[124] It is found that artificial muscles based on CP can also act as sensors. They can sense temperature, electrolyte concentration, and the current flowing through them. As a result, it can detect the problems along its way and make them performing. CP has several advantages over other actuator materials like piezoelectric polymers and shapes memory alloys. Its strain can be as high as 30%. The speed of the actuator's response can be examined by using different currents (5–25 mA).

A CP actuator, which is utilised as an optical endoscope for invasive surgery, can be used to create a steerable catheter. It can pass through turns in human vessels. When electrical stimulations are applied at any one end of the catheter, we can observe the contraction as well as an expansion which causes the catheter to bend.^[111] It can also be used in stretchable microvial for cell manipulation. Usually, this process is carried out in a petridish that contains a group of cells. A single cell can be studied in a microvial by shutting the lid to separate the cell from the external environment. The working principle of the lid is similar to that of a double-layer artificial muscle.

The main advantage of the CP actuator is it has low operating voltage, and it can provide higher strains than carbon nanotubes.^[124] But the efficiency of conversion from electrical to mechanical energy is less than carbon nanotubes due to electromechanical coupling. As a result, CP has limited application in large-scale actuators.^[125,126] In trilayer configuration, the energy consumed is used two times to produce the reactions and volume variations.^[126] Studies reveal that the CP actuator has many advantages over traditional ionic-polymermetal-composites in terms of conductivity, biocompatibility, responsive ability, and tunable properties.[127] However, the difficulties such as poor electroactive stability and mechanical properties^[99] and the movement of charge carriers in the CP needs to be improved for fast responses. Blending of CP with nanoparticles can solve this problem, although the biocompatibility of blended materials is a concern.^[72]

4.6 Conducting Polymer Hydrogels

Conducting polymer hydrogels are a group of composites formed with a combination of electrical functionality of CP with the mechanical properties and drug loading capacity of hydrogels.^[112] Blending with hydrogels improves the mechanical properties of CP^[124] and allows the formation of electroactive hydrogels. This combination provides the redox switching capabilities of CPs with fast ion movement and biocompatibility of hydrogels.^[30,128] PANI-PVP, PANI-polyacrylamide, and PPy/PANI-polyacrylamide hydrogels are examples of electroactive hydrogels.^[129]

Hydrogels are highly hydrophilic that swells in the aqueous environment, and it has mechanical properties similar to that

Figure 6. Polymer structure showing volume change and transition during the reaction. Anions move in the polymer film during oxidation and are released during neutralization [Reproduced with permission from Ref. [112] © ScienceDirect 2012].

of neural tissue.^[70,130] The main advantage of conducting polymer hydrogel is in medical electrodes. Bioelectrodes can deliver the charge and recording of neural activity in several neuroprosthetic devices.^[52,131-133] It has been proposed that conducting hydrogel composites will help to limit the chronic inflammatory response by reducing the strain mismatch at the tissue-electrode interface.^[134] CP coatings have limited loading capacity^[135] but conducting hydrogels have large loading capacities, allowing many drug compounds to accommodate it. In contrast, the drug release properties of CP are electrically maintained. Hydrophilic polymer can act as antifouling or antifibrotic material since it resists protein deposition.^[136] In neural interface application, alginate hydrogel is considered as the material that provides a better mechanical compatibility for neural tissue and modulates fibrotic responses.^[137]

The essential properties of conducting hydrogels include non-toxicity, biocompatibility, high electronic and ionic conductivity, porosity, and controlled morphology.[138] Polymerization of CPs is performed through hydrogel matrices, the most common method for making CP- hydrogel. In CP monomer solution, the absorbent hydrogel that is dried on a substrate is made to reswell and is polymerized by exposure to a chemical oxidant. There are alternate methods but are less common in which hydrogel and CP precursors are taken in a container and is polymerized simultaneously.^[139] The mechanical robustness of the CP hydrogel can be improved by introducing double and triple network hydrogels.[122,140,141] Consider an interfacial polymerization in which it contains two phases. The reactant side inside the hydrogel is one phase, and the second phase is outside the hydrogel. At the surface of immersed hydrogel, both the reactants meet. The conducting polymer membrane gets produced at the hydrogel surface at first when the oxidative polymerization starts. This is followed by an oxidation reaction between a monomer and an oxidant solution in which a conducting polymer separates them. The separating layer is generated by the CP, while polymerization continues on the monomer side. The concurrent transfer of protons maintains electroneutrality. Monomer (e.g., aniline hydrochloride), oxidant (e.g., ammonium peroxydisulphate), and conducting polymer (e.g., polyaniline) are some of the conceivable techniques for synthesizing hydrogels, as shown in Figure 7. Polyaniline is formed when aniline is oxidised. Peroxydisulphate accepts the electrons released in this step, forming reduced hydrogen sulphate.^[142,143] This is a method of preparing CP within the hydrogel matrix.

The significant applications of CP hydrogels are based on two streams: biosciences and energy conversion and storage. Biosensors and bio stimulation, electrostimulated drug release devices, and neural prostheses are the major promising areas of biomedicine.[144,145] Polyaniline-based hydrogel with chitosan was reported to have antimicrobial properties.^[146] It also meets the requirements for biomedical applications such as cytotoxicity, cell proliferation, and in-vivo inflammatory response.[147,148] CP hydrogels can participate in controlled drug release under a suitable environment. They can promote the electrically tunable release of several drugs, such as anti-inflammatory antibiotic,^[34,149] and anti-cancer agents. The strength and period of electrical stimulation determine the amount of drug released.; that is, polycaprolactone without any electrical stimulation can remove 40% of the drug; at the same time on the consistent application of 3 V potential destroyed its hydrogel network, resulting in the release of 90% of drug.[150] Aerogels and carbogels are the derived materials from CP hydrogels. Hydrogels, after removal of water, are turned to be macroporous material called aerogels.^[151] Aerogels obtained from polyaniline hydrogel have potential applications in neural tissue engineering. CPs are capable of converting nitrogencontaining carbons when heated above 500⁻C in an inert atmosphere. If the carbonization substrate is a hydrogel, then the resulting material can be called carbogel. The carbogel, which is formed from the conversion of polyaniline hydrogel, is used for the adsorption of creatinine. The biocompatibility of the implantable devices can be improved by conducting polymer hydrogel coating.

The conducting hydrogels used in biomedicine is ranked among soft matter which is used for stimulation and monitor-

Figure 7. The growth of PANI at the membrane interface on the monomer.

ing of cardiac cells, neural cells and tissues.^[152] For biomedical application, biodegradability is the most important property.^[86] Its porous structure maintains high concentration of drug at the targeted tissue.^[153] The water content of a swollen hydrogel determines the solute diffusion and mechanical behavior of the hydrogel. Since they can mimic the natural extracellular matrix, thereby offering support for cell migration, proliferation and adhesion.^[86] Thus, CP hydrogel can be considered as an emerging field with several advantages combined, especially as an attractive alternative, not only for drug delivery but also as scaffolding materials to fabricate artificial muscles. All these applications are dependent on the design and development of CP hydrogel.^[154] In conducting polymer hydrogels for therapeutic applications to be successful, more drug must be supplied, proper control over drug release must be gained, and longterm stability is required.^[153,154]

5. Conclusion

Substantial advancement in the development of CPs has been made in the past decades. They have been extensively utilized in biomedical applications because of their conductivity, lowcost processability, and compatibility. Biomedical applications of CP are its relation with biology that creates a new research area called organic electronics. It is noted that nanoscale CPs exhibit more properties than bulk parts. Bioengineering researchers were more attracted to this field because of the advantages of conducting polymers. This area of research is the classic example that involves expertise from chemistry, physics, biology and technology. Basically, the applications are made possible by exploiting the existence of conjugation in polymers. CPs have enchanting polymer-like properties at the same time they possess electrical and optical properties similar to metals and semiconductors.. The transmission of polarons and bipolarons is the process of electrical conductivity in conducting polymers. Several biomedical applications of conducting polymers, such as smart textiles, neural prosthesis, bioactuator, hydrogel, and tissue engineering are reviewed in this work. Smart textiles are wearable textiles that can sense external conditions and respond to them intelligently. In bioactuators, polymer converts electrical input to mechanical work. This process deals with simultaneous expansion and contraction which is similar to that of natural muscles. CP hydrogels show unique properties of combination of a material within the aqueous form that is hospitable to biological molecules. Conducting polymers are widely used in tissue engineering applications because of its capacity to electrically stimulate many cell types such as neurons, osteoblasts, fibroblasts, and skeletal myoblasts.

Conducting polymers are used to make biomedical devices that are extremely selective, specific, stable, cost-effective, and convenient. They can satisfy the material requirements in medical implants. The most often utilised CPs are PPy, PANI, PT, and PEDOT, which can be made using chemical or electrochemical redox polymerizations. Biomedical engineers functionalize CPs with different biomolecules that helps in finding different signaling pathways for various cellular processes. However, there are certain areas in which conducting polymer requires improvement. The two critical issues are biodegradability and hydrophobicity. Recently, degradable and electrically conductive polymer has developed which makes a solution for non-degradability. Using monomers containing both redox centres and hydrophilic chains that blend with CPhydrogel composites, the hydrophobicity of CP can be reduced. Another problem is that the impact of CPs on human health and the environment has not been well investigated, making it impossible to precisely estimate toxicity. Usually, the biocompatibility testing is carried out in in-vitro and, further development of these materials which can be used for clinical application requires appropriate animal studies. Investigations are being carried out to overcome all these problems associated with the field of CPs. Conducting polymers are certain to become a promising material for biological applications.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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Analysis of Challenges Experienced by Students with Online Classes During the COVID-19 Pandemic

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Abstract In the current context of the COVID-19 pandemic, due to restrictions in mobility and the closure of schools, people had to shift to work from home. India has the world's second-largest pool of internet users, yet half its population lacks internet access or knowledge to use digital services. The shift to online mediums for education has exposed the stark digital divide in the education system. The digitization of education proved to be a significant challenge for students who lacked the devices, internet facility, and infrastructure to support the online mode of education or lacked the training to use these devices. These challenges raise concerns about the effectiveness of the future of education, as teachers and students find it challenging to communicate, connect, and assess meaningful learning. This study was conducted at one of the universities in India using a purposive sampling method to understand the challenges faced by the students during the online study and their satisfaction level. This paper aims to draw insight from the survey into the concerns raised by students from different backgrounds while learning from their homes and the decline in the effectiveness of education.

Keywords Online education • Digital divide • COVID-19 • Education sector • Work from home • Teaching • Quality education • Student experience

1 Introduction

The world made an abrupt shift to online mode to reduce the mobility of people in order to tackle the spread of the pandemic. Lockdown and social distancing measures imposed due to the COVID-19 pandemic have closed educational institutions all across the country. With the closure of educational institutions across the country, the education of 300 million students in India was disrupted as they had to move on to a digital platform for learning. However, the education system in India was not equipped to deal with the abrupt shift to online education.

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India as a developing country still lacks access to digital technology and Internet service for all the citizens. They must adapt with little or no other alternatives available as they are forced to adopt a system they are not prepared for. Students who were not able to adapt due to the inaccessibility of technology or lack of digital literacy faced challenges when it came to their learning.

Teachers and students had to learn new ways to approach education as they adapted to digital learning. Classes were delivered through various online platforms like Zoom, Cisco Webex, Google Teams, etc. There are pedagogical changes that were implemented to the teaching material such as audio and video content. The transition from the traditional classroom setting with face-to-face learning to online learning was an entirely different experience for both the learners and the teachers [1]. While education is still accessible, these efforts are not likely to provide the same quality of education and student satisfaction as compared to the lectures delivered in classrooms.

This work was initiated to understand the challenges faced by the Indian teachers and students with regard to the quality of education and student satisfaction in the context of the COVID-19 pandemic. There were students and teachers from middleclass backgrounds who were also not able to arrange the infrastructure for the online classes. During the pandemic, it was observed that many schools and college students dropped out of school due to unavailability of the resources. The demand for Internet connectivity increased in the last two years. Due to pandemics, there was a major impact on the learning of the students. As the youngsters are the backbone of the country, it may have a long-term effect on the country. Considering this, the study is relevant in the current scenario.

This work presents insight into the impact of pandemics on the quality of education due to technological barriers. For this research work, a survey was conducted among the students of age group 18–29. The study has given various helpful results such as people facing challenges with an Internet connection like the lack of Internet connections at home or slow speed of network due to all workforce working from home. Other challenges were scarcity of appropriate places to connect to class, lack of knowledge about the usage of electronic devices, the concentration of the children during the class.

The rest of the chapter is designed as follows, Sect. 2 presents the discussion about the literature that gives details about the offline and online mode of education and the impact of the pandemic on the quality of education. Section 3 shows the problem defination, the research challenges and dataset description. Section 4 presents the Methodology used for data collection and data analysis. The results and discussion are presented in Sect. 5. Section 6 presents the conclusions and future directions.

2 Literature Review

Online education in India has a long history as learning content has been broadcasted through All India Radio and the Doordarshan as recorded material for both higher

education and school-going children as early as the 1960s [2]. Interestingly, after 60 years, they had to broadcast virtual classes through regional channels during the pandemic as physical education has been closed [3]. Though huge investments have been made by concerned ministries on educational content broadcasting, conclusive evidence on the positive impact of those initiatives by AIR and Doordarshan are limited [4]. The last few decades have witnessed the gradual evolution of technology from one-way telecast to teleconferencing, a dedicated national education channel, the launch of Edusat satellite to the current two-way video communication, and a plethora of technological alternatives. A significant milestone was the implementation of the right to education in 2010 with the aim of universalization of primary education. It followed a greater focus on technological upgradation in private and public schools with the distribution of laptops and tablets and the introduction of whiteboards and smartboards [5]. The last decade has also seen an array of edtech start-ups gaining a stronghold in online education in India. Between January 2014 and September 2019, more than 4450 edtech start-ups have been launched in India [6]. At the same time, these technological innovations in education cater only to less than 30% of the population that constitutes the middle or upper classes of Indian society.

The adoption of digital technology has risen significantly in the past few years, but COVID-19 has accelerated this growth to exponential levels as educational institutions across the globe were forced to shut down the physical classes. There has been a huge surge in the usage of digital tools during the pandemic, whether it is language apps, virtual tutoring, video conferencing tools, or online learning software [7]. At the same time, many educators struggled to move away from the traditional teacher-centered education as most of them had limited exposure to integrating technology into their pedagogy. When COVID-19 struck, most of the teachers had to change their methods overnight related to teaching, assessment, research, student support, and other administrative chores [8]. Although institutions are left with no other choice than to adopt online education amidst the pandemic, evidence of the challenges of effective implementation continues to build up [9].

For developing countries, with limited infrastructure for the majority of institutions, the transition to online education was a huge challenge [10]. An extensive survey conducted by QS I-Gauge revealed that the technological infrastructure in India has not developed to the level required for providing efficient and effective online education to students across the country [11]. Technical challenges like inadequate power supply and insufficient data connectivity are very much the norm in most parts of the Indian subcontinent. An added challenge is the stark urban–rural contrast and digital divide in terms of access and affordability of necessary resources that facilitate a smooth transition to online education [5]. Studies have reported an array of different concerns during the migration to a new learning space relating to policy, pedagogy, logistics, socioeconomic factors, technology, and psychosocial factors [12]. Students had to encounter various difficulties like concerns about new learning and evaluation methods, overwhelming task load, technical difficulties, and confinement [13].

3 Problem Definition, Research Challenges, and Dataset Description

3.1 Problem Definition

The problem is to analyze and measure the views of students amidst the pandemic. This paper aims at a detailed understanding of the dataset. The exploratory data analysis has been conducted using Python which helps in visualization and coming to conclusions.

3.2 Challenges

The dataset was required for the study as it was not readily available, a survey was conducted to collect the data. This data was used to measure the students' views on satisfaction during online classes and challenges faced by them to overcome the immediate need of switching to online classes due to pandemics.

3.3 Dataset Description

The primary dataset was created with the required features for the analysis. The major features considered for the study are 'age', 'Gender', 'Education_Level', 'screen_Time', 'difficulties', 'net', 'device_comfort', 'Preference', 'study_matt', 'new_device', 'o_attendance', 'o_satisfaction'.

4 Methodology

A survey of a population-based sample of college students was conducted to measure their views on online education and collect relevant data. The aim was to survey students from universities whose education was impacted due to the online studies and understand the contributing factors to the hindrance in learning online. Participants were asked to fill in the survey anonymously. The major challenge of remote learning is the disparity in access from electricity and Internet connections, the availability and affordability of the devices, etc.

The pandemic has left many of the bright minds off school due to various factors like availability of the resources to attend online classes, financial inability to procure the devices, house infrastructure to get a peaceful environment, etc. In order to address the issue, initially, domain knowledge is gained by going through previous literature in the area of online education, the impact of pandemics on education,

Fig. 1 Methodology

and understanding the kind of work done. The data was collected through a survey conducted for the college-going students, the exploratory data analysis was carried out and the inferences are represented as graphs. The Python programming language is used to code in a Jupyter notebook.

Following steps are followed involved methodology as shown in Fig. 1:

Step 1: Data Collection: Since the data which was required to conduct the research was unavailable, a survey was conducted through which the primary data was collected. This survey was directly filled by several students of the institution.

Step 2: Data Cleaning: The data collected from the survey was addressed for missing values and checked for biasedness if any. In the first round, the data collected was male dominated, so the second round of the survey was conducted targeting female participants so the bias can be removed. Then using Python missing values and null values was addressed and was replaced with the mean values for research purposes.

Step 3: Exploratory Data Analysis (EDA): This process was broken down into three parts: univariate, bivariate, and multivariate analysis. Each of them offered unique insights into the data at hand. The attributes were compared against each other to see if there were any relations.

Step 4: Data Visualization: Using the visualization tools offered by the Python programming language and its library, graphs were plotted based on the EDA.

Step 5: Building Inferences: Based on the graphs, the determination of the subject, establishment of what each category and subcategories represent, understanding the relationship between axes and diagonal line, relative percentages that each bar represents, and other inferences were made.

5 Results and Discussion

The primary data collected from the survey and the secondary data received from the national survey deliver some insight to understand the impact of the pandemic on the quality of education. Factors that impacted the quality of education were such as the

age of the child, the availability of the Internet connection, the device to attend the school, and comfort with the device usage. This section will demonstrate the results of the study to get a better understanding of the challenges faced by the students.

The choice of having offline classes rather than online classes is gender-neutral. As shown in Fig. 2, the number of females willing for in-person classes is more than the opting for online classes. Similar is the trend for the males. This choice is largely based on the need for a better understanding of the subject and getting exposure to the resources available for exploring the current trends in the technology area.

Figure 3 shows that more than 60% of the data considered for the study invested in new technological devices to facilitate online studies. The need for such purchases was highly influenced by the predicted change in learning culture with education moving online due to pandemics.

Figure 4 shows some degree of positive correlation between online class satisfaction and device comfort. In general, a trend has been seen that over time as comfort level with the device increased, the satisfaction level of the students and teachers

Fig. 3 Percentage of people purchased new devices for online classes

Percentage of People Purchased New Devices for Online Classes

also increased. The drop mapped against 7 and 8 ratings on device comfort signifies that even though the device comfort is satisfactory, individual commitment and concentration during the lecture also play a significant role in online class satisfaction.

As presented in Fig. 5, there exists a strong positive correlation between device comfort and online class satisfaction. This correlation can be well explained as a better device facilitates faster, smoother, multi-tasking, better visual and audio choices for the students. Device comfort and screen time also have a high correlation. The only negative correlation discovered is that of age and class satisfaction.

6 Conclusion and Future Work

The COVID-19 pandemic has impacted the lives of people in many ways like economically, physically, their education, career-wise, etc. The longer duration of study from home has left many children away from their regular interactive learning. However, digitization came as a bliss in many cases such as online payment, food delivery, online education but there is a major portion of underprivileged people who suffered a lot during the pandemic. It has been observed that the daily wage worker

was the one who was starving for food due to the sudden lockdown in the country. The government came up with various policies for them but the children's education was majorly left out. This is not only the condition for the poor but also for the middle class and others in society. The quiet space, Internet connectivity, connections, availability of electronic devices were some of the main concerns reported during the analysis. This pandemic needs policies to address the inequality in the education sector. The scope of online education is huge provided the required infrastructure is available. The result of the study shows that most of the students prefer offline learning over online; the device comfort plays an essential role in online class satisfaction.

In the future, the government should come up with policies that enrich learners from diverse backgrounds to adapt to the hybrid modes of learning. It should emphasize the policies which can bridge the digital divide. This not only helps individuals but also the country as a whole. In case of any such pandemic when an expert resource is required, it is easily available in the virtual environment to learn, grow, and achieve the sustainable development goal.

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Authentic leadership in a pandemic world: an exploratory study in the Indian context

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Abstract

Purpose – The purpose of this paper is to explore the strategies that helps leaders be authentic in order to be able to respond proactively and become effective in helping their organisations they lead in the context of the COVID-19 pandemic.

Design/methodology/approach – Using a qualitative approach, 25 business leaders from diverse sectors were interviewed to understand what sustained them in an adverse context.

Findings – Results reveal various dimensions of authentic leadership in a disruptive environment. Authentic leaders have to exhibit distinct behaviours that stems from re-examining oneself to reaffirming organisational purpose. Reimagining the work is emerged as the newer dimension to the authentic leadership considering the context of COVID-19.

Practical implications – The results of the study provides insights for anyone leading organisations in today's disruptive business environment. The findings of this study can be used further to undertake quantitative studies to test professional relationships and understand the leadership strategies at different time frames. **Originality/value** – This paper addresses the strategies that leaders successfully follow to withstand the COVID

crisis and highlights the different roles and behaviours that helped leaders to address the crisis confidently.

Keywords Leadership, Authentic leadership, Crisis, COVID

Paper type Research paper

Introduction

The COVID-19 outbreak has transformed the world in a very short span of time. Along with health concerns, the global pandemic has caused an unprecedented economic and social crisis that hit many industries and disrupted the way organisations operate (Donthu and Gustafsson, 2020; Smart *et al.*, 2021). The disruption has massively impacted people's livelihoods and set a new normal that has altered the ways in which people live and interact (Carroll and Conboy, 2020). Even though the global economy witnessed multiple crises from time to time, the human dimension is the one that sets the COVID-19 pandemic apart from the rest (Collings *et al.*, 2021). As the magnitude and pace of collapse of various activities are unparalleled, it becomes impossible to predict what the new world will look like. However, the shape of the new world will greatly depend on how effectively leaders take decisions today (Dirani *et al.*, 2020).

Although the extant literature studies extensively deal with the leadership in the event of a crisis (for instance, Marcus *et al.*, 2006; Betta and Owczarzak-Skomra, 2019) and had unveiled the many characteristics of effective leaders in managing during times of uncertainty (for instance, Bligh *et al.*, 2004; James and Wooten, 2005; Bhaduri, 2019), the context of the COVID-19 pandemic poses a unique and challenging test for leadership across the globe (Alam, 2020). COVID-19 seems to be acting as an accelerator for making drastic changes in the workplace in the recent past. Many organisations had to suspend or change their mode of operations which resulted in a massive adjustment in the work structure that led to a large number of workers losing their jobs (Caringal-Go *et al.*, 2021). The questions of how long the

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pandemic world COVID crisis will persist and if there will be future waves have intensified the uncertainty of organisational leaders. Managing these situations and overcoming the crisis of unprecedented magnitudes require organisational leaders to exhibit distinct competencies (Koehn, 2020). In the backdrop of this crisis, it has become important to deepen our understanding on how leaders can effectively lead their team and manage crisis in challenging times (Caringal-Go *et al.*, 2021).

There is a substantial growth in leadership theoretical frameworks and progress in specifying the patterns of leadership-forming conditions (Mumford et al., 2008; Schmid et al., 2018). In order to lead the team effectively and bring about a positive organisational climate, a considerable amount of research in the field of leadership studies suggests that leaders need to follow and practice authentic leadership (Gardner et al., 2011; Liu et al., 2017; Daraba et al., 2021). Authentic leadership is defined as "a pattern of leader behaviour that draws upon and promotes both positive psychological capacities and a positive ethical climate, to foster greater self-awareness, an internalised moral perspective, balanced processing of information, and relational transparency on the part of leaders working with followers, fostering positive self-development" (Walumbwa et al., 2008, p. 94). Authentic leadership has been linked to a wide range of employee attitudes, behaviours and outcomes. Earlier studies on examining authentic leadership suggested various antecedents, for instance, hope and optimism (Jensen and Luthans, 2006), work and non-work domain factors such as hope, family support, mentoring self, challenging life events (Sarkar, 2019) and outcomes for instance, job satisfaction (Giallonardo et al., 2010), organisational citizenship behaviours (Walumbwa et al., 2010), increased quality care (Puni and Hilton, 2020). In this study, anchored on the premise of authentic leadership, we found that in order to manage the crisis, leaders have to exhibit distinct behaviours that stems from re-examining oneself to reaffirming organisational purpose. Using an explorative method, we attempted to understand the strategies used by organisational leaders to handle the pandemic crisis from an authentic leadership perspective. Our key research question was "how are leaders tackling the pandemic crisis and what strategies can they adopt to overcome the challenges posed by the context of the pandemic?" The study contributes theoretically to the existing authentic leadership literature in the context of crisis by exploring different behaviours that help leaders to be effective. It may also provide leaders with insight on how effectively they can better respond to the crisis that continues to unfold and confidently address it.

Crisis leadership and COVID-19

Crises refer to deviant events that disrupt the routine activities of the organisation (Maitlis and Sonenshein, 2010). Organisational crisis refers to "a low-probability, high-impact event that threatens the viability of the organization and is characterized by ambiguity of cause, effect, and means of resolution, as well as by a belief that decisions must be made swiftly" (Pearson and Clair, 1998, p. 60). The COVID-19 crisis has severely impacted organisational functioning which has resulted in the altering of organisational policies and procedures in an unprecedented manner that we have not seen before. This has led many researchers to explore the implications of the pandemic on organisations (Bapuji *et al.*, 2020). Leaders in a crisis context require extraordinary behaviours that go beyond their early conventional emotional responses to threat. Moreover, they also have to move beyond regular problem solving strategies to find out solutions (James *et al.*, 2011). In a recent paper, Tourish (2020) argued that the COVID-19 crisis is essentially a crisis of leadership theory and practice and further opined that "mainstream leadership theories are of little help, since an environment of radical uncertainty means that leaders have less information, expertise and resources to guide them than is often assumed." (p. 261).

Earlier research studies have conceptualised significant elements of crisis leadership. As the crisis management comprises of varied tasks like sensing and diagnosing the problem, decision response, mobilisation of resources and execution, coordination of both internal and external information flow (Boin *et al.*, 2013), crisis leaders also need to identify and manifest competencies required at various stages of crisis situations (Wooten and James, 2008). The abilities to manage relationship, promote team work, effective communication, self-awareness and the ability to take risks are some of the essential competencies required for crisis leaders. Allied to personality traits of crisis leaders, researchers also focused on trying to understand the situational context in which a crisis occurs to authenticate the importance of leadership behaviours and traits (Zaccaro, 2007).

The COVID-19 outbreak has challenged the decades-long practices of leadership (Caringal-Go *et al.*, 2021; Farhan, 2021). It ranges from the individual level, for instance, remote working (Kirchner *et al.*, 2021), the inability to separate work and private life (Carnevale and Hatak, 2020), employee layoffs (Kniffin *et al.*, 2021) to organisational level challenges such as untold economic devastation (Bufquin *et al.*, 2021), virtual leadership and management (Kniffin *et al.*, 2021), increasing level of changing working scenarios, concern of productivity, and employee welfare (Giurge and Bohns, 2020). In this context, grounded on the idea of authentic leadership, this study unfolds how leaders behave in such situations and understand various strategies leaders follow to overcome the crisis.

Crisis and authentic leadership

Authentic leadership takes into account the ethical components of leadership and moves beyond the transformational leadership. Authentic leaders are characterised as leaders with self-awareness and a balanced approach on information processing while also exhibiting relational transparency and internalise moral perspectives (Avolio and Gardner, 2005). The active engagement of leaders to know the impact of their leadership on different stakeholders and for continues reassessment about self-concept is described as self-awareness (Delić *et al.*, 2017). During the global financial crisis scenario, authentic leadership was promoted to clear away the complexity and ambiguity (Liu *et al.*, 2018). Having a deep sense of self-awareness, authentic leaders have better self-control and can make sure that all their actions are in align with their values (Chambers *et al.*, 2010). Relational transparency describes being open and true in communication and avoid inappropriate emotional expressions and unnecessary behavioural manifestations (Peus *et al.*, 2012). As the facts keep changing in a prolonged crisis such as a pandemic, it becomes important for leaders to be authentic and transparent to stay focused on long term goals of the organisation (Erickson, 2021).

As authentic leaders uphold self-concordant behaviours, they approach questions related to morality by valuing their own judgements rather than the preferences of other stakeholders including society. Internalised moral perspective governs the consistency of authentic leaders in their decision-making behaviours which are guided by a leader's internal moral values (Delić *et al.*, 2017). The foresight to undertake a morally correct action plan or decision by having a deep analysis of the relevant information is a prominent character of authentic leaders (Walumbwa *et al.*, 2008) which results in the sustainable operation of organisations (Cavazotte *et al.*, 2021). The COVID-19 pandemic is the time for authentic leaders to rise up to the crisis and help stakeholders to overcome their fears and inspire confidence in them to perform better.

Methodology

We selected a diverse sample consisting of organisations with various characteristics with respect to industry, size and ownership that allowed us to get a comprehensive understanding on changing leadership roles in this crisis period. We conducted 25 semistructured interviews with senior professionals who were in key leadership positions with

Authentic leadership in a pandemic world many years of experience in the organisation. Expert sampling method, a purposive sampling method, is used in the study. The samples were selected after thorough deliberation about the expertise which they possess (Etikan *et al.*, 2016; Sharma, 2017). Expert sampling depends only on the experts from the area of research to be the subject of purposive sampling (Etikan et al., 2016). The demographic details of the participants are given below in Table 1.

Study design

Using semi-structured interviews with 25 industry experts from multiple selected sectors, the study explored the strategies used by managers in the context of pandemics. The interview guidelines were derived using a topic list after a literature search on leadership, authentic leadership, crisis, and leadership in crisis.

Sample

The focus of the sampling strategy was to identify industry leaders who could provide inputs about the leadership during the time of pandemic. To hold on to the heterogeneity of the study, only upper-middle and top-level managers of the organisations operating in India with 200+ employees were approached. Potential participants were sorted after analysing their work and LinkedIn profiles. Only leaders who worked with organisations with a defined hierarchical and organisational structure and who possessed some expertise in the domain were purposively selected. To enhance the relational experience in handling the employees during pandemic situations, 25 leaders aged between 30 and 60 were selected based on multiple attributes including: 5 or more years of experience in handling human resources; sector and industry; current role in the organisation; and role function. No more than one sample is selected from the same organisation.

| | | Position | Age | Experience (Yrs) | Sector |
|------------------------|----|-----------------------------|-----|------------------|----------------|
| | 1 | Team Leader | 30 | 7 | IT |
| | 2 | Manager-Risk and Compliance | 44 | 17 | Insurance |
| | 3 | Managing Director | 53 | 25 | IT |
| | 4 | IT Manager | 35 | 8 | IT |
| | 5 | Lead Manager | 28 | 6 | Logistics |
| | 6 | Marketing Manager | 47 | 12 | Hospitality |
| | 7 | HR Leader | 33 | 8 | Hospitality |
| | 8 | Vice President | 48 | 15 | Infrastructure |
| | 9 | HR Manager | 34 | 12 | Telecom |
| | 10 | Vice-President Marketing | 57 | 15 | Telecom |
| | 11 | General Manager | 59 | 9 | Logistics |
| | 12 | Marketing Manager | 42 | 17 | Logistics |
| | 13 | Senior manager | 38 | 10 | Logistics |
| | 14 | Project Manager | 47 | 19 | IT |
| | 15 | General Manager | 55 | 35 | IT |
| | 16 | Senior Assistant Manager | 36 | 9 | Pharmaceutical |
| | 17 | Assistant Manager | 45 | 15 | Technology |
| | 18 | Vice President | 51 | 17 | Logistics |
| | 19 | Deputy Manager | 51 | 17 | IT |
| | 20 | Regional Manager | 45 | 12 | Oil and gas |
| | 21 | Project Manager | 47 | 7 | FMCG |
| | 22 | Sr. Manager | 46 | 17 | Chemicals |
| | 23 | Senior Vice president | 50 | 8 | Chemicals |
| Table 1 | 24 | Manager | 56 | 26 | FMCG |
| Detail of participants | 25 | Executive Director | 49 | 11 | Hospitality |

IMD

Semi-structured interview

To portray an account narrative outlook that linked the leadership and the decision they took, leaders were asked to recollect major decisions they had taken during the time of pandemic which was essential for them to propel the organisation. The interview began by asking them to elaborate what were the major constraints that they faced while taking critical decisions for the organisations. The interviews were conducted with the help of interview guidelines that were formulated on the basis of the literature of authentic leadership (Puni and Hilton, 2020). The interview questions included the following queries: 'How do you lead your team in the COVID scenario', 'what were the key changes you think the leaders have undergone in general and what about you', 'what were the key challenges faced during the pandemic while making key decisions' and 'how do you ensure authenticity in your leadership engagement'.

Data analysis

We used a thematic analysis to address the objective of the study. Thematic analysis allows in-depth description of the data set and categorisation of specific construct (Braun and Clarke, 2019). The interviews were conducted with an exploratory view and the anonymity of the participants, and their organisations were guaranteed. All the interviews were taken either by telephone or video call and lasted for 60–90 min. The researchers were careful not to ask any leading and assumption-based questions. The interviews were recorded after taking the prior approval of participants. All the interviews were completed in one sitting; the interviewer had received permission to follow up either via mail or telephone if there was any further need. Data analysis was conducted in three stages: In the first stage, interview transcripts were thoroughly read by authors and they came out with initial codes. In the second stage, these codes were clubbed together and common categories were developed and in the final stage, after analysing the categories, a final thematic map was drawn that achieved our research objectives. In order to minimise the bias, authors shared the developed codes with research colleague to ensure interrater reliability and trustworthiness of the data (Podsakoff *et al.*, 2003).

Results

Re-inventing the self

One major theme emerged from the study is the renewed focus among leaders to reinvent themselves in this new environment. Most participants acknowledged a self-realisation that they need to modify their personal approach towards leadership. Reflecting on the changing context and their responses helped them gain insights with regard to self-transformation. As one senior manager explained,

Things are very uncertain and each day we are learning new lessons. It is the time for us to rethink about our processes, system and skill sets and act proactively. Have to continuously relook on how we react in this complex situation.

There are a few sub-themes related to the aspect of leaders' pursuit of re-inventing themselves:

Relying on anchors

It has been found that many leaders are trying to find a few anchors that can give stability, security, reassurance and the feeling of "being grounded" in their career and life amidst the chaos and disruption they face around them. It requires them to reassess their primary values and focus on strengthening their impact in their life. Though anchors vary among different

Authentic leadership in a pandemic world leaders, a few recurring ones were having a mentor, enhanced bonds with family, and personal time. A few responses from the leaders are as follows:

Family time is what keeps me going. After a hectic day with its fears and anxieties, I forget everything when I have dinner with my family and listen to my wife and daughters about what happened in their lives that day. It just cools me down. It actually help me to identify the true meaning of self

Particularly in the pandemic crisis, being authentic is everything; owning your own experiences and acting in accordance to your true self. My day begins with about 30 minutes of me-time. Whether you call it meditation or anything, that's fine. But it helps me to see things and issues with clarity.

Increasing psychological capital

Leaders rely on their inner resources to respond to the external challenges. The conviction and urge to continually strengthen the psychological capital to be more effective in their authentic leadership role was evident in the study. Authentic leaders are responsible for ensuring that their employees remain creative, open and moderate risk-takers which are outcomes of the psychological safety they experience. As one HR manager said,

I used to be too tentative and indecisive whenever I face conflicts related to staff. Having conversations with my mentor who helped me to be strong emotionally and I'm pretty good to handle difficult situations now.

Master new literacies

The self-reinvention project is also about mastering the new literacies that make one efficient in this era of unbridled technological complexity and change. Authentic leaders find themselves wanting in terms of new generation literacies like data, digital, social media literacies which have become an essential part of communicating and collaborating in the work context. Most of the respondents reiterated the need for mastering new literacies for themselves to stay relevant. Responses from of two managers are as follows,

Learn, relearn and unlearn is the mantra that I practice to overcome many bottlenecks. See how intensively technology has infiltrated in daily routine. Have to chart out new ways of doing things if you want to be relevant by integrating technology in all possible ways.

The amount of data which we have to consider is increasing exponentially as days pass on. I often feel overwhelmed by the vastness and complexity of data and constantly has to enhance my ability to draw insights from it to make evidence-based decisions.

Lead with integrity

Sustainable organisations have leaders with integrity. A culture of trust and mutual respect can only be nurtured by leaders whose words and actions are in harmony. In the context of complexity and uncertainty influencing the energy levels of the teams negatively, authentic leaders recognise their key responsibility of keeping the spirits up of their employees by manifesting more integrity and honesty. As a marketing manager said,

Without the support of your team, you cannot successfully sail through the crisis. Acting with honesty and integrity is the key. Plain speaking is what I follow.

Most of the respondents of the study observed that integrity is a key characteristic of a leader to make their institution sustainable. Here are some responses:

It's important to walk the talk. I used to introspect before I address my staff whether I truly believe in what I am saying to them.

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I am conscious that my actions can have huge reputational consequences for my company. I visualise the big picture before making decisions.

Sense of purpose

Having a proper understanding on the purpose of organisational existence helps leaders to engage and communicate with their teams in more appropriate way. Leaders take effort to percolate the purpose of existence among the employees in a clear manner so that they know their behavioural boundaries and expected outcomes.

The question of why we even exist helps to clear my routes particularly in the crisis situation and guide my team in a more focused approach.

Open to ambivalence

In a complex and uncertain environment, decision making becomes ambivalent. Leaders have to be comfortable with ambivalence due to the fuzzy nature of the information available to them for decision making. One participant of the study commented:

We have to make quick decisions, but there's hardly any clear information as to what's going to happen. Expert opinions are divided about everything about pandemic and what's in store for us as a business! Taking decisions is like a blind a leap, but leap we must!

Being transparent

In the onset of unpredictability and ambiguity, the team expects the leader to be honest and transparent in their communication as well as decision making process. The trust quotient of the leader and corresponding organisational commitment from the employees are significantly influenced by the transparency exhibited by the leaders. One senior manager noted,

Hiding the information may hamper work. Keep your employees posted about the recent changes and convince them using different channels. If you are not open to employees, a cobweb of scepticism will prevail. We have experienced it and it will have an impact on productivity.

Display flexibility

The importance of being flexible to disruptive changes has been accelerated in the wake of pandemic. Here flexibility has to pervade everything, from different decisions related to work to various relationships within and outside the organisation. One chief executive officer noted,

Everyone is under pressure in one way or the other. Understanding the scenario, we provide flexibility for instance, in work hours, punching, targets etc. It is done to show that we are very much with our employees in these difficult times.

Enduring relationships

In the context of complexity and uncertainty sapping the synergy of the teams, leaders recognise their key responsibility of building enduring relationships. Leaders observed that the relationship has to shift from a mere transactional level to a level of continuous engagement. Sometimes it requires an ability to empathise with the pain your supplier or partner goes through and involves a long-term view than a short-term profit approach. A marketing manager said,

Authentic leadership in a pandemic world Without the support of your team, you cannot successfully sail through this crisis. Ensuring that we are here for each other with support is the way forward. We conduct various activities to foster team spirit and deepen relationships.

Emotional well-being

The study has revealed leaders' heightened interest in the emotional wellbeing of self and their employees. They recognise the high stress level at the workplace due to the disruptions in business and health concerns arising from pandemic in the families. Many leaders prioritise initiatives to enhance the emotional wellness of their staff. One participant said,

Protecting ourselves as well as employees and their family members from getting exposed to virus is a major concern while they come to office. We appointed counsellors and employees can approach them to ventilate their mental stress and boost confidence.

Reaffirm the purpose

Purpose-driven organisations are well-equipped to traverse the stormy waters they find themselves in. Leaders understand their role in revisiting the purpose on which each of their businesses are being built and whether the purpose could withstand the test of the current chaos. The significant question they had to ask themselves was if their purpose is aligned with the priorities of their customers in the changed scenario. One manager said,

I strongly believe that COVID-19 has pushed us to introspect and re-examine our priorities that we had in the organisation.

Re-imagining the work

The study revealed that the leaders realise the need for re-imagining the work itself in the disrupted environment of the pandemic. The nature and process of the work has to be re-examined. In the words of one of the participants of the study

The pandemic compelled us to have a deeper look at how our company is working. We decided to eliminate non-essentials, focus on the core, and redesign different jobs.

Rethinking the workspace

If the pre-pandemic world assumed going to the office for work as the best alternative, the pandemic changed that narrative completely. After a year of living with the pandemic caused leaders to seriously consider the possibility of working remotely from anywhere as a serious choice. Though the study shows divided opinion about this option, more leaders are coming to terms with this idea and starting to redesign the workspace itself to suit this imperative. Responses from two of the participants were as follows,

The pandemic has opened our eyes to realise that it is foolish to compartmentalise between work and life. It's possible to balance between them. Now I think work can be performed effectively from anywhere, not only from the office building!

The concept of work and the language used for work is redefined. When we took an analysis of work, we found a mixed response on productivity. Few are happy and others are not. There may be various reasons for that. The point is office space or atmosphere is no more an important requirement to run the business.

Accelerate technology adoption

Over the past two decades, technology has made greater inroads in the nature of work being done. Leaders observe that technology has shifted from being a support tool to the key driver

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of work itself. As technology is being embedded in the way work is being performed, leaders are reimagining and repurposing the work in organisations. A manager said,

Technology was primarily the task of IT department. Now I realize everyone of us has equal stakes to embrace technology and make a difference in terms of productivity gains and overall impact of the job.

Preserve the natural capital

The study revealed that more and more leaders are convinced today that our planet has limited resources and they have a huge role to play in preserving the natural capital. This demands a reconsideration of the use of various resources by each organisation and a means to regenerate usage of resources. One senior manager said,

COVID also taught us how to work under severe resource constraints. Accounting for natural capital is a responsibility of every organisation.

Discussion and leadership implications

Due to the fast adaptation of the world to the new normal, being authentic is the kind of leadership that creates a positive work environment (Puni and Hilton, 2020). While analysing the context of the pandemic, the themes emerged in the study corroborate with existing studies. The sub-themes were placed into the existing authentic leadership frameworks such as self-awareness, internalised moral perspective, balanced processing and relational transparency. However, in addition to the existing dimensions of authentic leadership, a new dimension–re-imagining the work has been emerged from our study. The below Table 2 summarises the dimensions revealed in this study.

The pandemic and associated disruptions challenged much of the existing leadership paradigms. Understanding the self and being aware about the context plays an important role in determining the effectiveness of a leader in a crisis scenario. The premise of authentic leadership revolves around how deeply leaders are aware of what they think and how they act (Avolio and Gardner, 2005). Authentic leaders are recognised by others for their heightened ability to understand themselves, others and the context along with an empathetic and moral outlook (Walumbwa *et al.*, 2008). The themes emerging from the present study also revolved around leaders' ability to recognise the constraints, demands and opportunities of the self, their team, organisation and the context and respond in proactive ways to stay effective and make relevant contributions to the organisations they serve.

Our study reveals that leaders should have the self-awareness necessary to propel the organisation during the turmoil. The ever evolving process of self-discovery is considered as self-awareness (Rasheed *et al.*, 2018). Self-awareness is dynamic in nature (Dziopa and Ahern, 2009) and helps one to understand the strength and weakness which will result to be true to self and be authentic (Walumbwa *et al.*, 2008). Authentic leaders had to reinvent themselves to stay relevant and effective. The social and emotional turmoil they experienced led them to introspect on their own personal and career anchors to fall back on, having an anchor or secure base as a person, place and object that offers safety and caring and a sense of protection. It is also an inspirational source and instils energy to explore, take risks and challenge the status quo (Kohlrieser *et al.*, 2012). Previous studies show that psychological safety is very much important for an individual to be adaptive and exhibit innovative ways of doing things (Edmondson, 2018). The study reiterates the need for reliance on a few anchors and strengthening their impact on the authentic leaders' lives. Leaders also need to invest time to build their psychological capital. It is the source of self-efficacy, hope, optimism and resilience that are essential for a leader to thrive in challenging situations (Jensen and

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Table 2. Dimensions of authentic leadership

| Self awareness Internalised moral perspective Balanced processing | essing Relational transparency | *Reimagining the work |
|---|---|---|
| Re-inventing the self Relying on anchors Relying on anchors Increasing psychological Master new literacies Note(s): *authors contribution Source(s): Adapted from Walumbwa <i>et al.</i> (2008) | Being transparent Display flexibility Enduring relationship Emotional wellbeing | Reafifirm the purpose Rethink of work space Accelerate technology adoption Focus to preserve natural capital |
| | | |

Luthans, 2006). As technology has become an integral enabler of everything an organisation does at every level of the value chain, authentic leaders have to imbibe the new literacies with technology as their base. Apart from understanding and practising new literacies, leaders need to open to emerging leadership literacies to engage with an increasingly uncertain world (Pasmore *et al.*, 2019; Johansen, 2017). Also, adopting new ways of doing things by relearning and mastering new literacies is considered as a key in managing the organisations in the crisis context (Bartsch *et al.*, 2020).

Internalised moral principles marks how consistent a leader is in his/her actions and judgement (Shapira-Lishchimsky, 2014). It governs their ethical values and guides their actions (Walumbwa *et al.*, 2008). Authentic leaders will inculcate confidence and trust in their followers and thus will lead with integrity (Astin and Astin, 2001). Leading with integrity will results in exemplary leadership and positive organisational outcome (Storr, 2004). A leader's role in sustaining the organisation is about leading with integrity. Authentic leaders are characterised by an internalised moral perspective that is related to their beliefs, and values compatible with their behaviours (Walumbwa *et al.*, 2008). The biggest challenge faced by the leaders in the new environment is the sustainability of the organisation. Purpose-oriented companies report 30% higher levels of innovation and 40% higher levels of workforce retention than their competitors (Bersin, 2015). Authentic leaders have to continually communicate the purpose with conviction and build it into the core fabric of the organisation.

The study throws light on the importance of being open to ambivalence as a trait of authentic leadership in the context of pandemic. Ambivalence is the state where an employee has a mixed feeling toward the organisation (Conner and Sparks, 2002). In the context of high uncertainty, it's natural that employees can have ambivalence. The leaders should understand that employees can have a mixed feeling towards the organisation. This finding corroborates the previous studies stating that leaders have to embrace both positive and negative feelings and should be open to ambivalence. It suggests that leaders follow a balanced processing approach while evaluating the information and take an unbiased decision (Northouse, 2016). As the grey areas of the business environment increases, leaders are faced with the challenge of taking decisive action against fuzzy and muddled inputs and data. A proactive response to ambivalence can help leaders to be more creative, build a bridge between conflict and adaptation, be open cognitively for new processes and develop new behaviours to adapt to the emerging situations (Rothman *et al.*, 2017).

A leader's role to nurture enduring relationships amidst a pandemic is crucial. This theme corresponds to one of the attributes of an authentic leader in the literature called relational transparency forming trust and cooperation, and nurturing teamwork among colleagues (Avolio and Gardner, 2005). Our study observed the realisation of leaders about the need for being more transparent to all stakeholders. Managing the crisis in a disruptive environment requires an increased amount of trust between leaders and members. Higher levels of transparency are expected to build a higher level of trust between leaders and members of the organisation (Walumbwa *et al.*, 2008). Our study also revealed that most of the leaders felt managing the ongoing crisis became a key aspect of their role. Authentic leaders had to develop flexibility as a trait in terms of questioning their own mental models to discover different ways to respond to situations. As the leaders encounter unforeseen challenges for which prescriptive strategies do not work, they have to rely more on their flexible cognitive approaches to create meaningful responses.

In a work environment, where team dynamics are susceptible to trust deficit, leaders have to take the lead and ensure their team has a psychological safety net (Park *et al.*, 2020). Participants from the study emphasised the need for authentic leaders to ensure that their team members are comfortable with giving their opinions without reservations, asking for

Authentic leadership in a pandemic world support, questioning hierarchy without fear of negative consequences to build a flexible and innovative culture that can withstand the disruptive external environment. It is fundamental in psychological science that stress stems from dealing with uncertainty (Peters *et al.*, 2017). The emotional well-being of the team members is hence another significant factor to keep the team members energised (Bartsch *et al.*, 2020). Being available for open dialogue, displaying integrity and empathy, and organising relatable engagement events are all means by which authentic leaders can foster the emotional well-being as well as engagement at the workplace.

In addition to the themes that emerged in the study and that were corroborated with extant literature, reimagining the work is the additional theme emerged in this study. particularly in the context of the pandemic. We found that along with the existing dimensions of authentic leadership, this new theme-reimagining the work-consists of sub themes such as reaffirming the purpose, rethinking of work space, accelerating technology adoption and focus to preserve natural capital. The pandemic context and associated risks and disruption challenged the leaders to reimagine their work itself. Leaders had to think beyond incremental gains and efficiency-boosting activities, and explore new sources of value and meaning to remain relevant in the market (Schwartz, 2021). One dimension of the new work is the changed context of work itself, work from anywhere. In the study, leaders recognise the need for redesigning the work to make it more result-driven in the context of work from anywhere. Social support has been identified as a key variable by helping remote workers overcome social isolation, leaders have to consider this dimension to make remote working more effective. Technology has been recognised as the game changer for future organisations by all the leaders in the study. As organisations prioritise digital transformation as the primary strategy for adapting to the future, leaders are willing to invest in upgrading their technology irrespective of the industry. Many leaders in the study expressed their anxiety with regard to the overstretched resources on account of unexpected business disruption. The new normal demands a greater judicious as well as optimised use of resources by organisations to survive the testing times. The work has to be revisioned to capitalise on the optimum use of available resources.

Other sub themes emerged in relation to reimagining the work were digital transformation of businesses through technology adoption and the increased concern for preserving natural capital. Reimagining the workplace with a sensitivity to the interdependence of human and ecosystem would be a significant attribute of authentic leadership.

Conclusion and limitations

The current study is a re-visualisation of authentic leadership in a changed context of crisis and disruption brought by the pandemic. It has brought forth five key dimensions of authentic leadership in which four were corroborated with existing studies and one has emerged as an additional dimension considering the pandemic context. These combined dimensions are important for an authentic leader has to interact with and transform in order to remain effective and create meaningful impact. It starts with established dimension of selfawareness – the realm of self and reinventing oneself. Subsequently, all the themes revealed in the study are mapped with the existing dimensions of authentic leadership. Reimagining the work is the fresh attribute of an authentic leader emerging from the disruptive context itself. An authentic leader's credibility comes from his/her ability to sustain the organisation amidst chaos and destruction.

It is clear that leading an organisation during a crisis is distinctively different from leading in a normal time. Our study further indicates that the new normal demands authentic leaders for self-reinforcement, adoption of new practices and procedures to engage with teams and reaffirm organisational purpose to meet the challenges and create a positive impact. Since the study is of exploratory nature by approaching leaders at diverse sectors in India, we urge further systematic studies are required to understand how leaders are effectively engaging with specific sectors. Longitudinal studies will be required to understand the effectiveness of leadership during pandemic and explicate the relationship in different time frames. Also, future studies can be conducted to extrapolate current findings to conduct quantitative studies that will help to triangulate the data and enrich these insights.

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THE EFFECTS OF YOGA AND MEDITATION ON THE STRESS LEVELS OF INDIAN LOCO PILOTS: WITH REFERENCE TO PUNE DIVISIONAL RAILWAYS

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Abstract:

Indian Railways is one of the industries that contribute significantly to National Development and job generation. The Loco Pilot job is a prestigious and well-paid position, but it is also extremely demanding, and it is regarded as a job that causes occupational stress. Hypertension is a widespread medical issue that affects people all over the world. High blood pressure is caused by a combination of factors including work load and stress. It can lead to heart stroke and death if not treated promptly. Yoga is an ancient discipline that combines postures, breath control, and meditation. It's a type of alternative medicine that's said to help with blood pressure regulation. The purpose of the study on Occupational stress among Loco Pilots of Pune region was to determine the effectiveness of Yoga and Meditation in reducing hypertension caused by work stress. An intervention by a Clinical Psychologist was used in conjunction with an experimental test group of 63 Loco Pilots aged 25 to 50. For stress management, this group had to participate in a one-week meditation and yoga programme. This study also makes dietary and physical activity suggestions for reducing work stress in the experimental group.

Keywords: Yoga, Meditation, Loco Pilots, Occupational Stress, Indian Railways.

Introduction:

Occupational stress, which is caused by a combination of high job demands, has been related to the development of hypertension and is a primary cause of cardiovascular deaths in the world. Employees in India's railways are under a lot of stress at work. Overtime, shift work, and workplace accidents are some prime elements that contribute to stressful working conditions among Loco Pilots leading adverse health conditions, including hypertension.

Yoga has been shown to aid with a variety of health issues, as well as stress management. It is effective in the management of work-related stress which leads to cardiovascular disorders such as ischemic heart disease, coronary artery disease, angina, chronic heart failure, hypertension and also digestive disorders such as irritable bowel syndrome, hyperacidity, colitis and indigestion. Many Yogic poses are beneficial for stress relief and they are beneficial for maintaining excellent health, preventing sickness, and rehabilitation.

Mental silence-oriented Sahaja Yoga meditation is a safe and effective strategy for dealing with work stress and depressive feelings. Yoga meditations have unique benefits on job stress and, as a result, occupational health.

Studies have revealed that certain Yoga postures like Shavasana and Sahaja Meditation can benefit employees in coping with Occupational Stress.

The objective of this study is to see how Yoga and Meditation will help Indian Loco Pilots with stress-related hypertension. The study group included 63 Loco Pilots from Pune Railway Division for the purpose of the experiment. An eight days program was organized in conjunction with a Clinical Psychologist and a Yoga trainer. Observations were recorded for employees with hypertension before and after the conduct of the program.

Objective of Study

1. The purpose of this paper is to determine the effectiveness of Yoga and meditation practices in lowering stress levels among Loco Pilots of Indian Railways.

2. This study will examine a variety of resources in order to determine the function of Yoga and meditation in occupational stress management.

Scope Of The Study

- i. The Scope of this research paper is limited to Loco Pilots of Pune Divisional Railways.
- ii. The Scope can be further extended to other sectors where the employees exhibit Occupational Stress.

Review of Literature

(**Raja & Muthukumaran, 2015**)¹ "A study about work place stress in Food Industries in Various Level of Employees in India" identified that the pressure in the workplace is inevitable because of the work demand. Total burn rate of people employed in the food industry is one of the highest. The pressure of work, labor demand, without control over labor, long working hours, trying to please all, miscommunication, the responsibilities of the job are important factors of the stress. Stress can be handled positively or negatively depending on the situation. Different strategies are used by them to manage stress as writing the wish list, time management, talk to others, exercise or meditation, review your goals, stop worrying and learn to say "no".

Bratman GN, Hamilton JP, Hahn KS(2015)^2 Nature experience reduces rumination and subgenual prefrontal cortex activation. American Heart association in their several articles like "10 Ways to Relax in Nature and Stress Less", "Spend Time in Nature to Reduce Stress and Anxiety" identifies the importance of nature in reducing the stress level of an individual. It suggests that if we spend time out in nature it can help us emotionally, mentally and physically. Spending time in nature can help relieve stress and anxiety, improve the mood and also boost feelings of happiness and well being. Research shows that a 90-minute walk in nature lowers activity in the part of the brain linked to negative rumination.

Najmoddin Nekzada and Selama witFisseha Tekeste (2013)³ in their thesis "A qualitative study on the causes of stress and management mechanisms at Volvo Trucks AB, Umea" discusses the kinds of stress that an employee of a multinational company has. The study was based on qualitative approach, with a descriptive and exploratory case study approach. The data used are collected through conducting semi-structured interviews with 6 different employees from Volvo Trucks AB, Umea one of whom works as a therapist at the company. The study concluded that the causes of stress at the work place range from personal problems to work overload physical working environment, work situation and conflicts among colleagues and managers. Many employees struggle with stress, in worst cases leading to uncertainties and severe impairments on health and performance.

Hari Kumar P $(2012)^4$ "Stress among airport employees a case study of Bangalore International Airport" reveals that the stress among airport employees are at very high level because of the complexity in their work involved. According to several surveys, the main sources of stress reported by airport employees are connected both to operative aspects and to organizational culture. The airport employees, despite their rank or field of working, always have to run under the pressure of time to deliver the services which should not only be valuable to the customers but also proficient to the employee and therefore have to undergo tremendous stress during the working Title: Stress among airport employees a case study of Bangalore International Airport

Suparn Sharma and Jyoti Sharma (2008)⁵ "Stress and cope-up strategies of service sector executives" has studied Stress has become a part of everyday life Live each individual. Stress differs from person to person. Work demanding, stressful relationship and excessive working hours may be the cause. To overcome the problem, listen to music on medication for depression, attend social activities, balanced diet, go for a walk, etc., can reduce the stress level. Management programs stress

¹Raja, D. V., & Muthukumaran, M. (2015). A study about work place stress in Food Industries in Various Level of

Employees in India. International Journal of Advanced Research in Management (IJARM) , 6 (2), 14-20

²Bratman GN, Hamilton JP, Hahn KS et al (2015) "Nature experience reduces rumination and subgenual prefrontal cortex activation". Psychological and Cognitive Sciences, doi: 10.1073/pnas.1510459112

³Najmoddin Nekzada and SelamawitF isseha Tekeste (2013), "A qualitative study on the causes of stress and management mechanisms at Volvo Trucks AB, Umea" Umeå School of Business and Economics, Spring semester 2013, Bachelor thesis, 15 hp.https://www.diva-portal.org/smash/get/diva2:693132/FULLTEXT01.pdf

⁴Hari Kumar P (2012), "Stress among airport employees a case study of Bangalore International Airport" PhD University of Mysore, http://hdl.handle.net/10603/73373

⁵Suparn Sharma and Jyoti Sharma (2008) "Stress and cope-up strategies of service sector executives" Indian Management Studies Journal 12 (2008) Pg.19-35

can be effective tools to control. It is essential to identify the factors that lead to stress in order to fight and overcome

Methods and Materials

The intervention period for the experimental group was 8 days, with 1-hour Yoga and Meditation sessions. The group was instructed to practice for 20–30 minutes twice a day at home. Each instructional session emphasized the need of abiding to this routine. Instructors for the experimental group were experienced and qualified meditation Clinical Psychologist and Yoga Instructors.

Participants

63 Participants in the age group of 25 to 55 who have been in service from 5 to more than 25 years in service were selected for the Yoga and Meditation sessions.

Interventions

An awareness programme was initially held under the supervision of a Clinical Psychologist to inform the group about the upcoming sessions. Questionnaires were given out to determine whether they had any stress-related health problems and if they had hypertension. A physical examination was performed to evaluate vital signs, as well as the measurement and recording of blood pressure.

Sukhasana, Balasana, Setu Bandha Sarvangasana, and Savasana were among the yoga poses demonstrated to the attendees. The experimental group was taught how to induce mental stillness, sometimes known as "thoughtless awareness." The method is based on Sahaja yoga, a noncommercial and "traditional" approach to meditation. The core approach is based on a conventional understanding of yogic psychophysiology and uses a simple series of silent affirmations. Meditation was promoted as subjects sat silently in a chair or in a comfortable position that aided their meditation experience.

Data Collection and Analysis

Primary and Secondary Data Collection method was used. Structured Questionnaire was administered to 63 Participants in the age group of 25 to 55 and Years in service from 5 to more than 25 years were selected as the experimental group.

| Tuble 2 Tereeprior regurang neural complaints | among Loco | i noto do per | jeurs of service (10 of ugree) | |
|--|------------|---------------|--------------------------------|--------------|
| Statement | Up to 5 | 6 to 15 | 16 to 25 | More than 25 |
| You suffer from Hypertension | 3 | 19 | 11 | 30 |
| You quickly feel short of breath. | 21 | 16 | 12 | 14 |
| You occasionally feel pain in the chest or heart | 20 | 15 | 12 | 16 |
| region. | | | | |
| You frequently feel tired. | 20 | 15 | 17 | 11 |
| You occasionally suffer from a headache. | 28 | 7 | 3 | 25 |
| You occasionally have an upset stomach. | 19 | 14 | 17 | 13 |
| You experience a numbing feeling or a tingling | 18 | 12 | 17 | 16 |
| sensation in your limbs. | | | | |
| You occasionally feel pressure or swelling in your | 17 | 16 | 12 | 18 |
| stomach | | | | |

Table 2.4. Perception regarding health complaints among Loco Pilots as per years of service (% of agree)

From the above table we can infer that Loco Pilots

1. In service for more than 25 years suffer from Hypertension and Headaches.

2. In Service up to 5 years suffer from Headaches, experience numbress in limbs and have stomach related complaints with occasional chest pain and shortness of breath.

Chart 2.4. Perception regarding health complaints among Loco Pilots as per years of service

From the above Chart it is evident that Loco Pilots undergo Occupational stress and have symptoms related to Hypertension including chest pain, numbress, breathlessness and headache.

Loco Pilots In service for more than 25 years suffer from Chronic Hypertension and Headaches. While those in Service up to 5 years suffer from Headaches, experience numbress in limbs and have stomach related complaints with occasional chest pain and shortness of breath.

Results

The percentage changes in primary outcome scores were labelled "1" for improvements of 50% or greater and "0" for changes of less than 50%. After completing the training, both Occupational Stress symptoms including Headache and Hypertension reduced significantly (HT). Diastolic and Systolic Blood Pressure were found to have reduced in 81 percent of the patients.

Findings

Yoga and meditation have traditionally been associated with stress reduction due to their capacity to diminish physiological arousal. Yoga Postures and Sahaj Yoga style of meditation efficiently reduce physiological responses to stress.

1. Out of 63 Loco Pilots, 47% working for more that 25 years exhibited chronic Hypertension, as compared to 25% Loco pilots working for up to 15 years who had occasional hypertension and chest pain.

2. Yoga Asana's including Sukhasana, Balasana, Setu Bandha Sarvangasana, and Savasana have proved to be an effective tool for occupational stress management, the study shows that in 81% of Loco Pilots in the experiment group, Hypertension was reduced significantly.

3. Sahaj Yoga style of meditation efficiently reduce physiological responses to stress by having a calming effect on the mind. 4. All 63 respondents i.e. 100% of the Loco Pilots under the study have concluded by stating that they have reduced depression, reduced headaches and chest pain. 81% of them have reduced Hypertension 10 normal BP Ranges (i.e. an average between 120/80 to 130/90).

Conclusion

1. This study presents preliminary data to support the use of a Yoga and Meditation (Sahaja Yoga) programme to reduce job stress and hypertension among Loco Pilots. While the findings are interesting, more research is needed to evaluate and explore them.

2. Given the low cost, noncommercial nature of the intervention, and the low risk of adverse effects, it is not unreasonable to propose that this meditation could be effective as a health enhancing technique with great socioeconomic value to individuals and society.

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