ARTICLE

Impact of the organ-system integrated curriculum on the research productivity of a Philippine government medical school: An ARIMA-based bibliometric analysis

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ABSTRACT

The organ-system integrated (OSI) curriculum was pioneered in the country by the U.P. College of Medicine (UPCM) in 2004. Data on its impact on research productivity was lacking. This study aims to describe the trends in research productivity of UPCM in a time series and the impact of OSI implementation on publication trends. Relevant electronic databases (PubMed, Scopus, and WPRIM) were searched from the earliest indexed record until December 2023. The auto-regressive integrated moving average (ARIMA) time series analysis was used to compare the actual and predicted trends during the OSI implementation using the pre-OSI trend. A total of 2,705 articles were included. *Acta Medica Philippina* is the journal with the highest number of publications (n = 420, 20.24%). Although there is a considerable rise in the number of publications utilizing evidence synthesis and qualitative design, observational studies remain as the most common design (n = 293, 2021-2023 period). The leading clinical departments are Neurosciences and Medicine. The departments of Biochemistry and Clinical Epidemiology take the lead among basic sciences departments. Despite the glaring uptrend in publications

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KEYWORDS

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concurrent with OSI implementation, the actual trend is not significantly different from the predicted trend (LR $chi^2(1) = 0.37$; Prob > $chi^2 = 0.5432$). The OSI curriculum did not significantly change the trend of productivity. Medical curriculum designers should revisit strategies dedicated for research competencies. It is imperative to include activities for qualitative and mixed-methods designs. Future studies should consider relevant critical events in the time series forecasting models and the scientific outputs in the grey literature.

INTRODUCTION

Background

Research is an integral part of academic and clinical medicine. It continuously expands the frontiers of medical knowledge, opens doors to breakthrough discoveries, and enhances our understanding of the human body structure and functions, the mechanisms of diseases, and the potential treatments. Medical research allows clinicians to explore the causes and risk factors of the diseases and to empirically evaluate the impact of interventions (Diderichsen 2018). Sound appraisal and application of evidence from medical literature guide clinicians in their clinical decision-making. Furthermore, evidence from medical research influences health policy and is therefore fundamental in improving health and economic systems (Cruz Rivera et al. 2017). Arguably, competencies related to the conduct and appraisal of medical research are becoming integral components of medical education and training. In the United States, the Accreditation Council for Graduate Medical Education (ACGME) already included in the list of core competencies of physicians the knowledge and skills related to research - project understanding, technical skills, attention to details, analytical ability, communication with preceptor and research team members, and professionalism (Adkison and Glaros 2012). In the Philippines, the Commission on Higher Education (CHED), through the memorandum order number 18 series of 2016, emphasized that one of the ten program outcomes of medical graduates is engaging in research activities. Furthermore, the Philippine National Academy of Science and Technology clearly stipulated that research is one of the nine aspects to be evaluated in the accreditation of medical schools in the country (Arcadio 2017). It is, therefore, imperative to formalize teaching and learning activities related to research in the medical curriculum.

The past three decades have suggested the inevitability of the inclusion of research competencies and evidence-based medicine in the medical curriculum (Sehon and Stanley 2003). Coincidentally, curricular reforms in medical schools have emerged in the recent decades as well. As of November 2023, there are already 71 medical schools in the Philippines. Although there are strong forces that push for the implementation of outcomes-based medical education in the Philippines – the Philippine Qualifications Framework, the CHED memorandum on outcomes-based and typology-based quality assurance, and the global call for transformative education (Sana et al. 2015) – the medical schools still have the freedom to implement their own curricular strategies based on their philosophical and epistemological foundations (Atienza 2017). Majority of the medical schools adopt either the traditional discipline-based curriculum or the eclectic curricula (Atienza 2017).

In 2004, the University of the Philippines College of Medicine (UPCM) introduced and implemented the organ system integrated (OSI) curriculum. The aim of this innovation is to eliminate barriers among basic medical and clinical disciplines through the implementation of integrative approaches in teaching-learning activities. Inevitably, new courses involving student-led research projects and scientific literature appraisal were introduced as well as various research elective courses. The following are the new OSI courses that aim to develop research-related competencies among medical students: interdisciplinary course (IDC) 211 introduction to basic health research; IDC 211.1 laboratory research methods; IDC 213 introduction to evidence-based medicine; and other research elective courses in biochemistry (Biochem 291), clinical epidemiology (Clin Epi 291), medicine (Med 291), neurosciences (Neurosc 291), obstetrics and gynecology (Ob Gyn 291), ophthalmology (Ophtha 291), otorhinolaryngology (ORL 291), orthopedics (Ortho 291), parasitology (Para 291), pathology (Patho 291), pediatrics (Pedia 291.1), pharmacology (Pharma 291), and physiology (Physio 291). The introduction of OSI, however, was accompanied by significant changes in the faculty workload as well. In the traditional curriculum, much of the teaching-learning activities were centered on large plenary lectures with a single faculty delivering instructions to a hundred medical students at a given point in time. In the OSI curriculum, the teaching-learning activities are mostly in the form of small-group discussions requiring a dozen faculty members to cater to the learning needs of more than a hundred medical students.

Recent studies suggest that curricular strategies influence the students' engagement in research activities. In a cross-sectional study done in a medical school in India, the majority of students who participated in a competency-based research training module reported feeling satisfied and motivated to conduct more research projects (Patra and Khan 2019). Furthermore, a recent mixed-method study done in the United Kingdom demonstrated that exposure to appropriate curricular opportunities could significantly influence the development of research skills of medical students (Murdoch-Eaton et al. 2010). Organizational research culture also influences research productivity. In a recent cross-sectional study done among medical practitioners in a tertiary healthcare facility in Queensland, Australia, a positive correlation between number of publications and self-reported research capability and culture was demonstrated (Brandenburg et al. 2021). It can be surmised that the type of medical curriculum, especially if the curriculum follows an integrative perspective and features teaching-learning activities on research competencies, could potentially influence the research productivity of medical students and faculty. Demonstration of the potential influence of curricular strategies in OSI on the research productivity of the medical students and faculty in the Philippines, however, is still lacking. In this study, research productivity is operationally defined as the number of publications in peer-reviewed and/or indexed journals.

Objectives

1.) This study aims to describe the trends in research productivity of medical students and faculty of UPCM collectively. Specifically, this study intends to describe the number and types of studies published by investigators and co-investigators affiliated with the various departments of UPCM across time.

2.) This study also aims to demonstrate the impact of the implementation of the OSI curriculum on the publication trend of UPCM. Specifically, this study intends to compare the 2004-2023 (period of OSI implementation) forecasted publication trend using 1981-2003 (pre-OSI implementation) data series and the actual 2004-2023 publication trend using auto-regressive integrated moving average (ARIMA) time series analysis.
H_0 = The actual and forecasted 2004-2023 publication trends of UCPM students and faculty are similar.
H_1 = The actual and forecasted 2004-2023 publication trends of UPCM students and faculty are significantly different (two-tailed).

Purpose

Findings of this study will not only describe the current landscape of and the trends in research productivity of students and faculty of a medical school implementing the OSI curriculum but will also pave the way for appropriate and impactful reforms in the design and implementation of medical curricula in the country. Demonstrating the trend in the type of studies being conducted by UPCM investigators could dictate the prioritization of contents of various research-related courses (e.g., a growing trend in the number of studies utilizing qualitative methods could influence curriculum designers to prioritize contents related to this methodology). Furthermore, demonstration of the distribution of publications based on the departments involved could highlight which departments might need to revise their existing research-related courses and which departments could serve as benchmarks in terms of implementation of such courses.

METHODS

Inclusion criteria

All published articles that used any study design including randomized control trials, quasi-experimental trials (non-randomized control studies, before-and-after studies, or interrupted time series), observational-analytical studies (cohort studies, case-control studies, or analytical cross-sectional studies), descriptive studies (qualitative or cross-sectional surveys), case series or reports, literature reviews, and evidence synthesis studies (systematic reviews or meta-analyses) were included. Abstract-only publications, commentaries, editorials, conference proceedings, letters to the editor, book chapters, and incomplete or terminated studies were not included. All studies with at least one investigator or co-investigator who are affiliated with the UPCM during the conduct of the study that are published in English, or in any other language provided that they had an English abstract, were considered for inclusion.

Search methods and study selection process

The following electronic databases were searched for relevant articles: MEDLINE via PubMed, Scopus, and the World Health Organization Western Pacific Region Index Medicus (WPRIM). MEDLINE via PubMed was chosen for its versatile advanced search features and because it is dubbed as the most commonly used free platform for searching medical literature (Misra and Ravindran 2022). Scopus on the other hand is considered as one of the most diverse subscription-based database for science-related articles (Burnham 2006). The WPRIM is the official World Health Organization online index of medical and health journals of the member states of the Western Pacific Region including the Philippines. Two authors (CWRT and AJRM) performed the literature search from January 1 to 3, 2024. Articles from the earliest indexed record up to December 31, 2023 were included. The following term-based search strategy was used: (University of the Philippines College of Medicine[Affiliation]) OR (Philippine General Hospital[Affiliation]). Duplicate entries were excluded. Abstracts of the remaining studies were retrieved for screening. Studies with no investigators or co-investigators from UPCM were excluded. The full-text articles of the remaining entries were retrieved and were subjected to eligibility testing using the predefined inclusion criteria as stated above.

Descriptive data analysis

The following details were retrieved: year of publication, indexed journal, type of study, and the UPCM department involved in the study. In alignment to the first objective, the details regarding the departments involved were extracted to describe the trend of research productivity of each department and to demonstrate if there is increasing trend in collaborative projects among departments. Intuitively, the implementation of an integrative curriculum such as OSI could minimize, if not eliminate, the departmentalization and compartmentalization of research endeavors and other related teaching-learning activities (Magoma 2016; Drake and Reid 2020). Differentiating between student-led and faculty-led articles could not be implemented as the indexing systems of the involved databases do not discriminate in terms of author status and/or type of institutional affiliation. The trends in the total number of publications and the corresponding breakdown in terms of type of study department involved from the earliest indexed article to December 31, 2023 were summarized in appropriate line graphs. The indexed journals with highest number of publications were summarized in tabular form. Descriptive data were manually collated and summarized by two authors (CWRT and AJRM) using Microsoft® Excel for Mac. The descriptive data analysis is primarily intended to satisfy the first objective indicated above.

Inferential data analysis

The auto-regressive integrated moving average (ARIMA) modeling for time series data forecasting was used to predict a 2004-2023 trend in the number of publications using the actual 1981-2003 trend. This predicted trend would be compared to the actual 2004-2023 trend from the obtained bibliometric data. This statistical modeling is appropriate as this accounts for the pattern of decline or growth in the data, the rate of decline or growth, and the deviations between consecutive points given a time series data (Said and Dickey 1985). The ARIMA modelling process begun by examining the stationarity assumption of the time series data. Visual examination was done using line graph and statistical assessment was done through Augmented Dickey-Fuller test. A large negative Z(t) value and MacKinnon p-value less than 0.05 were used to identify violation of stationarity. As the time series data showed an inclining trend, the data was differenced to satisfy the stationarity assumption. Correlograms were used to identify the ARIMA (p, d, q) sequence. The MA sequence was determined using autocorrelations while the AR sequence was determined using partial autocorrelations. A total of three ARIMA sequence were identified: ARIMA (1,1,1), ARIMA (2,1,1), and ARIMA (1,2,1). The best model was chosen based on the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) for which the third ARIMA model showed the smallest, thus the best, AIC and BIC values. A likelihood ratio test was used to determine if an addition of a covariate (OSI) in the model would significantly improve the model. Both dynamic and one-step forecasting were done to forecast the frequency of publications from 2004-2023. Diagnostic checking of the model was done by examining the autocorrelation plot (autocorrelation decay to zero) and eigenvalues of AR (stability condition) and MA (invertibility condition) parameters. Although the publication trend from the earliest indexed journal was included in the descriptive data analysis, only the data from 1981 to 2023 were included in the ARIMA modeling as this period is officially labeled as a period of relative socio-political stability in the country (Sodusta and Palongpalong 1982). Prior to this period was an era of political turmoil and militaristic regime. During this era, radicalism and activism were prominent among the students of the University of the Philippines (Abinales 2008). Although the actual influence of this socio-political instability on research productivity has not yet been empirically documented, several related accounts suggest that socio-political instability leads to suboptimal public education quality (Nir and Sharma Kafle 2013; Devi 2017) and poor learning experience and motivation (Fung 2021). All statistical analyses were conducted using the Stata Statistical Software: Release 18. The inferential data analysis is intended to satisfy the second objective as stated above.

RESULTS

Included studies

A total of 3,129 studies were obtained using the term-based search strategy (PubMed: 884; Scopus: 2,207; and WPRIM: 38). A total of 470 publications were identified as duplicates and were excluded. A total of 2,659 publications were screened and 540 publications with no UPCM-affiliated investigator or co-investigator were excluded. The full text of the remaining 2,119 publications were obtained and were assessed for eligibility. A total of 2,075 publications satisfied the criteria for inclusion and were included in the analysis. Figure 1 shows the PRISMA flow diagram.

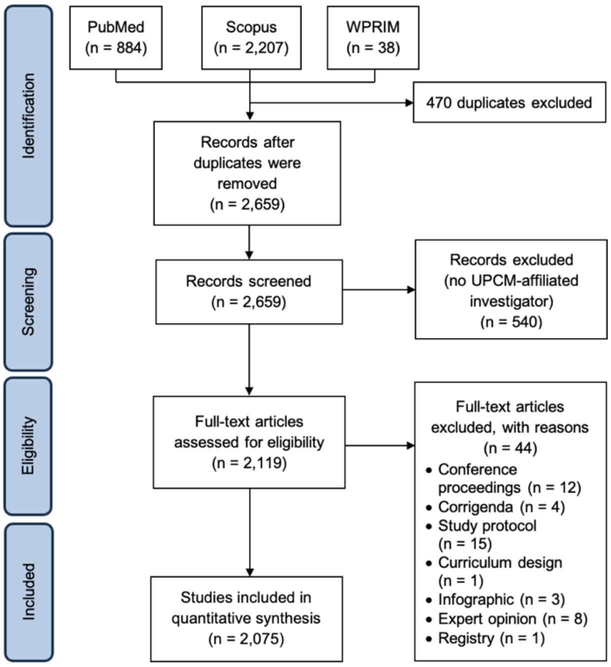

Figure 1: PRISMA Flow Diagram for Study Selection

Descriptive data: Trends in publications from 1913 to 2023

Figure 2 summarizes the publication trend of UPCM from the earliest indexed publication in 1913 to December 2023. There is an apparent increase in the number of publications from zero to nine publications per year in 1913 to 2002 to 10 to 62 in 2003 to 2016 eventually reaching the hundreds mark starting 2017. The biggest leap in terms of number of publications occurred between 2019 (n = 119) and 2020 (n = 229). The year with the highest number of publications is 2022 (n = 349).

Table 1 summarizes the indexed journals with the highest number of publications from UPCM-affiliated authors. *Acta Medica Philippina*, the official indexed journal for health-related studies of the University of the Philippines Manila, had the highest number of publications (n = 420) followed by the *British Medical Journal Case Reports* (n = 77).

Table 1: Journals with highest number of published articles by investigators and co-investigators from UPCM

Journal (descending order)	Frequency (%), N = 2,075
Acta Medica Philippina	420 (20.24%)
British Medical Journal Case Reports	77 (3.71%)
Philippine Journal of Internal Medicine	26 (1.25%)
PloS ONE	23 (1.11%)
Cochrane Database of Systematic Reviews	20 (0.96%)
Philippine Journal of Science	19 (0.92%)
World Neurosurgery	19 (0.92%)
Journal of Clinical Neuroscience	17 (0.82%)
Journal of the ASEAN Federation of Endocrine Societies	15 (0.72%)
International Journal of Environmental Research	14 (0.67%)
Southeast Asian Journal of Tropical Medicine	14 (0.67%)
Vaccine	14 (0.67%)

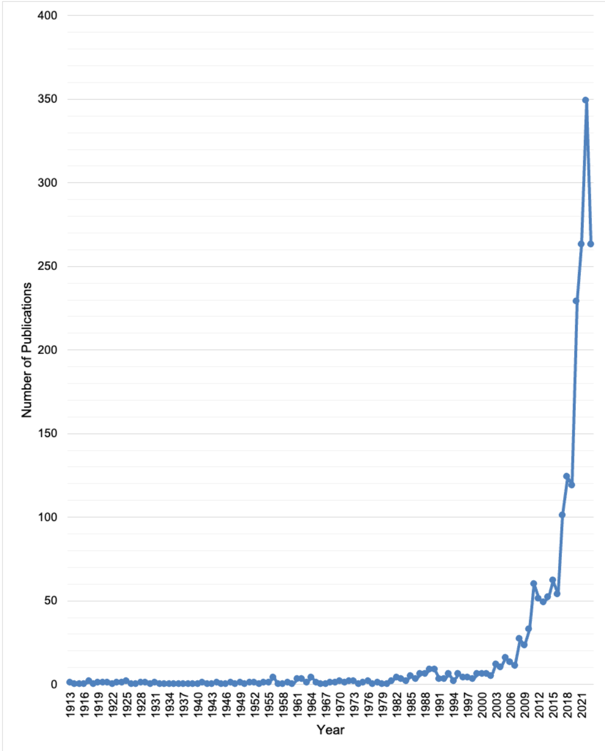

Figure 2: Publication trend from 1913 to 2023

Figure 3 summarizes the trend of publications from 1981 to 2023 according to the type of study. The observational category has the highest number of publications (n = 293 during the 2021-2023 period). There is also a consistent rise in the number of qualitative studies and other evidence synthesis (i.e., bibliometric studies) (n = 58 qualitative and mixed-methods studies during the 2021-2023 period; n = 138 evidence synthesis during the 2012-2023 period).

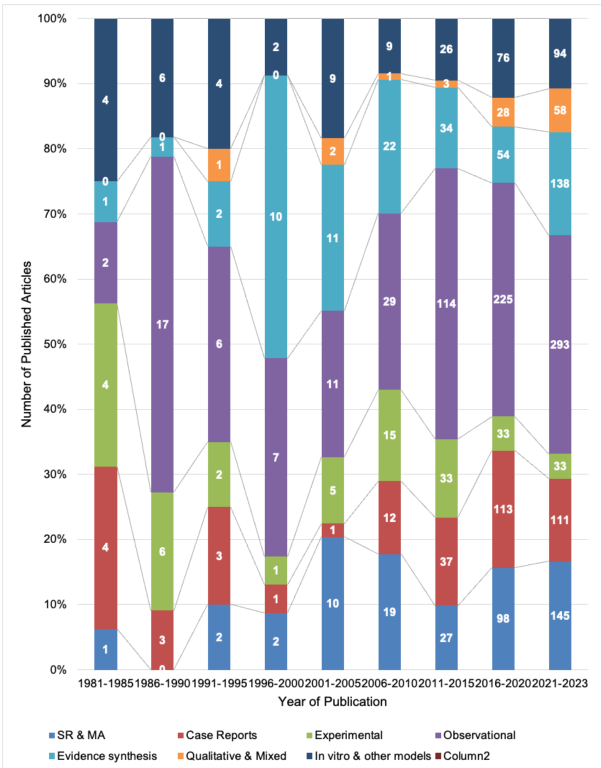

Figure 3: Distribution trend of publications according to type of study from 1981 to 2023

Figure 4 summarizes the trend of publications from 1981 to 2023 based on the departments involved. There is a steady rise the number of studies conducted by multiple departments (n = 342 during the 2021-2023 period). The departments of Neurosciences and Medicine are the leading clinical departments in terms of research productivity, garnering 215 and 128 publications respectively during the 2016-2023 period. The departments of Biochemistry & Molecular Biology and Clinical Epidemiology obtained the highest number of publications among the basic sciences departments, publishing 89 and 57 studies respectively during the 2016-2023 period.

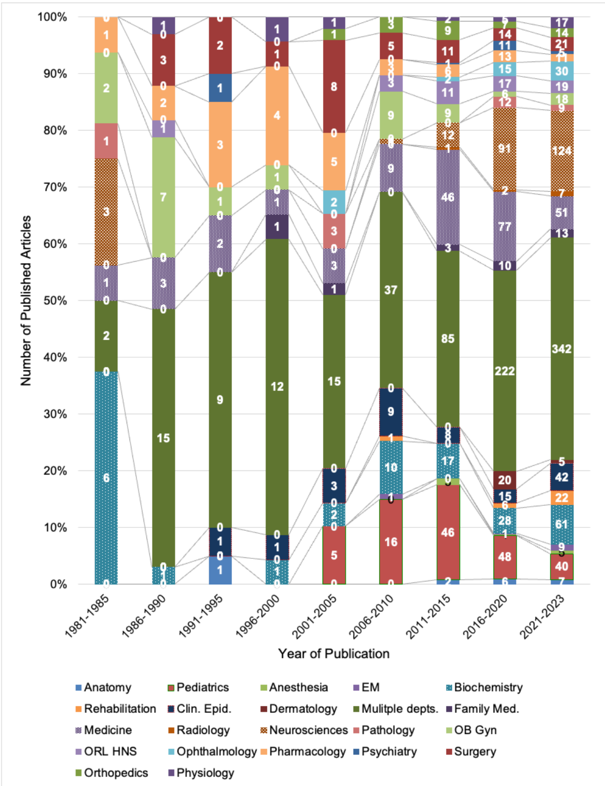

Figure 4: Distribution trend of publications according to the department involved from 1981 to 2023

Inferential data: Comparing the predicted and actual OSI trends

The graphical representation of the time series data spanning the period 1981 to 2023 using the frequency of publications as variable is presented in Figure 5. Only the data from 1981 to 2023 were included in the ARIMA modeling as this period is officially labeled as a period of relative socio-political stability in the country (Sodusta and Palongpalong 1982). Using the Dickey-Fuller test, the time series data was initially deemed as non-stationary (Z(t) = -0.824, p-value = 0.9636). The non-stationary data was differenced once to transform the time series into a stationary frequency data (Z(t) = -11.636, p-value < 0.001).

The ARIMA (1,2,1) model was deemed as the best model with an Akaike's information criterion (AIC) and a Bayesian information criterion (BIC) of 402.0531 and 409.0037 respectively. Hence, the ARIMA (1,2,1) model was used to demonstrate if the introduction and implementation of the OSI curriculum in 2004 significantly changed the predicted trend. Table 2 summarizes the ARIMA (1,2,1) regression analysis (sample: 1982-2023; no. of observations = 42; Log likelihood = -196.8417).

The likelihood ratio (LR) test revealed a non-significant p-value (LR $chi^2(1)$ = 0.37; Prob > chi^2 = 0.5432). The OSI curriculum did not significantly change the trend of productivity. Figure 6 demonstrates the observed or actual trend in the number of publications (blue line), the standard predicted trend (red line), and the dynamic or recursive forecasted trend (green line).

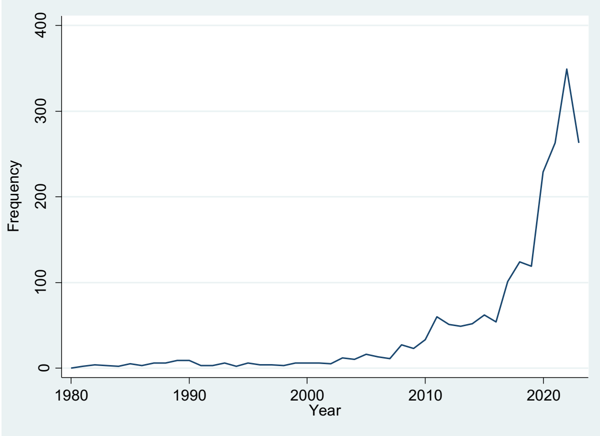

Figure 5: Frequencies of publications from 1981 to 2023

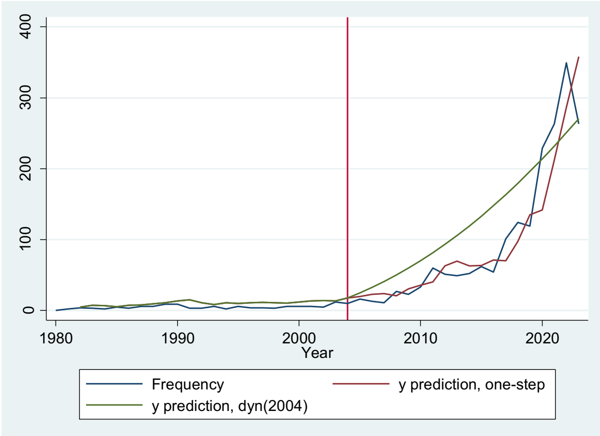

Figure 6: Observed and predicted ARIMA (1,2,1) frequencies

The autocorrelation plot is similar to a typical autocorrelation function of an AR(1) process for which the autocorrelation of a stationary AR (1) process decay to zero (see Figure 7A). The obtained Eigenvalues of the auto-regressive (AR) and moving average (MA) roots satisfy both the stability and invertibility conditions (AR roots Eigenvalue = -.4409043; MA roots Eigenvalue = 0.8848135). Figure 7 illustrates a graphical representation of the parametric autocorrelations of frequencies with 95% confidence intervals and the stability and invertibility conditions.

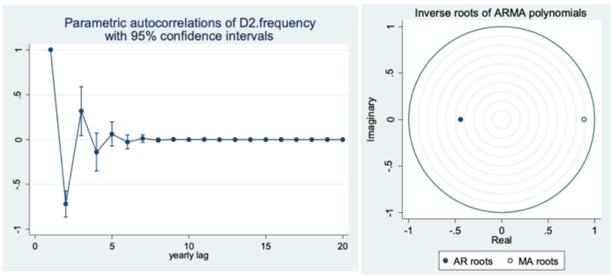

Figure 7: Parametric autocorrelations of frequencies; B. Eigenvalues of the auto-regressive (AR) and moving average (MA) roots in the unit circle

DISCUSSION

Changes in the trends in publications

To our knowledge, this is the first study that investigates the potential impact of a revision in the design and implementation of a medical curriculum (OSI) on the research productivity of the higher education institution using the ARIMA time series forecasting model. Demonstrably, there is a robust uptrend in the number of publications of UPCM students and faculty. The steady incline has been demonstrated since the early 2000s (the period when OSI was introduced and implemented) and peaked in the year 2022 (n = 349). This general uptrend may also be influenced by the implementation of the faculty tenure, rank, and promotions guidelines in 2004 requiring the faculty members of the University of the Philippines to publish scientific articles in refereed journals or to produce literary and creative works that are formally juried before being granted tenure and/or promotion as emphasized in the public document containing the minutes of the 1,349th meeting of board of regents in November 2019. Another possible factor for this trend is the launching of the evidence-based medicine (EBM) movement and the establishment of the Cochrane Collaboration during the early 1990s which placed a high premium on published research (Sheridan and Julian 2016). With the consistent uptrend, there is also demonstrable shift from publishing in local indexed journals (i.e., *Acta Medica Philippina* and *Philippine Journal of Internal Medicine*) to expanding the horizon to international refereed journals (i.e., *British Medical Journal Case Reports, PloS ONE, Cochrane Database of Systematic Reviews, World Neurosurgery*, and *Journal of Clinical Neuroscience*). This is consistent with the findings of a recent bibliometric study using citation documents which demonstrates a steady increase in the rate of internationalization of academic publishing (Gazni and Ghaseminik 2016).

It is interesting to note that demonstrable changes are seen not only on the rate of increase in the number of publications; there are also apparent changes in the distribution of publications in terms of type of studies. Figure 3 illustrates that although there is relative stagnation in the number of publications using experimental design and *in vitro* studies, there is consistent uptrend in the number of published studies using evidence synthesis methodologies (i.e., bibliometric studies and other reviews) and qualitative and/or mixed methodologies. This is consistent with the post-Flexnerian wave that highlights the shift of medical education, training, and research from following a purely biomedical perspective to pursuing a holistic and integrative bio-psycho-social perspective in medicine (Gonzalo et al. 2018). Furthermore, as illustrated in Figure 4, there is a steady rise in the number of publications entailing collaborative work from multiple departments in the college emphasizing the shift from working in academic silos to pursuing collaborative research projects. This is congruent with the call of Reilly and colleagues towards multilevel integrated systems approach in medical education and research (Reilly et al. 2023). Furthermore, this also suggests consistency with the findings of a recent descriptive study using social network analysis demonstrating an increase in cross-disciplinary collaborations among researchers under a clinical sciences grant in a university in the United States (Luke et al. 2015). Interestingly, the steady rise in the scientific productivity trend of the department of Neurosciences beginning in the 2016-2020 period may be due to the influence of certification requirements imposed by the Philippine Neurological Association particularly the first-author publication requirement for the applicants of its specialty certifying examinations.

Nonsignificant uptrend in research productivity during OSI

Despite the drastic rise in the trend of research productivity, the time series forecasting model illustrates that the actual trend is not significantly different from the predicted trend. The introduction and implementation of the OSI curriculum in 2004 did not significantly change the trend of research productivity. Several factors are considered. The first factor is the increase in teaching load. The transition from traditional curriculum to an integrated organ-system based teaching-learning activities entailed more focused small group activities and less big group didactics. This requires more teaching hours from the faculty members. A recent mixed-methods study done among faculty members in a local government university in Palawan suggested that an increase in teaching load significantly affected the research productivity of the faculty (Dangan 2014). Results of another similar cross-sectional study done among health sciences faculty in Saudi Arabia suggested that an increase in teaching load is an impediment to pursuing research projects (Alghanim and Alhamali 2011). It is interesting to note that a larger observational study involving 785 professors in Mexico suggests that teaching workload does not significantly influence scientific productivity (Ramirez-Montoya et al. 2023). These findings illustrate that the relationship between teaching workload and research productivity could be influenced by several other contextual factors and confounders.

Another possible factor is the general research and development landscape of the country. Several recent bibliometric analyses highlight that the Philippines, compared to its neighboring countries in Southeast Asia, is lagging in terms of scientific publications and the most commonly cited indicator is the low % gross domestic product (GDP) allocated for research and development (Pajo et al. 2020; Apor et al. 2021; Turalde et al. 2021; Jalipa et al. 2021; Apor and Jamora 2022; Sanchez et al. 2023).

The isolated peak in the number of publications in the year 2022 could be attributed to the surge of COVID-19-related studies that were published through expedited peer review procedures (Kambhampati et al. 2020; Raynaud et al. 2021).

Limitations of the study and the model

This study has limitations. The methodology relies on the process of indexing by the investigators. Should the investigators fail to indicate their affiliation with UPCM, the publications would not be included in the search strategy. Another limitation of the search methodology and the indexing systems of the included databases is the nondiscrimination between student-led and faculty-led publications; hence, the trend in research productivity was described collectively. The time series forecasting model used also has limitations. Although studies comparing the predictive accuracy of traditional statistical ARIMA and of the newer machine learning models for time series forecasting have contradicting results, a commonly cited limitation of the traditional ARIMA model is the nonobjectivity of its progress evaluation and the dependence of the reliability of the particular model on the experience of the statistician-forecaster (Kontopoulou et al. 2023).

Another limitation of this study is its focus on published and indexed articles. Research projects that are disseminated via the grey literature would not be included as well. Lastly, the inferential data analysis of this study did not include other significant changes in the landscape of medical education and training in UPCM such as, but not limited to, the propagation of local and international health research grants, the recruitment of physician-scientists through the Doctor of Medicine-Doctor of Philosophy (molecular medicine) program of the Philippine Council for Health Research and Development, and the internationalization of medical education through various partnerships and collaborations.

CONCLUSION AND RECOMMENDATIONS

There is a steady rise in the research productivity trend of UPCM students and faculty beginning in the early 2000s. Although the local indexed journals remain as the most common avenue for publishing scientific works, there is a demonstrable increase in the number of studies being published in international refereed journals. Significant uptrend in the number of published studies using qualitative and mixed-methods design is also demonstrated. There is a growing number of published studies that entail collaborations from multiple departments, basic and clinical alike. Despite the glaring uptrend in research productivity that is concurrent with the introduction and implementation of the OSI curriculum, the actual trend appears to be not significantly different from the predicted trend using the time series forecasting model. Several factors are considered including the effect of the increased teaching load and the general research and development funding landscape in the country. The following subsection presents the recommendations of the authors.

Medical curriculum designers should revisit the curricular strategies and teaching-learning activities dedicated for the transfer of research competencies. Owing to the inevitable paradigm shift of medical education and training from a purely biomedical pursuit to a holistic bio-psycho-social endeavor with emphasis on health systems sciences, it is imperative to consider the inclusion of activities dedicated for qualitative and mixed-methods research designs.

Future studies should consider including other critical events such as the inauguration of dual-track medical programs, proliferation of research grants and clinical research programs, and the internationalization of medical education through collaborations and partnerships in the time series forecasting models. Future studies may also consider other search methodologies that discriminates between student-led and faculty-led publications to obtain a deeper subgroup analysis on research productivity. In terms of time series forecasting models, future studies should also consider other innovative approaches including machine learning and the hybrid models. It is also imperative for future studies to consider including scientific outputs in the grey literature as well.

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CONFLICT OF INTEREST

The authors certify that they have no involvement in or relationship with any institution with any financial or non-financial interests in the subject matter or materials discussed in this manuscript.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

CWRT conceptualized the study and the protocol, established the data set, and wrote the first draft and the final version. AJRM and MBP contributed to the protocol writing and in running the statistical tests. EAS contributed to the design and implementation of the research.

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