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ORIGINAL

# Rapid growth and shifting geographic concentration of research on augmented reality in education

## Rápido crecimiento y cambio en la concentración geográfica de la investigación sobre realidad aumentada en educación

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**ABSTRACT**

Introduction: Research on augmented reality in education has expanded, but its distribution across world regions and income groups has not been quantified. Methods: This cross-sectional bibliometric study analyzed 9,769 articles and reviews published in 2010-2023 and indexed in OpenAlex, linked to World Bank regions, income groups and population. Annual growth was estimated with quasi-Poisson regression, and shares were reported with Wilson 95% confidence intervals. Results: Output grew by 27.9% per year (95% CI 26.4-29.4%). Upper-middle-income countries accounted for 49.3% of works with country information and high-income countries for 46.3%. High-income countries produced 2.50 works per million inhabitants, against 0.19 in lower-middle-income countries. Latin America and the Caribbean contributed 6.5% of works, and its share fell from 9.8% in 2010-2016 to 6.1% in 2017-2023. A search that added Spanish and Portuguese terms raised the regional share to 13.2%. Country data were missing for 25.3% of works. Conclusions: Output grew rapidly and moved toward upper-middle-income countries, whereas output per inhabitant remained concentrated in high-income countries. The share of Latin America and the Caribbean declined, and its level depended on the language of the search terms.

Keywords: augmented reality; education; bibliometrics; income groups; Latin America.

**RESUMEN**

Introducción: La investigación sobre realidad aumentada en educación se ha expandido, pero no se había cuantificado su distribución entre regiones del mundo y grupos de ingreso. Métodos: Este estudio bibliométrico transversal analizó 9769 artículos y revisiones publicados en 2010-2023 e indexados en OpenAlex, vinculados con las regiones, los grupos de ingreso y la población del Banco Mundial. El crecimiento anual se estimó con regresión de cuasi-Poisson y las proporciones se presentaron con intervalos de confianza de Wilson del 95 %. Resultados: La producción creció 27,9% por año (IC 95 %, 26,4-29,4%). Los países de ingreso medio alto aportaron 49,3% de los trabajos con información de país y los de ingreso alto, 46,3%. Los países de ingreso alto produjeron 2,50 trabajos por millón de habitantes, frente a 0,19 en los de ingreso medio bajo. América Latina y el Caribe aportó 6,5% de los trabajos, y su proporción bajó de 9,8% en 2010-2016 a 6,1% en 2017-2023. Una búsqueda con términos en español y portugués elevó la proporción regional a 13,2%. Faltaba información de país en 25,3% de los trabajos. Conclusiones: La producción creció con rapidez y se desplazó hacia los países de ingreso medio alto, mientras que la producción por habitante siguió concentrada en los de ingreso alto. La proporción de América Latina y el Caribe disminuyó y su nivel dependió del idioma de los términos de búsqueda.

Palabras clave: realidad aumentada; educación; bibliometría; grupos de ingreso; América Latina.

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## INTRODUCTION

Augmented reality overlays digital objects on the physical environment, and education has been one of its main fields of application. Reviews describe gains in learning performance and motivation, together with usability and implementation difficulties.(1-3)Syntheses now exist for STEM learning, language learning, K-12 settings and professional training, and one meta-analysis of 70 empirical studies estimated a pooled effect size (g) of 0.717.(4-8)Most comparative studies, however, set augmented reality against another medium, which limits what they reveal about when and why it works.(9)

Much less is known about where this evidence is produced. Bibliometric studies of augmented reality in education have mapped topics, authors and sources in Web of Science and Scopus, but the geography of output and its relation to national income was rarely the main question.(10-13)In other fields, output concentrated in wealthy countries and in North America and Europe.(14-16)Whether the same holds for augmented reality in education matters for Latin America, where local trials and design reports provide the direct evidence on classroom conditions.(17,18) The objective of this study was to quantify the growth of research output on augmented reality in education between 2010 and 2023 and to describe its distribution across World Bank regions and income groups.

To pursue this objective, a cross-sectional bibliometric study used aggregated counts of articles and reviews indexed in OpenAlex,(19)linked to the World Bank country classification and population data.(20)The design addresses the volume and geography of output across the whole period. It does not assess the effectiveness, quality or topical content of the studies counted, and it cannot identify which classroom applications drive the trend.

## METHODS

### Design and reporting

This was a cross-sectional bibliometric study with a time-series component, reported according to the STROBE principles for descriptive observational research and adapted to aggregated bibliographic counts. The unit of analysis was the indexed work, defined as a journal article or review, and the study covered publication years 2010 to 2023. No protocol was registered. An analysis protocol that fixed the outcomes, the comparison groups and the main model was written before the counts were retrieved.

The query strings and grouping variables are given below so that the counts can be retrieved again. The index is updated continuously, so later retrievals may differ slightly from the counts reported here.

### Statistical analysis

Annual growth was estimated with a log-linear regression of yearly counts on publication year, fitted as a Poisson generalized linear model with the scale parameter set to the Pearson chi-square divided by the residual degrees of freedom (quasi-Poisson). The annual growth rate was the exponentiated slope minus one, expressed as a percentage, with a 95% confidence interval from the same model. Relative growth used the same model with the logarithm of all indexed articles and reviews of each year as an offset, which separates the growth of the topic from the growth of the index. Growth was also estimated separately for 2010-2016 and 2017-2023, two periods of seven years each.

Shares were calculated with works with country information as the denominator, and 95% confidence intervals used the Wilson method. Differences between the two periods were expressed in percentage points, with Wald intervals for independent proportions. Because one work can belong to several groups, groups overlap, and no tests were run between groups. Estimates are reported with confidence intervals and not with p values.

Four descriptive indicators were added after the first inspection of the results, to compare the findings with earlier studies and to describe the timing of growth. They are the share of works with authors in the United States, the United Kingdom, Canada or Australia, the share with authors in North America, Europe or Central Asia, the share with authors in six Southeast Asian countries, and the share of works published after 2019. These indicators are exploratory, and no other analysis was modified after the first run.

## Variables

The main outcome was the number of indexed works. Each work was assigned to every World Bank region and income group in which at least one author affiliation was located, so that a work with authors from two groups counted once in each group. Regions followed the seven World Bank regions, and income groups followed the four World Bank classes (high, upper-middle, lower-middle and low income), taken as served by the World Bank country list and applied to the whole period without reclassification. Taiwan does not appear in that list, and its works were reported separately and excluded from regional and income estimates.

Works with a single author country were counted separately to avoid overlap. International co-authorship was defined as two or more distinct author countries in one work. Population was the mean annual total population of each country across 2010-2023, and works per million inhabitants were the number of works of a group divided by the summed mean population of its countries in millions. Works with no author country recorded in the index were excluded from geographic denominators, and their number was reported for each period.

## Data sources and corpus definition

Counts were retrieved by program from the public API of OpenAlex, which indexes scholarly works from several sources, using the snapshot available from the public API. Comparisons of bibliographic databases found different coverage in each, so counts from one index cannot be read as a census of the literature.(21-23)The corpus consisted of works of type article or review with publication years 2010 to 2023 whose title or abstract matched the query “augmented reality” AND (education OR educational OR teaching OR student OR students OR classroom OR school OR schools OR pedagogy OR pedagogical OR curriculum OR “learning outcomes” OR “learning environment” OR “learning environments” OR “e-learning” OR “mobile learning”). The search engine applied stemming to the terms. The education terms were chosen to cover the educational level (school, classroom, curriculum), the actors (student, teaching, pedagogy) and the learning setting (learning environment, e-learning, mobile learning), and general terms such as learning and training were left to the broad definition because they also match computer science works on machine learning. The period starts in 2010 and ends in 2023, as defined for the volume in which the study is reported.

## Data retrieval and quality control

Counts were obtained by grouping the matching works by publication year and by author country, and by filtering on lists of country codes, so that no individual record was downloaded. Four consistency checks were applied. The sum of yearly counts had to equal the total number of matching works, the grouping by country had to return every group, the country codes of the index had to match the two-letter codes of the World Bank list, and two consecutive runs of the analysis had to give identical values. Codes with no match in the World Bank list were counted and reported.

Missing author countries were not imputed. For each period, the number of works with and without country information was recorded, and geographic shares referred only to works with country information. The two periods were defined as two halves of equal length so that period comparisons would not depend on the choice of a break point near the years of fastest growth.

## Sensitivity analyses

Four alternative definitions were applied. The broad definition replaced the education terms with education, learning, teaching, students, classroom, school and training. The title-only definition required the augmented reality term in the title together with education, educational, teaching, learning, student, students, classroom or school. The third definition kept the main query and admitted all document types. The fourth definition added the Spanish and Portuguese terms for augmented reality (realidad aumentada, realidade aumentada) and the corresponding education terms, such as educación, enseñanza, estudiantes, educação, ensino and alunos, to the main query, because an English-only query can miss works written in the languages of Latin America. For each definition, annual growth, the shares of high-income, upper-middle-income, low- and lower-middle-income countries, the share of Latin America and the Caribbean, and the income shares in each period were recalculated.

## Ethical considerations

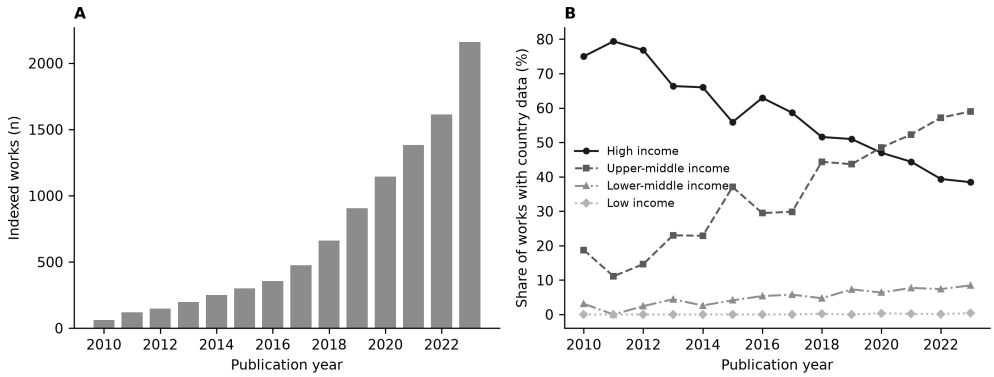
The study used aggregated bibliographic counts and country-level public statistics. It involved

no human participants or individual-level data, and no ethical approval was sought.

## RESULTS

Annual output of indexed works on augmented reality in education grew by 27.9% per year (95% CI 26.4-29.4%) over 2010-2023 (Figure 1). Output rose from 61 works in 2010 to 2,160 in 2023, a 35.4-fold increase. The peak occurred in 2023, the last year of the series.

**Figure 1. Annual output on augmented reality in education and share of works by income group, 2010-2023.**




Note: Panel A shows indexed articles and reviews per publication year. Panel B shows the share of works with country information that had at least one author in each income group; shares add to more than 100% because works are counted in every group represented.

Counts reached 356 works in 2016, 906 in 2019 and 1,613 in 2022, and passed 1,000 works per year for the first time in 2020. The increase between 2022 and 2023 was 547 works, equivalent to 33.9%.

The topic reached 3.62 works per 10,000 indexed articles and reviews in 2023, up from 0.11 in 2010, which gave a relative growth of 28.4% per year (95% CI 27.2-29.6%). Total indexed output across all topics changed by 0.5% per year (95% CI −0.3 to 1.2%) in the same years.

The 2017-2023 period contributed 8,339 works and represented 85.4% of the series. Annual growth stood at 28.0% in 2010-2016 (95% CI 22.5-33.8%) and at 26.2% in 2017-2023 (95% CI 23.3-29.3%). The two intervals overlapped. Reviews increased from 14 to 391 works between the periods.

Upper-middle-income countries accounted for 49.3% (95% CI 48.2-50.5%) of works with country information (Table 1). High-income countries represented 46.3% (95% CI 45.1-47.4%). Lower-middle-income countries stood at 6.9%, and low-income countries at 0.2% with 15 works.

The high-income share fell from 65.6% in 2010-2016 to 43.7% in 2017-2023, a change of −21.8 percentage points (95% CI −25.3 to −18.4). The upper-middle-income share moved in the opposite direction, from 25.7% to 52.4% (26.7 points; 95% CI 23.5-29.9). Low- and lower-middle-income countries combined rose from 3.7% to 7.5% (3.8 points; 95% CI 2.4-5.2).

**Table 1. Output on augmented reality in education by World Bank income group.**

| Group | Works, n | Share, % (95% CI) | Single-country works, n | Works per million inhabitants | International co-authorship, % | Annual growth, % (95% CI) | Share 2010-2016, % | Share 2017-2023, % |
|---|---|---|---|---|---|---|---|---|
| High income | 3,376 | 46.3 (45.1-47.4) | 2,571 | 2.50 | 23.8 | 25.8 (23.9-27.7) | 65.6 | 43.7 |
| Upper-middle income | 3,599 | 49.3 (48.2-50.5) | 3,139 | 1.22 | 12.8 | 46.0 (42.5-49.6) | 25.7 | 52.4 |
| Lower-middle income | 506 | 6.9 (6.4-7.5) | 384 | 0.19 | 24.1 | 45.4 (41.1-49.8) | 3.7 | 7.4 |
| Low income | 15 | 0.2 (0.1-0.3) | 4 | 0.02 | 73.3 | 74.7 (43.2-113.1) | 0.0 | 0.2 |

Note: A work is counted in every income group with at least one author affiliation, so shares add to more than 100%. Period shares use works with country information in each period as denominator. Annual growth derives from a quasi-Poisson model of yearly counts; the estimate for low-income countries rests on 15 works. Taiwan is not classified in the World Bank country list and is excluded.

High-income countries produced 2.50 works per million inhabitants, against 1.22 in upper-middle-income, 0.19 in lower-middle-income and 0.02 in low-income countries. The ratio between the high-income rate and the combined rate of low- and lower-middle-income countries was 15.7. Annual growth reached 25.8% (95% CI 23.9-27.7%) in high-income countries and 45.8% (95% CI 41.6-50.1%) in low- and lower-middle-income countries.

East Asia and Pacific held the largest regional share at 41.6% (95% CI 40.5-42.7%), followed by Europe and Central Asia at 31.7% (Table 2). North America represented 14.2%, and Latin America and the Caribbean 6.5% (95% CI 5.9-7.1%). Sub-Saharan Africa stood at 0.8% with 61 works. Per million inhabitants, North America reached 2.88 works and Latin America and the Caribbean 0.76.

**Table 2. Output on augmented reality in education by World Bank region.**

| Group | Works, n | Share, % (95% CI) | Single-country works, n | Works per million inhabitants | International co-authorship, % | Annual growth, % (95% CI) |
|---|---|---|---|---|---|---|
| East Asia and Pacific | 3,037 | 41.6 (40.5-42.7) | 2,630 | 1.33 | 13.4 | 41.8 (39.2-44.4) |
| Europe and Central Asia | 2,314 | 31.7 (30.6-32.8) | 1,770 | 2.54 | 23.5 | 31.2 (28.2-34.2) |
| Latin America and the Caribbean | 473 | 6.5 (5.9-7.1) | 337 | 0.76 | 28.8 | 25.2 (22.0-28.4) |
| Middle East and North Africa | 489 | 6.7 (6.1-7.3) | 341 | 0.69 | 30.3 | 45.3 (37.6-53.5) |
| North America | 1,040 | 14.2 (13.5-15.1) | 793 | 2.88 | 23.8 | 24.5 (21.5-27.6) |
| South Asia | 236 | 3.2 (2.9-3.7) | 187 | 0.15 | 20.8 | 53.8 (48.8-58.8) |
| Sub-Saharan Africa | 61 | 0.8 (0.7-1.1) | 40 | 0.06 | 34.4 | 63.6 (50.4-78.1) |

Note: A work is counted in every region with at least one author affiliation, so shares add to more than 100%. Shares use works with country information as denominator (95% Wilson CI). Works per million inhabitants use mean annual population in 2010-2023. Annual growth derives from a quasi-Poisson model of yearly counts. Taiwan is not classified in the World Bank country list and is excluded from regions.

Latin America and the Caribbean contributed 473 works, and 24 of its 42 countries recorded at least one. The leading countries of the region were Brazil (139), Mexico (110) and Colombia (76). The regional share fell from 9.8% in 2010-2016 to 6.1% in 2017-2023 (−3.7 points; 95% CI −5.8 to −1.6). Annual growth in the region was 25.2% (95% CI 22.0-28.4%).

East Asia and Pacific grew by 41.8% per year, and South Asia and Sub-Saharan Africa by 53.8% and 63.6%. The North American share fell from 20.8% to 13.4% between the two periods.

Indonesia was the largest contributor with 1,503 works (20.6%), followed by the United States (931) and Malaysia (472). The five largest countries were on 48.1% of works with country information, and the ten largest on 64.0%. A total of 131 of 217 World Bank economies recorded at least one work, including 7 of 25 low-income economies.

Taiwan, which the World Bank list does not classify, contributed 307 works (4.2%) and was excluded from regional and income estimates. Among the 6,341 works with a single author country, 49.5% came from upper-middle-income and 40.5% from high-income countries. Six Southeast Asian countries (Indonesia, Malaysia, Thailand, the Philippines, Vietnam and Singapore) appeared on 30.7% of all works with country information.

International co-authorship applied to 958 works, or 13.1% of works with country information. The proportion was 11.6% in 2010-2016 and 13.3% in 2017-2023. Regional values ranged from 13.4% in East Asia and Pacific to 34.4% in Sub-Saharan Africa, and Latin America and the Caribbean stood at 28.8%.

The broad definition yielded 12,606 works with annual growth of 27.9% (95% CI 26.5-29.3%). The title-only definition yielded 3,930 works and growth of 26.1% (95% CI 24.3-27.8%). High-income countries held 50.8% of works in the broad corpus and upper-middle-income countries 45.8%. In the title-only corpus, the values were 41.7% and 53.3%. Including all document types gave 18,083 works and growth of 23.8%. In every definition the high-income share declined and the upper-middle-income share rose between periods; the 2017-2023 high-income share was 48.5%, 39.2% and 48.9% in the broad, title-only and all-types corpora, and the upper-middle-income share was 48.7%, 57.0% and 46.4%. Latin America and the Caribbean held between 6.0% and 7.6% of works with country information across these three definitions, and its share declined between periods in each of them.

The definition with Spanish and Portuguese terms yielded 11,150 works with annual growth of 26.1% (95% CI 24.5-27.7%). Latin America and the Caribbean held 13.2% of works with country information under this definition, and its share moved from 16.6% in 2010-2016 to 12.8% in 2017-2023.

The upper-middle-income share was 51.3% and the high-income share 45.1%.

The corpus comprised 9,769 works, of which 9,364 were articles and 405 were reviews (Table 3). Country information was present for 7,299 works (74.7%), with coverage of 58.5% in 2010-2016 and 77.5% in 2017-2023. The remaining 2,470 works were left out of geographic denominators.

**Table 3. Characteristics of indexed works on augmented reality in education by publication period.**

| Characteristic | 2010-2016 | 2017-2023 | Total |
|---|---|---|---|
| Indexed works, n | 1,430 | 8,339 | 9,769 |
| Journal articles, n | 1,416 | 7,948 | 9,364 |
| Reviews, n | 14 | 391 | 405 |
| With author country information, n (%) | 837 (58.5) | 6,462 (77.5) | 7,299 (74.7) |
| International co-authorship, n (% of works with country information) | 97 (11.6) | 861 (13.3) | 958 (13.1) |

Note: Counts refer to articles and reviews. Country information refers to at least one author affiliation with a recorded country. International co-authorship indicates two or more distinct author countries.

## DISCUSSION

The sustained growth of output implies that the evidence base on augmented reality in education is expanding faster than the research system as a whole, so any synthesis covers a shrinking share of what is published. Recent meta-analyses combined between 70 and 134 empirical studies, and the present corpus holds several thousand works per period.(6,8,24)The gap reflects inclusion criteria and not disagreement, because meta-analyses admit only studies with comparable outcomes, while the counts here include any indexed article or review that matches the query.

Bibliometric studies agree on the direction of the trend. Analyses of Web of Science found rising interest between 2018 and 2022 and a corpus of 777 publications on augmented reality in education, and a Scopus analysis described continued growth in augmented and virtual reality for learning between 2001 and 2021.(10-12)A review of 84 articles published in 2014-2019 reported a relatively low increase in studies.(25)That window closed before most of the growth recorded here, since 64.5% of the works appeared after 2019, and its selection criteria were narrower than a keyword query.

The relative growth rate did not change between the two halves of the period, although absolute counts climbed steeply after 2019. Emergency remote teaching raised interest in extended reality in universities and national digitalization agendas,(26,27) which may have sustained the trend, but a descriptive design cannot attribute growth to the pandemic. A constant relative rate is also what a field in early diffusion would show, and the series is too short to separate these explanations.

The query does not restrict the field, so the counts combine applications that reviews usually treat separately. Systematic reviews exist for primary education, health education, professional training and the combination of augmented reality with gamification.(7,28-30) Growth in the aggregate may hide different trajectories by subject and educational level, and aggregated counts cannot separate them. Reviews of game-based augmented reality in primary and secondary schools describe trends within a single application area.(31)

The geographic pattern differs from the ones reported for other fields. Authors in the United States, the United Kingdom, Canada and Australia appeared on 19.7% of works here, whereas those four countries accounted for 80% of medical education papers and 74% of papers in the broader education category in PubMed.(14) Authors in North America and Europe appeared on 82% of HIV/AIDS publications in Web of Science, against 44.3% of works here in North America, Europe and Central Asia combined.(15) Public health research was likewise concentrated in North America and Europe, although other regions were gaining capacity.(16)

Three features of the data may explain why augmented reality in education is less concentrated. The topic is applied and technology-driven, which favors institutions with computing and teacher-training programs in many countries. Indexing matters as well, because OpenAlex covers more regional and national journals than selective databases, and earlier comparisons showed that Web of Science and Scopus favor English-language journals and the natural and biomedical sciences.(19,22,32)A third explanation is national policy, as Indonesian reviews describe immersive

and extended reality technologies as priorities for education and post-pandemic recovery.(27,33)

The shift from high-income to upper-middle-income countries is unlikely to be an artifact of missing affiliations alone. Coverage of author countries increased over time, which could change shares if older works without affiliations came disproportionately from one group. The decline of the high-income share and the rise of the upper-middle-income share appeared in all four definitions and among single-country works, although the order of the two groups in 2017-2023 depended on the definition. The check is limited by the absence of affiliations for a quarter of the works.

The role of Southeast Asia needs a careful reading. Indonesia alone supplied about one fifth of works with country information, and six Southeast Asian countries supplied nearly one third. Part of this output may come from locally edited journals and conference proceedings that are indexed in OpenAlex, so the counts partly reflect editorial infrastructure and not only research intensity. Visibility in other indexes can differ, and differences between sources are well documented.(21,23)

Counts per inhabitant show that the shift toward upper-middle-income countries does not remove the gap. High-income countries still produced a much higher number of works per million inhabitants than upper-middle-income, lower-middle-income and low-income countries. This pattern matches the disparities in research spending and output reported for South American countries.(34)Adjusting output by gross domestic product, rather than by population, led some African nations to perform well in public health research,(16)so the choice of denominator changes the reading of capacity, and the population denominator used here is the more demanding one.

Regions with small starting volumes showed the fastest relative growth, as expected when counts are low at the beginning of a series. South Asia, Sub-Saharan Africa and the Middle East and North Africa grew faster than North America and Latin America and the Caribbean, in line with the report that the Eastern Mediterranean and South-East Asia gained public health research capacity faster than other regions.(16)Rapid growth from a low base does not close absolute gaps, and its intervals are wide when annual counts are small. Low-income economies mark the limit of the method, because their growth estimate rests on 15 works and should not be used to compare them with other groups.

The language of the query changed the level of the Latin American share but not its direction. Adding Spanish and Portuguese terms roughly doubled the regional share, which indicates that an English-only search leaves out a large part of the production written in the region’s languages. The share still declined between periods, and it remained far below the combined share of East Asia and Pacific and of Europe and Central Asia. The same bias applies to any other region whose research is published in languages other than English, and it is consistent with the language and discipline skew documented for selective indexes.(32)

Latin America and the Caribbean contributed a small share that declined between the two periods, even though its output kept growing at a fast annual rate. Its per capita output was below that of North America, Europe and Central Asia and East Asia and Pacific. The region showed a higher proportion of internationally co-authored works than East Asia and Pacific, which agrees with evidence that Brazilian highly cited researchers relied on collaborators from the United States, the United Kingdom and Australia.(35)Counts alone cannot show who leads these collaborations, and Colombian studies report that Southern partners were associated with higher production while Northern partners were associated with larger contributions to local knowledge.(36,37)

Where output is produced does not necessarily determine which questions are asked. Research agendas about the Global South are often set in the Global North and supported by northern agencies,(38) and the literature on Colombia discusses the claim that collaboration with northern partners reorients local research toward northern agendas.(36) The topical mix of augmented reality studies by region could not be examined with aggregated counts, but it is a plausible route through which the geography of output shapes the evidence that reaches classrooms.

The transferability of the global evidence to Latin America remains open. Given this regional distribution of output, pooled effects of augmented reality on learning probably draw mainly on studies conducted outside the region,(8,24) since East Asia and Pacific produced several times more works than Latin America and the Caribbean. The local studies that exist point in the same direction as the global syntheses. A randomized comparison with 99 students at a Mexican university found gains in learning and motivation with a web-based extended reality tool,(17)and a comparison of three Latin American universities documented how design choices depended on local conditions.(18)

Reviews and meta-analyses that synthesize augmented reality across educational levels, from K-12 to professional training, address its effects on learning outcomes and motivation.(39-41)The present counts do not test those effects, and a large volume of output does not by itself indicate that the evidence is strong, since the field relies heavily on media comparisons.(9)

Context can still limit transfer. Reviews list technical problems, material costs and teacher knowledge among the barriers to classroom use,(25,26) and low-cost headsets have been proposed for resource-constrained settings.(42)Because 80% of the 92 primary studies in one review set augmented reality against another medium,(9)effect sizes estimated elsewhere may not describe how augmented reality performs against local alternatives. Sub-Saharan Africa contributed less than 1% of works, and most low-income economies recorded none, which leaves the evidence for the lowest-income contexts almost entirely indirect.

Its strengths are the use of open data retrieved without manual steps, a corpus of several thousand works, a normalization against total indexed output, and the agreement of growth estimates across five definitions of the topic. The shares of high-income and upper-middle-income countries changed order depending on the definition, which indicates that the near parity between the two groups should not be read as a ranking. The rest of the findings were stable across definitions.

Several limitations qualify these results, and each suggests a specific remedy. First, topic assignment relies on keywords, so works on machine learning or on training outside education may be included and relevant works may be missed, and the main query was written in English; a manual or classifier-based check of a random sample would estimate precision and recall, and queries in more languages would reduce the language gap. Second, about one quarter of works lacked author countries, and coverage rose from 58.5% to 77.5%; geographic shares should be recomputed with affiliations enriched from other sources before comparing years. Third, whole counting and the absence of authorship position prevent conclusions about leadership; analyses of first and corresponding authors would address it. Fourth, one index supplied all counts, and replication in Scopus and Web of Science would measure database dependence. Fifth, the World Bank classification is fixed over the period, and period-specific classes would capture countries that changed group. Sixth, population is a coarse denominator, and the number of researchers or education spending would measure capacity more directly.

For authors of future syntheses, the language gap implies that searches restricted to English will under-represent the regional literature, and that the evidence from Latin America, Africa and parts of Asia may enter meta-analyses only through its English-language fraction. Including Spanish and Portuguese terms and regional repositories in the search strategy is a low-cost correction.

For research funders and ministries in Latin America, the figures indicate that local evidence is a smaller share of a rapidly growing literature. Priority could go to trials that compare augmented reality with locally available alternatives, to the registration of design reports that document costs and infrastructure, and to collaboration agreements in which regional teams lead authorship. For journals in the field, reporting the country of implementation and the income context of each study would make future counts of this kind more reliable.

## CONCLUSIONS

Output of research on augmented reality in education grew at a fast and steady relative rate between 2010 and 2023, well above the growth of the index as a whole. The share of Latin America and the Caribbean declined between the two periods, its level depended on the language of the search terms, and its output per inhabitant stayed below that of North America, Europe and Central Asia and East Asia and Pacific. Upper-middle-income countries reached or exceeded the share of high-income countries in absolute output, while output per inhabitant remained concentrated in high-income countries and was minimal in low-income countries. International co-authorship involved a minority of works and was more frequent in Latin America and the Caribbean than in East Asia and Pacific.

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