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h-indices in a university department of anaesthesia: an evaluation of their feasibility, reliability, and validity as an assessment of academic performance

M. D. Bould[1]*, S. Boet[2], B. Sharma[3], E. Shin[3], N. J. Barrowman[4] and T. Grantcharov[3]

[1] Department of Anesthesiology, The Children's Hospital of Eastern Ontario, University of Ottawa, Ottawa, Ontario, Canada
[2] Allan Waters Family Patient Simulation Centre, [3] Department of Surgery, St Michael's Hospital, University of Toronto, Toronto, Ontario, Canada
[4] Department of Pediatrics, Children's Hospital of Eastern Ontario Research Institute, University of Ottawa, Ottawa, Ontario, Canada

* Corresponding author. E-mail: dbould@cheo.on.ca

Editor's key points

- *h*-index has been described to assess an individual's research output.
- *h*-index of 268 members of an anaesthesia faculty was measured, and its validity assessed for academic ranks.
- Values for the *h*-index varied slightly by the database, but these were significantly different for different ranks.
- The paper is among the first few to describe utility and limitations of *h*-index in assessing individual research outputs.

Background. The *h*-index is a tool that is increasingly used to measure individual research productivity. It is unknown whether its use as an evaluation of individual research impact is reliable and valid within the context of anaesthesia.

Methods. We calculated the *h*-indices of 268 faculty members of a university department of anaesthesia using Scopus™ and Web of Science®. Agreement between the databases was investigated with a Bland–Altman plot. The construct validity was examined by comparing the *h*-indices for faculty grouped by academic rank.

Results. The mean bias between the Scopus™ and Web of Science® *h*-indices was 0.09 but 1.96 SD limits of agreement were −5.7 to 5.9. The Web of Science®-derived *h*-indices showed a statistically significant difference between the different academic ranks ($P<0.001$): median *h*-indices were 0 for lecturers, 2 for assistant professors, 9 for associate professors, and 16 for full professors. The Scopus™-derived *h*-indices also showed a statistically significant difference between the different academic ranks ($P<0.001$): median *h*-indices were 0 for lecturers, 1 for assistant professors, 9 for associate professors, and 17 for full professors. *Post hoc* testing found statistically significant differences in all comparisons between academic ranks (all $P<0.01$). Ignoring self-citations did not affect construct validity of the *h*-index. We found no evidence that the *h*-index is superior to counting the total number of publications.

Conclusions. Agreement between the two databases was problematic. There was evidence of construct validity; however, the overlap between academic ranks limits the discriminative power of a low *h*-index.

Keywords: anaesthesia; bibliometric analysis; education

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The *h*-index is a tool designed to 'quantify the cumulative impact and relevance of an individual's scientific research output'.[1] A scientist has index *h* if *h* of his or her papers (Np) have at least *h* citations each and the other (Np−*h*) papers have ≤*h* citations each. As such, the *h*-index is little affected by researchers who have published prolifically but without impact in their field (50 publications each cited once will give an *h*-index of 1) or by researchers with a single high impact publication (one publication cited 500 times will also give an *h*-index of 1).

The *h*-index was first developed for use in basic sciences such as physics but is increasingly described for the health-care professions[2–4] and has recently been suggested for use in anaesthesia.[5] Several search engines can now provide the *h*-index for individual authors including Scopus™ and Web of Science® allowing for rapid comparison between researchers. These search engines reference different sets of journals, and when an *h*-index is calculated in Scopus™, citations from before 1996 are not included due to incomplete citation information. The purpose of the *h*-index is evaluative: bibliometric indices such as the *h*-index and also total number of publications, mean citations per publication, number of publications with citations >*n*, and journal impact factors are used to assess the productivity of researchers when considering academic advancement or funding.[5] [6] The *h*-index has theoretical advantages compared with other bibliometric indices: it is a single number that considers both the number and impact of papers, rewarding high productivity and broad sustained impact.[1]

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It is unknown whether the use of the *h*-index as an evaluation of individual research impact is reliable and valid within the context of anaesthesia and how it compares with the more qualitative peer-reviewed process of academic promotion within a university department of anaesthesia. This study aimed to investigate the properties of *h*-indices as a tool to evaluate individual researcher productivity within an anaesthesia department. In order for evaluation tools to be useful, they must be feasible, reliable, and valid. There is little previous *h*-index research that considers the inter-search method reliability of Scopus™ and Web of Science®, that is, do two search engines return the same *h*-index for the same scientist? We hypothesized that the *h*-index would differ between academic ranks of the University of Toronto Department of Anesthesia, therefore supporting the construct validity of this evaluation tool for academic promotion.

The University of Toronto Department of Anesthesia is the largest academic department of anaesthesia in Canada, with most faculty members based at 12 hospitals in the Greater Toronto Area. Faculty members have a predominantly clinical practice combined with a university appointment. There is a hierarchical system of academic rank and each academic appointment links with an academic rank. The lowest rank is lecturer and any anaesthetist working at a University of Toronto affiliated teaching hospital is at least this rank. Faculty can be promoted from lecturer to assistant professor, then associate professor, and then full professor. Each promotion has to be approved by a university promotions committee based on a range of criteria including research, educational, or leadership activities. In this study, we compared the *h*-index of faculty grouped by academic rank.

Methods

All academic staff with an appointment of lecturer, assistant professor, associate professor, and full professor at the University of Toronto Department of Anesthesia were included. Faculty and academic rank were identified using the departmental website: http://www.anesthesia.utoronto.ca/people/faculty.htm. Academic staff with the appointment of adjunct professors, professor emeritus, or cross-appointments from other departments were excluded ($n=6$). The departmental website also provides a link to each faculty member's publications on the PubMed website (National Library of Medicine, Bethseda, MD, USA) which was used to guide the identification of appropriate publications using Scopus™ (Elsevier, Amsterdam, Netherlands) and Web of Science® (Thompson Reuters, New York, NY, USA). We used the *author search* function of Scopus™ and extended the documents linked to relevant author matches. Output was sorted by the number of citations per document, relevant publications were identified, and the *citation tracker* function was used to provide a Scopus™ *h*-index. Using the *overview options*, we also calculated a Scopus™ *h*-index without self-citations by any authors.

We then used the *author finder* function of Web of Science® to identify faculty members. Subject categories were limited to life sciences and biomedicine and to multidisciplinary science and technology. Relevant publications were identified and the *create citation report* function was used to determine a Web of Science® *h*-index, the total number of publications found, the total number of citations found, and the mean citations per publication. If no relevant author was found with either of the search engines, then it was assumed that the *h*-index and other bibliometric indices were 0. Bibliometric indices for Scopus™ and Web of Science® were calculated on the same day for each subject. After all data were collected, another investigator checked a random selection of 25% of the data points using the same methodology. The difference between the Scopus™ and Web of Science® *h*-indices were calculated for each faculty member and data points were also checked by a second investigator if the difference between Scopus™ and Web of Science® *h*-indices was more than 1 SD of the mean difference.

Descriptive statistics [median, inter-quartile range (IQR), range] were calculated for the Web of Science® *h*-index, Scopus™ *h*-index, the Scopus™ *h*-index without self-citations by any authors, the total number of publications, the total number of citations, and the mean citations per publication for each academic rank.

Analysis of reliability

A Bland–Altman plot with 95% confidence intervals (CIs) for mean bias and 1.96 SD limits of agreement was used to assess the agreement between the measurement of the *h*-index by Web of Science® and Scopus™.[7 8] On the basis of previous data from other medical specialities,[2–4] we decided *a priori* that 1.96 SD limits of agreement of ± 3 would represent a significant bias in terms of faculty evaluation. We qualitatively examined the publications and citation counts for faculty members whose Scopus™ *h*-index–Web of Science® *h*-index fell outside the 1.96 SD limits of agreement in order to attempt to identify reasons for outliers' poor reliability.

Analysis of construct validity

For our primary outcomes, we used the Kruskal–Wallis test to compare the Scopus™ and Web of Science® *h*-indices for each academic rank.

As secondary outcomes, we compared other bibliometric indices to academic rank using the Kruskal–Wallis test. The other indices were: (i) the Scopus™ *h*-index without self-citations by any authors, (ii) the total number of publications found, (iii) the total number of citations found, and (iv) the mean citations per publication. A *post hoc* Tamhane test for groups of unequal variance was used to identify differences between groups. We used receiver-operating characteristic (ROC) curves and the area under the curves (AUCs) to compare the predictive values of the Web of Science® *h*-indices with the other Web of Science® bibliometrics (number of publications, number of citations, and mean citations per publication) in identifying subjects as (i) either associate professors or full professors and (ii) full professors.

Cochran's *Q* test of homogeneity was used for significance testing when comparing the AUCs for different bibliometrics, using R 2.10.0 (http://www.R-project.org). All other data were analysed using SPSS 16.0 (Chicago, IL, USA).

Results

The *h*-indices of 268 faculty members of the University of Toronto Department of Anesthesiology were analysed.

Assessment of reliability

The Bland–Altman plot (Fig. 1) showed that although the mean bias between the Scopus™ *h*-index and Web of Science® *h*-index was only 0.09 *h*-index points (95% CI −0.3 to 0.4), the 1.96 SD limits of agreement were −5.7 to 5.9 (95% CI −6.3 to −5.1 for lower limit of agreement and 5.3–6.5 for upper limit of agreement). Bias increases with increasing mean of *h*-indices. When we qualitatively examined the publications and citation counts for the six faculty whose Scopus™ *h*-index–Web of Science® *h*-index fell outside the 1.96 SD limits of agreement, the most significant source of error appeared to be differences in the functionality of the of Web of Science® *author finder* function and the Scopus™ *author search* function. For instance, one outlier had published using one initial in some publications but two initials in others; the Scopus™ *author search* function identified all publications, whereas the Web of Science® *author finder* function did not. Another outlier had multiple international institutional affiliations and more of these were identified by Web of Science® than Scopus™.

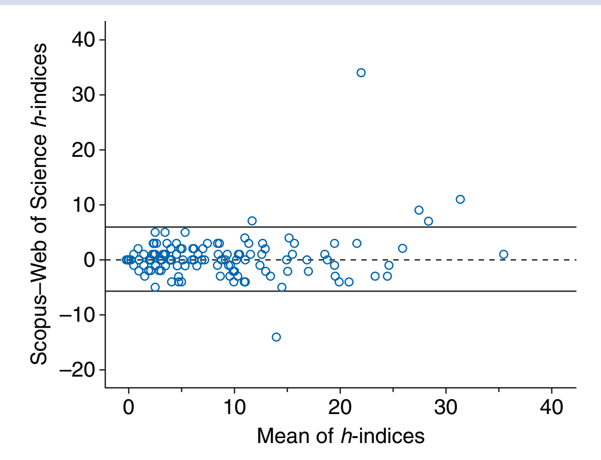

Fig 1 The Bland–Altman plot for Scopus™ and Web of Science®-derived *h*-indices. The dashed line indicates the mean bias (the mean of the differences between the Scopus™ and Web of Science®-derived *h*-indices) and the solid lines are ±1.96 SD of the mean bias. Because of discreteness, many of the data points were in identical positions. So that all of the data points could be displayed, a small normal random perturbation with mean 0 and SD 0.1 was added to each horizontal coordinate (the mean of the *h*-indices).

Assessment of validity: primary outcomes

The Web of Science®-derived *h*-indices showed a statistically significant difference between the different academic ranks (h=102.8, df=3, P<0.001): median *h*-indices were 0 for lecturers, 2 for assistant professors, 9 for associate professors, and 16 for full professors (Table 1). A *post hoc* Tamhane test found statistically significant differences in all comparisons between academic ranks (all P<0.01). The Scopus™-derived *h*-indices also showed a statistically significant difference between the different academic ranks (H=110.0, df=3, P<0.001): median *h*-indices were 0 for lecturers, 1 for assistant professors, 9 for associate professors, and 17 for full professors (Table 1). *Post hoc* testing found statistically significant differences in all comparisons between academic ranks (all P<0.01). There was considerable overlap between the groups: two high-scoring outliers in the lecturer and assistant professor groups (with values over three times the IQR) had *h*-indices above the median of the full professor group and the lowest scoring full professors had an *h*-index equal to the median of the assistant professor group (Fig. 2).

Assessment of validity: secondary outcomes

The Scopus™-derived *h*-indices without self-citations by any author also showed a statistically significant difference between the different academic ranks when self-citations by all authors were excluded (H=103.5, df=3, P<0.001). *Post hoc* testing found statistically significant differences in all comparisons between academic ranks (all P<0.01).

There was also a statistically significant difference between the total number of papers published for the different academic ranks (H=103.4, df=3, P<0.001) (Table 1). *Post hoc* testing for the total number of papers published also found statistically significant differences for all comparisons between academic ranks (all P<0.01) (Table 1).

A statistically significant difference between the total number of citations for the different academic ranks was detected (H=102.0, df=3, P<0.001) (Table 1). *Post hoc* testing found statistically significant differences for comparisons between academic ranks (P<0.01) except for between the lecturer and assistant professor (P=0.14) and between the associate professor and full professor (P=0.10). Similarly, there was a statistically significant difference between the mean number of citations per paper for different academic ranks (H=61.6, df=3, P<0.001) (Table 1). *Post hoc* testing for the mean number of citations per paper found statistically significant differences between the lecturer and associate professor (P=0.018), between the lecturer and full professor (P=0.001), and between the assistant professor and full professor (P=0.007) but not between the lecturer and assistant professor (P=0.14), nor between the assistant and associate professor (P=0.17), and nor between the associate professor and full professor (P=0.32) (Table 1).

Table 1 Web of Science® bibliometrics by academic rank. Citations/paper are the mean number of citations per paper. Values are median [IQR (range)]

	Lecturer (n=46)	Assistant professor (n=161)	Associate professor (n=36)	Full professor (n=25)	All (n=268)
h-index	0 [0–1 (0–19)]	2 [0–4 (0–17)]	9 [4–13 (0–25)]	16 [9–24 (2–35)]	2 [0–6 (0–35)]
Publications	0 [0–2 (0–57)]	3 [1–10 (0–59)]	23 [7.25–51 (1–106)]	60 [23.5–101 (4–166)]	4 [1–18.75 (0–166)]
Total citations	0 [0–3 (0–1076)]	24 [1–101 (0–811)]	335 [69–661 (0–2569)]	1088 [346–1970 (12–9382)]	30 [0–199 (0–9382)]
Citations/paper	0.0 [0–2.1 (0.0–69.0)]	4.3 [0.0–11.7 (0.0–61)]	10.7 [6.1–18.6 (0.0–60.7)]	20.1 [9.8–25.7 (3.0–78.2)]	5.0 [0.0–14.2 (0.0–78.2)]

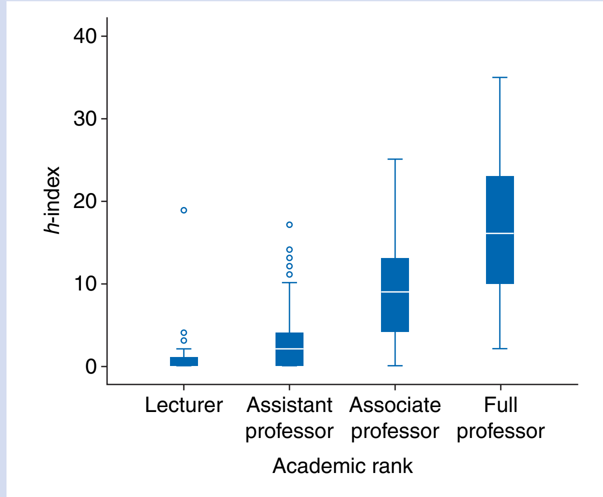

Fig 2 Box plot of Web of Science® *h*-index for each academic rank. The height of the box is the IQR. The white horizontal line is the median. The lower whisker extends to the lowest value within 1.5 IQR of the lower quartile, and the upper whisker extends to the highest value within 1.5 IQR of the upper quartile. More extreme values are represented by circles.

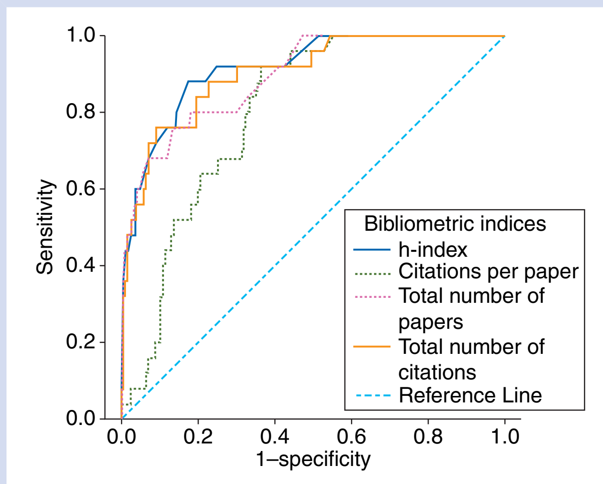

Fig 3 ROC curve for predicting a rank of full professor with the Web of Science® *h*-index. Diagonal segments are produced by ties. Citations per paper, mean citations per publication; *h*-index, Web of Science®-derived *h*-index; publications, total number of publications; citations, total number of citations.

When ROC curves were calculated for the ability of the Web of Science® bibliometrics to predict subjects being full professors, the *h*-index (AUC=0.92, 95% CI 0.86–0.97) performed at least as well as the number of citations (AUC=0.90, 95% CI 0.84–0.96), the number of publications (AUC=0.89, 95% CI 0.83–0.96), and the mean citations per paper (AUC=0.80, 95% CI 0.74–0.87) (P=0.15) (Fig. 3). As an example, if the cut-off *h*-index to identify a full professor is chosen to be ≥7, then the sensitivity is 88% and the specificity is 83%. When ROCs were calculated for the ability of the Web of Science® bibliometrics to predict subjects being either associate professors or full professors, the *h*-index (AUC=0.89, 95% CI 0.85–0.94) also performed at least as well as the number of citations (AUC=0.87, 95% CI 0.82–0.92) and the number of publications (AUC=0.88, 95% CI 0.83–0.93) and appeared to be superior to mean citations per paper (AUC=0.77, 95% CI 0.71–0.83) (P=0.006). If the cut-off *h*-index to identify a rank of at least associate professor is chosen to be ≥4, then the sensitivity is 87% and the specificity is 75%.

Discussion

Our data show that although the *h*-index differed significantly in every comparison between academic ranks, in common with the total number of publications but in contrast to the total number of citations and the mean number of citations per paper. This supports construct validity for the use of the *h*-index but we did not find evidence that the *h*-index is superior to counting the total number of papers published by an individual. The large degree of overlap between academic groups results in little differentiating ability for a low *h*-index. There was a relevant bias between Scopus™ *h*-index and Web of Science® *h*-index, suggesting that the use of either one of these alone could be an unfair evaluation. Our data suggest that self-citation does not significantly affect this form of evaluation.

Benway and colleagues[2] have previously investigated 266 academic urologists who were identified as being in the top 20 urology programmes in the USA and also found statistically significant comparisons between all academic ranks. The median *h*-indices of these urologists were higher than we found in this study: assistant professors 7 (range 0–25), associate professors 14 (0–32), and full professors 21 (1–53). Choi and colleagues described the *h*-indices of all radiation oncology faculty members at US residency training programmes (n=826) over an 11-yr period. They found similar median *h*-indices to our study: assistant professor 2 [IQR 1–6 (range 0–29)], associate professor 8 [4–14 (0–26)], and full professor 16 [9–24 (0–41)]. Using recursive partitioning analysis, they found an *h*-index threshold of 15 that separated full professors and chairpersons from junior faculty members; however, they too found significant overlap between the *h*-indices of senior and junior faculty. Lee and colleagues investigated the *h*-indices of faculty members from randomly selected neurosurgery programmes in the USA (n unspecified) and found a significant difference in Scopus™ and Google Scholar *h*-indices by academic rank but again there was considerable overlap between the groups. Pearson's correlation was used to correlate Scopus™ and Google Scholar *h*-indices, which is a questionable choice of statistic to analyse the agreement between measurement tools when there is no well-established gold standard.[8] Our findings that the *h*-index compared well with other Web of Science®-calculated bibliometrics in terms of construct validity are also supported by research in the field of physics that found that the *h*-index predicted future productivity better than these other bibliometrics.[9]

The considerable overlap in *h*-indices between academic groups is likely to be due to at least two factors. First, a lead-time bias is likely as academic promotion from lecturer to full professor is a slow, sequential process over many years that is dependent on the administrative processes of the university. Secondly, the *h*-index provides no information on aspects of academic productivity aside from publications: such as securing grant funding, teaching, mentorship, and contributing to innovations in departmental and professional development. Anaesthetists' academic interests cover broadly different areas, such as basic science research, applied clinical research, and education that are likely to have different citation patterns. It seems likely that a high *h*-index is significant when evaluating academic staff in anaesthesia but that a low *h*-index is not necessarily of importance and may just reflect academic interests that are not recorded by this number. Further research to identify whether being a high-scoring outlier predicts future promotion would help to determine the predictive value of the *h*-index in this context and the importance of a lead-time bias. Comparison across specialities and institutions internationally is warranted to investigate this. The use of the impact factor of the journals that publications are in instead of the *h*-index may reduce the effect of lead-time bias, although this has the limitation of being a surrogate measurement, which is likely to predict future impact, rather than a measurement of the actual impact of a researcher's publications.[10 11] Our study looked only at measures of long-term academic achievement. Another way to reduce the possibility of lead-time bias would be to investigate the *h*-indices of faculty members when applying for academic promotion to identify whether a higher *h*-index predicted success. For this comparison, an *h*-index restricted to, for example, the previous 5 yr may be more relevant as the *h*-index of even an inactive academic is likely to continue to increase over time.[5] This question was beyond the goal of our study.

The limits of agreement between the Scopus™ *h*-index and Web of Science® *h*-index were problematic. These literature databases index different numbers of journals over different fields. Web of Science® includes publications from 1900 to the present, whereas Scopus™ includes publications from 1966.[12] When an *h*-index is calculated in Scopus™, citations from before 1996 are not included in the number, because complete citation information for articles published before 1996 is not available in this database. It is possible that the apparent increase in bias between the Scopus™ *h*-index and Web of Science® values with increasing *h*-indices is in part due to Scopus™ missing some earlier citations for senior faculty members who tend to be older. It has been found that Scopus™, Web of Science®, and indeed other databases such as Google Scholar produce qualitatively and quantitatively different citation counts.[13] This suggests that if such bibliometrics are used as part of the evaluation of scientific productivity within a faculty, then a standardized process must be used. A further threat to reliability is uncertainty that all relevant publications have been included for each faculty member and that none has been omitted as indicated by our qualitative analysis of outliers of reliability in out data set. We hypothesize that errors may be particularly likely if the author has a common name, if they have published using various combinations of initials, if they have worked at a number of geographically disparate locations, or if they have a broad focus to their research interests. A solution to this problem is found in the French academic system: the mandatory SIGAPS system requires each academic physician to confirm that each of the publications linked with them is indeed correct and that none is missed in the database.[14] In order to use the *h*-index as an evaluative tool, it must be a reliable measure of both the individual being evaluated and but also of a sample of others in the field, so that there is a reasonable basis for comparison. Therefore, it is not enough to simply have the individual confirm their list of publications but this must be done systematically within a field or institution.

Our study has limitations intrinsic to the *h*-index, which does not account for whether a publication has been peer-reviewed, whether citations are negative or critical responses to the original article, or the position of authorship, although weighting for authorship position has previously been found to have little effect on the *h*-index.[4] The *h*-index may be manipulated by 'gratuitous authorship' or the writing of review papers, which tend to be highly cited.[15] Also, national and regional cultural differences may affect citation patterns and the findings of this study may not be generalizable to other universities and different systems of academia. We note that there are numerous other novel bibliometric indices that we considered to be outside the scope of this study.[16 17] Likewise, we did not compare *h*-indices based on Google Scholar searches which include grey literature that is not peer-reviewed.

In conclusion, our study showed that the *h*-index appears to be at least as valid as other bibliometrics to quantify the impact and relevance of an individual's scientific research output in the context of a university department of anaesthesia. However, we found the limits of agreement of the Scopus™ and Web of Science® *h*-indices to be problematic and the use of such bibliometrics can only be recommended if the means of calculating *h*-indices is standardized by institutions and if the data used are confirmed by the academic staff being evaluated. Moreover, it must be accepted that such quantitative tools can only focus on a limited proportion of the qualities that are required for academic advancement. We have not found evidence that a low *h*-index is significant for the evaluation of faculty members. Although the *h*-index is objective, transparent and most certainly concise, as Kotov[18] noted, the reduction of a lifetime's work to a numerical score 'such as the cost of a painting or manuscript at auction' is reductionist at best.

Conflict of interest

None declared.

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