Research in Engineering Education Symposium &
Australasian Association for Engineering Education Conference
5 – 8 December, 2021 - Perth, WA

Engineering education and non-education research: a scientometric comparison of 7 countries

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ABSTRACT

CONTEXT

Over the last decade there has been a growing interest in the global evolution of engineering education research (EER) as a field of inquiry and a variety of approaches have been adopted to study this process.

PURPOSE OR GOAL

Studies mapping engineering education research in different parts of the globe have mostly been human-curated and thus limited to relatively small samples. Recent advances in computer data analysis permit machine-curated study of larger data sets and this paper adopts such an approach.

APPROACH OR METHODOLOGY/METHODS

The study assembles scientometric data on EER publications in Australia and compares it with that of 6 European countries: 4 Nordic countries (Denmark, Sweden, Finland, and Norway) and 2 Southern European countries (Portugal and Spain). This is achieved by identifying 651 authors that published in 13 leading EER journals in the period 2018-2019 and then analysing their entire research output throughout their careers in both educational and non-educational publications - 32934 publications in all.

OUTCOMES

There are notable differences in the career evolution and EER output across the 7 countries and these in turn influenced the h-index values of the researchers in our sample. For Australia, as in the cases of Finland, Norway and Spain, engineering academics published over three times more non-educational than educational. This in turn affected their h-index values. In addition, our data suggest that Australian educators, along with those in Portugal, Sweden and Spain, are typically 6 to 8.5 years on average into their publishing careers when they publish their first educational work whereas in the case of Denmark, Finland and Norway this tends to occur earlier in their careers.

CONCLUSIONS

Scientometric findings acquired through analysis of large bodies of data, as in this study, can have a valuable role in informing both institutional and national policy decisions regarding support for engineering education research and can also help individual engineering educators in planning their own research career.

KEYWORDS

Scientometrics, citation analysis, engineering education research, Australia

https://doi.org/10.52202/066488-0053

Introduction

Over the last decade interest in the evolution of engineering education research (EER) has been growing and a variety of approaches have been adopted to study this process. Froyd and Lohman (2014) used criteria for defining the field of science education research (Fensham, 2004) to point out that while engineering education has been seen as an area of interest for educators since the end of the 19th century, over the last two decades there have been significant indicators of a transition to an interdisciplinary, more scholarly field of scientific inquiry into engineering education. Borrego and Bernhard (2011) have compared Northern and Central European approaches to EER with those of the U.S. using a framework from the European *didaktik* tradition, which focuses on answering the w-questions of education. Borrego and Olds (2011) employed an analysis of National Science Foundation funded projects as a way of characterizing development in EER in the US while Williams and Alias (2011) used a scientometric approach to track the evolution of EER in Malaysia.

Neto and Williams (2011) analysed historical studies of the European Journal of Engineering Education (EJEE) to provide insights on the European context. Other studies looked at specific European national contexts (Williams, Wankat and Neto, 2018; Edström et al. 2016; van Hattum-Janssen, Williams and Oliveira, 2015; Nyamapfene and Williams, 2017).

Strobel and colleagues at Purdue University applied bibliometric analyse to gauge the presence of interdisciplinarity in EER (2012) and the growth of loose networks within the EER community (2011).

The present study examines data gathered by using a quantitative scientometric approach to understand the characteristics of EE researchers who were affiliated with tertiary institutions in Australia. A small set of data from the Australian context was earlier reported based on analysis of three EER journals (Valentine, 2020) whereas the present study considers data from 13 publications. This allows us to create a more granular profile of Australian EER output. To put the data in context we compare the Australian figures with those previously collected by the authors relating to EER publication patterns of researchers in two European contexts: researchers based in two Southern European countries (Valentine and Williams, 2021a) and those in four Nordic ones (Valentine and Williams 2021b).

Methodology

Data Sources

Data were gathered from the Scopus API (http://api.elsevier.com and http://www.scopus.com) during January-March 2021 using the pybliometrics Python library (Rose and John, 2019). Data was gathered over several months due to limitations of the Scopus API.

A comprehensive list of EER publications from each of the respective countries was required. To create this list, thirteen research journals relevant to the field of engineering education (EE) were consulted (Table 1). For each journal, the list of all authors who had published at least one article between 2019-2020 (inclusive) was considered. The tertiary institutions of each author were checked, and this was used to establish which countries the author was affiliated with.

Comprehensive details for each author were then retrieved from Scopus. This included their full publication history. For subsequent analysis, only articles, conference papers, reviews, book, and book chapters were included. Other publication types such as editorials, letters, erratum or notes were excluded. Key details of each publication were captured including document title, source title (e.g. JEE), document publication year, document type (e.g. article), author keywords, subject category, citation count (note that this can change over time; this is a limitation of the study), and DOI. A total of 32934 publications until the end of 2020 were captured for the 651 authors.

Journal	Finland	Spain	Portugal	Denmark	Norway	Australia	Sweden
Advances in Engineering Education	0	0	3	0	0	0	0
Australasian Journal of Engineering Education	0	1	0	0	0	29	0
Education for Chemical Engineers	2	100	7	8	0	2	0
European Journal of Engineering Education	14	22	27	7	4	43	20
Global Journal of Engineering Education	1	2	0	0	0	5	0
IEEE Transactions on Education	1	19	2	2	0	12	2
International Journal of Electrical Engineering Education	1	31	0	0	0	4	0
International Journal of Engineering Education	3	218	10	4	3	11	9
International Journal of Engineering Pedagogy	2	1	11	0	0	1	0
International Journal of Mechanical Engineering Education	0	0	0	0	1	1	0
Journal of Engineering Education	0	0	0	4	0	0	0
Journal of Engineering Education Transformations	0	0	0	0	0	2	0
Journal of Professional Issues in Engineering Education and Practice (now Journal of Civil Engineering Education)	0	8	0	0	1	8	0
Total (duplicates removed)	23	397	58	23	9	111	30

Table 1: Engineering education journals where authors from each country were sourced from (note it was possible that authors may have published in multiple journals)

Data Analysis

Publications were subsequently classified as being either educationally focused or non-educationally focused. The purpose of this was to build an understanding of how educational and non-educational publications contribute to the research track record of each author. Because this involved analysis of thousands of publication records, it was not feasible to do this manually. A computer aided approach was therefore required to assist with automating the process. Accordingly, an algorithm was created, using a combination of keyword search and Scopus data fields.

An extensive manual scoping search involving several iterations (and testing) was undertaken to identify suitable Scopus fields and keywords (this is similar to how a scoping search is implemented for systematic literature reviews).

A publication was deemed to be educationally focused if:

1. *any* of the following Scopus fields:
   'authkeywords', 'subject_areas', or 'publicationName'
   included *any* of the following terms
   - 'education', 'student', 'teach', 'tutor', 'novice', 'MOOC', 'ASEE', 'SEFI'

   OR

2. the Scopus 'title' field included the term 'learn'
   - AND the term 'learn' appeared at once outside the term 'machine learn'

The inclusion of criterion 2 was necessary because "learn" was identified as a term that was absolutely essential for some papers to be correctly flagged as educational (i.e. there were no other terms which may have worked). However, an issue arose where papers in "machine learning" were then often flagged as educational when they were not (this is also why "learn" was restricted to the 'title' field). To try and address this issue, it was required that 'learn'

 https://doi.org/10.52202/066488-0053

appeared at least once in the title outside the context of the term ‘machine learn’. This increased the accuracy, but some machine learning publications were still incorrectly flagged as being educationally focused.

To test the efficacy and accuracy of this algorithm (compared to human judgement), a random subset of 1000 publications were manually coded by the authors as being either educationally focused or non-educationally focused. This was then compared to the output of the algorithm.

- 400 papers from the Portugal, Spain authors were checked
  - there was a 99.7% agreement between human judgement and the algorithm
- 300 papers from the Denmark, Finland, Norway, Sweden authors were checked
  - there was a 97.3% agreement between human judgement and the algorithm
- 300 papers from the Australian authors were checked
  - there was a 98.3% agreement between human judgement and the algorithm

There was an overall 98.6% agreement between authors and the algorithm (11 false positives, and 4 false negatives). This was deemed to be reasonable accuracy for analysing the larger dataset and making conclusions (with the acknowledged limitation that about 1.4% of publications may be incorrectly flagged).

Following this, information for each of the 651 authors was then established, including:

- the number of years the author had been publishing, and when they published their first educational paper;
- the distribution of the publications by document type including articles, conference papers, book chapters, books, and reviews;
- the percentage of publications which were educationally focussed;
- the number of citations on educational and non-educational publications;
- the author’s overall h-index, and that of their educational publications, and non-educational publications.

Results

Ratio of educational and non-educational publications per country

Country	Population (million)	Educational Publications	Non-educational Publications	Total Publications
Australia	26	1377	4924	6301
Denmark	6	318	663	981
Finland	6	334	1066	1400
Norway	5	98	307	405
Portugal	10	667	1690	2357
Spain	47	4479	15909	20388
Sweden	10	493	609	1102
Total		7766	25168	32934

https://doi.org/10.52202/066488-0053

Table 2: The number of publications which are educationally focused and non-educationally focused, per country

Overall, authors from each country published more non-educational publications than educational publications (Table 2). While Sweden published slightly more non-educational publications compared to educational publications, some other countries had published over 3 times as many non-educational publications (Australia, Finland, Norway, Spain) as educational publications.

Average author percentage of publications which are of each document type

Country	Number of Authors	Type of Document	Article	Book	Chapter (Book)	Conference Paper	Review	Total
Australia	111	Educational	28.2%	0.1%	2.1%	15.8%	1.5%	47.7%
		Non-educational	27.5%	0.2%	1.5%	21.3%	1.7%	52.3%
Denmark	23	Educational	27.9%	0.3%	5.7%	24.8%	0.9%	59.7%
		Non-educational	24.0%	0.1%	6.2%	7.1%	2.9%	40.3%
Finland	23	Educational	32.9%	0.0%	0.8%	29.4%	0.1%	63.2%
		Non-educational	14.9%	0.0%	2.4%	18.7%	0.8%	36.8%
Norway	9	Educational	21.9%	0.0%	4.6%	11.3%	0.8%	38.6%
		Non-educational	22.8%	0.0%	2.9%	35.2%	0.5%	61.4%
Portugal	58	Educational	18.8%	0.0%	1.2%	19.8%	8.7%	48.4%
		Non-educational	29.1%	0.1%	2.6%	18.5%	1.4%	51.6%
Spain	397	Educational	24.1%	0.0%	0.6%	9.3%	0.3%	34.3%
		Non-educational	43.4%	0.0%	1.6%	18.9%	1.7%	65.7%
Sweden	30	Educational	29.2%	0.6%	1.4%	34.0%	0.6%	65.7%
		Non-educational	18.5%	0.0%	0.7%	14.0%	1.1%	34.3%

Table 3: The mean percentage of authors' publications which are educationally focused for each document type, per country

Table 3 shows that authors from Denmark, Finland and Sweden publish on average more educational papers at 59.7%, 63.2%, and 65.7% of their overall total, respectively. Conversely, authors from Australia, Norway, Portugal and Spain publish less educational papers at 47.7%, 38.6%, 48.4% and 34.3% of their overall total on average, respectively.

h-index

For each country, the h-index of non-educational publications is higher than the h-index of educational publications (Figure 1). While the difference between mean values is relatively large for Australia, Denmark, Norway, Portugal and Spain, it is closer for Finland and Sweden. The differences between h-index of non-educational publications and h-index of educational publications for each country was evaluated for statistical significance using the paired samples t-test with IBM SPSS 26. It was found that there was a statistically significant difference for Australia ($t=-4.244$, $df=110$, $p<0.001$), Norway ($t=-2.468$, $df=8$, $p=0.039$), Portugal ($t=-3.553$, $df=57$, $p<0.01$), and Spain ($t=-13.221$, $df=396$, $p<0.001$), but not Denmark, Finland, or Sweden. Considering all 651 authors, while the h-index of educational publications was significantly correlated with the overall h-index (Pearson Correlation=0.196, p<0.001), the h-index of non-educational publications was a lot more strongly correlated with the overall h-index (Pearson Correlation=0.956, p<0.001).

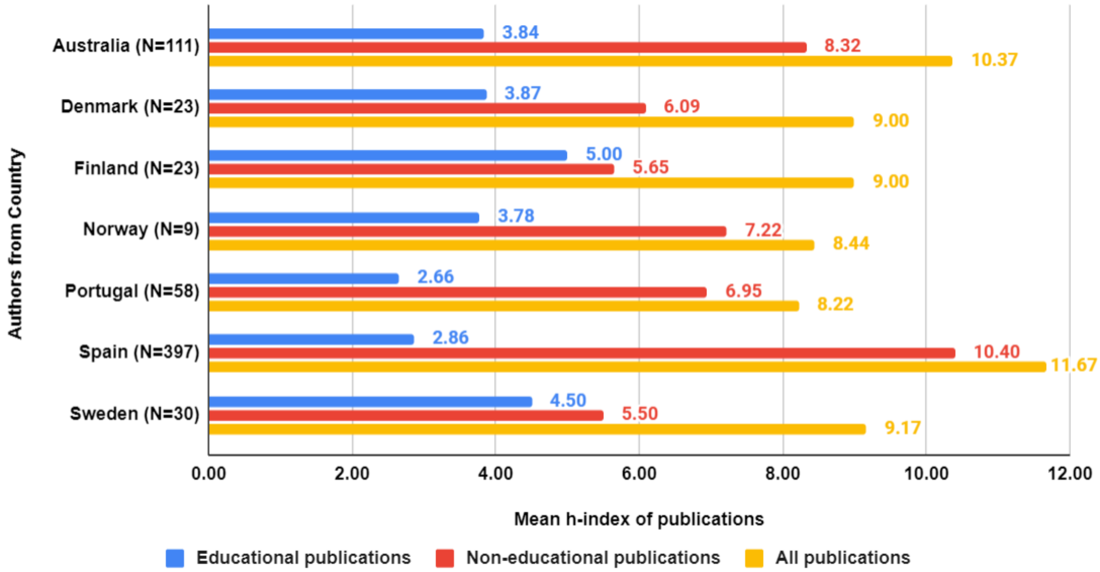

Figure 1: Mean h-index for each author per country for (i) all publications, (ii) educational publications, and (iii) non-educational publications

Evolution of Publication Careers

Years into Career Until First Educational Publication	Australia (N=111)	Denmark (N=16)	Finland (N=21)	Norway (N=9)	Portugal (N=58)	Spain (N=397)	Sweden (N=30)	Total
0	43	13	15	2	18	119	13	223
1-5	17	4	3	5	9	79	4	121
6-10	19	3	2	2	8	59	4	97
11-15	16	1	1	0	11	57	5	91
16-20	9	0	1	0	7	44	2	63
21+	7	2	1	0	5	39	2	56

Table 4: Mean number of years into a researcher's career before an educational publication is published (counting from the date of their first research publication) (N is number of authors)

https://doi.org/10.52202/066488-0053

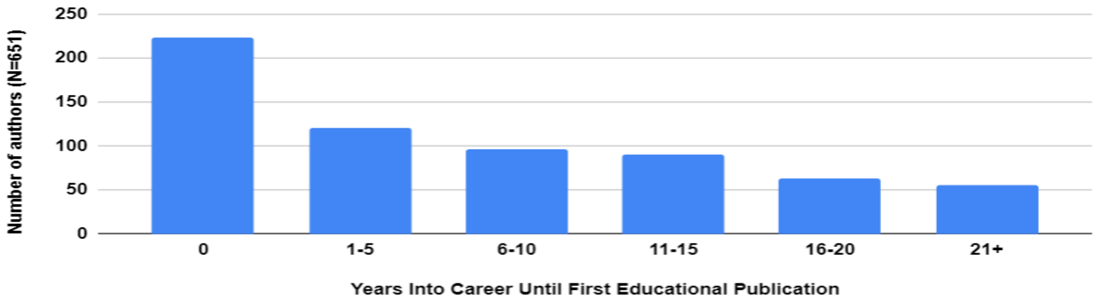

Figure 1: Mean number of years into a researcher's career before an educational publication is published (counting from the date of their first research publication)

Table 4 and Figure 1 demonstrate that many authors begin their careers publishing educational research, while others commence educational research at a later time during their career. Figure 2 shows the mean of years which authors from each country take until publishing their first educational publication, while Table 5 also shows the median number of years. Median values of 0 may be attributed to the small sample sizes of these countries.

Number of years until educational publication	Australia (N=111)	Denmark (N=16)	Finland (N=21)	Norway (N=9)	Portugal (N=58)	Spain (N=397)	Sweden (N=30)
Mean	6.44	4.26	3.43	3.56	8.26	8.17	7.60
Median	4.00	0.00	0.00	2.00	6.00	6.00	4.00

Table 5: Number of years into a researcher's career before an educational publication is published (N is number of authors)

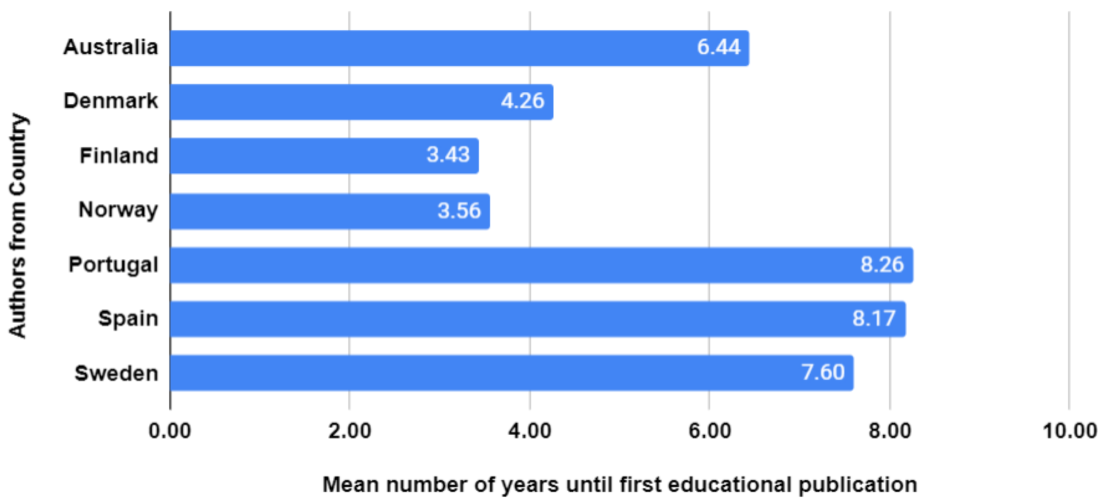

Figure 2: Mean number of years into a researcher's career before an educational publication is published

Limitations

Although we believe these data provide a valuable snapshot that allows us to compare the publishing patterns in these countries, as the number of authors is relatively small in some

https://doi.org/10.52202/066488-0053

cases this can reduce the generalisability of the findings. We note for example that whereas Valentine and Williams, 2021b studied data from 12 EER journals, for analysis in this paper we added a further journal (Education for Chemical Engineers) to provide a larger sample; while this led to similar overall findings there are some minor differences between the results here and those of the smaller sample.

Conclusions

With regard to the ratio of education focused and non-education focused publications (Table 3), there is considerable variation between the 7 countries: authors from Denmark, Finland and Sweden on average publish more educational papers whereas those from Norway and Spain publish significantly more non-educational. In the case of Australia and Portugal, there is a small preponderance of non-educational publications. These data help us begin to characterise the current research culture in each country viz a viz research publication by engineering educators.

Taking population differences into account, output from Australian EER scholars is broadly similar to that of the other 5 EU countries. Globally, Spain appears to be something of an outlier, even taking into account the fact it has the largest population: it publishes a large number of journal articles, almost exclusively in two technically focussed journals, while conference publications from Spain are rather lower than those of the other countries. This is probably due to a nationally defined career progression system there that strongly privileges journal publications in both educational and non-educational fields (Valentine and Williams, 2021a).

The above publication patterns in turn affect the h-index of the 651 authors included in our study. In addition, our data suggest that non-educational publications play more of a role in determining the h-index than educational ones as they tend to acquire more citations. This reflects a generalized phenomenon that was noted in the 1970s by citation analysis pioneer Ernest Garfield – founder of the ISI system and credited with being the initiator of the journal impact factor concept – when he observed that "citation potential can vary significantly from one field to another." (Garfield, 1979). In general engineering education articles tend to have much lower citation rates than those in specialized engineering fields. This can be seen in the impact factor of journals: for example, the most cited journal in the field of EER, Journal of Engineering Education, has a 2020 impact factor of 3.146 while those of the three highest ranked in the field of Mechanical Engineering are Nature Materials 43.84, Materials Science and Engineering: R: Reports 36.21 and Advanced Materials 30.85.

The mean number of years until educational publication is in the range 6 to 8.5 years for Australia, Portugal, Spain and Sweden while engineering educators in Denmark, Finland and Norway on average begin earlier in their academic careers. This may be due to the increasing number of PhD programs in engineering and STEM education provided in these countries: the Engineering/STEM Education Graduate Programs online resource curated by the University of Arizona lists 4 programs in Sweden and one in Denmark but none for the other countries. These results merit further study.

To conclude, scientometric findings acquired through analysis of large bodies of data, as in this study, can have a valuable role in informing institutional and national policy decisions regarding support for engineering education research and can also help individual engineering educators in planning their own research career.

References

Borrego M. and Bernhard J., (2011), "The Emergence of Engineering Education Research as an Internationally Connected Field of Inquiry." *Journal of Engineering Education* 100: 14 – 47.

Borrego M. and Olds B. (2011). Analysis of Trends in United States National Science Foundation Funding for Engineering Education: 1990 – 2010. Research in Engineering Education Symposium, 175 – 183.

Edström K., Kolmos A., Malmi L., Bernhard J., and Andersson P., (2016). A bottom-up strategy for establishment of EER in three Nordic countries–the role of networks. European Journal of Engineering Education, 1-16.

Engineering/STEM Education Graduate Programs online resource, http://engineeringeducationlist.pbworks.com/w/page/27610307/Engineering%20Education%20Departments%20and%20Programs%20%28Graduate%29 consulted 25 Sep. 2021

Fensham P. J. (2004) Defining and identity: The evolution of science education as a field of research, New York, NY, Springer

Froyd J. E & Lohmann J. R., (2014). Chronological and ontological development of engineering education as a field of scientific inquiry. Cambridge Handbook of Engineering Education Research, 3- 26. http://dx.doi.org/10.1017/CBO9781139013451.003

Garfield, E. (1979). Is citation analysis a legitimate evaluation tool? Scientometrics 1(4), 359-375.

Neto P. and Williams B. (2017). The European Journal of Engineering Education as a venue for engineering education research publication: a meta view. In 45th SEFI Conference, Azores, Portugal Sep 2017.

Nyamapfene A. and Williams B. (2017). "Evolution of Engineering Education Research as a Field of Inquiry in the UK", 7th Research in Engineering Education Symposium (REES 2017): Research in Engineering Education, Bogota, Colombia.

Rose, M. E., and John R. K. (2019). Pybliometrics: Scriptable Bibliometrics Using a Python Interface to Scopus. *SoftwareX,* 10: 100263

Strobel, J. M. J., Radcliffe, D. F., Rajan, P., Nawz, S., Luo, Y., & Choi, J. H. (2011). AC 2011-2836: Loose Networks and The Community of Engineering Education Research: A Definition by Bibliometric Standards - mapping the domain of engineering education research. ASEE Annual Conference and Exposition. https://doi.org/10.18260/1-2-18302

Strobel, J. M., Radcliffe, D. F., Yu, J. H., Nawaz, S., Luo, Y., & Choi, J. H. (2012). Is the Engineering Education community becoming more interdisciplinary? ASEE Annual Conference and Exposition, Conference Proceedings. https://doi.org/10.18260/1-2-21621

van Hattum-Janssen N, Williams B., and Nunes de Oliveira J.M., (2015). Engineering Education Research in Portugal, an Emerging Field. International journal of engineering education, 31(2), 674-684.

Williams B. and Alias M. (2011). Strategic Pathways to Engineering Education Research: case study of a top-down initiative. Proceedings of the Research in Engineering Education Symposium (REES 2011).

Williams B., Wankat P. C, and. Neto P, (2018). Not so global: a bibliometric look at engineering education research. European Journal of Engineering Education, 43(2), 190-200.

Valentine, A. (2020). Do Australian engineering education researchers publish more educational or non-educational research? A bibliometric analysis. In 31st AAEE Conference, Sydney, Australia, Dec 2020.

Valentine, A., Williams, B., (2021a) Evolution of Engineering Education Research in Portugal and Spain: a scientometric study. Proceedings of CISPEE, 2021, Lisbon, Portugal 21 -23 June 2021.

 https://doi.org/10.52202/066488-0053

Valentine, A., Williams, B., (2021b) Engineering Education Research in the Nordic Countries: Scientometric Insights into Publication and Career Patterns, Proceedings of the 49th Annual Conference of the European Society for Engineering Education (SEFI), Berlin, 13 -16 September 2021.

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https://doi.org/10.52202/066488-0053