WHAT EVERY ENGINEER SHOULD KNOW ABOUT ENGINEERING EDUCATION

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1. INTRODUCTION

The purpose of this paper is to present the current status of the literature of engineering education. In order to accomplish this task several questions are discussed: Who publishes them? What are the topics of the articles published? How to find them? and Where to publish them? The author also discusses the deficiencies found in existing databases caused by the lack indexing a great deal of information of significant importance and proposes the development of an engineering education gateway to overcome this problem.

As has been reported in previous works done by the author (Osorio, 1998) and (Osorio and Osorio, 2002) the literature of engineering education is an active endeavour. Similarly to other subject related educational literatures like mathematics education, the engineering education literary production includes articles in journals, scholarly periodicals, trade magazines, papers in proceedings, conference proceedings, reports, books, dissertations, software and audiovisuals. Professional associations in engineering such as the American Society for Engineering Education (ASEE) and the European Society for Engineering Education (SEFI); colleges and universities; state and federal agencies; non-profit organizations and other institutions are making important contributions to the field by providing the support needed by researchers to get their research done and to present it and publish it.

Based on an extensive analysis of the literature done by searching for documents related to engineering education in several key databases the author has identified a core list of journals, conference proceedings and publishers. It is the hope that this information will help professionals in this field to make decisions about selecting possible avenues for their own publications.

In this paper also the results obtained by Wankat (2004), Whitin and Sheppard (2004) , Osorio and Osorio (2002) will be presented in order to identify prevailing subject topics and trends; the demographic data about authors; the type of articles and content or articles, and some other important bibliometric data.

Finally, another aspect of this paper is introducing the idea of creating awareness about a large portion of the literature of engineering education that has not been covered by conventional indexing databases. As suggested by De Petro (2002) there is a need to incorporate this missing

part of the literature into the main stream of the bibliographic process. The author proposes the creation of an engineering education gateway as a solution to this problem.

2. WHO PUBLISHES THEM?

In this section the principal characteristics of authors in the field of engineering education are presented. The data was obtained from the previous work done by Osorio and Osorio (2002), and by Wankat (2004). The first of these two articles collected data about the *Journal of Engineering Education* (JEE) and the *European Journal of Engineering Education* (EJEE) and compared the outcomes of these two publications during the period from 1998 to 2000. Wankat's article is about the out-put of the *Journal of Engineering Education* from 1998 to 2002 and compares it with data previously obtained from 1993 to 1997. Through out this and the next section the results of these two works are presented. Although descriptively compared with the purpose of showing the many different components in engineering education it is not intended to be a critical evaluation of these works. Basically, only the facts are presented.

According to Osorio and Osorio (2002) 331 articles covering the period from 1998 to 2000 were analysed and the following information about authorship was obtained:

JEE and EJEE authors come from 29 countries. The larger number of contributors come from the USA, UK, Australia, Canada, and Germany. They represent the77% of all authors.

The combined author's professional status for these two journals is: teaching faculty (248), university administrators (37), and university professional staff (13). These three groups account for 91.5% of all authors. Others groups found are: graduate assistants, practicing engineers, consultants, counsellors, federal/state agency staff, corporate administrators, and federal/state agency administrators.

The main place of employment of these authors are: public funded universities (240); or privates universities (73). These two groups represent 94.6% of all authors. Other sources of employment for authors found are federal agencies, corporations, high school faculty and private consultants.

These results are consistent with the following factors characterized in these two publications: 1. the membership of both sponsoring societies is mainly from academic institutions, 2. the main audience of both journals are people involved in higher education and 3. the editorial board of both publications are made up mainly of persons from the academic world.

Wankat's works shows a gender comparison of authors and whether or not they are professional engineers. Table 1. indicates that 26.6% are female authors; and that 74.9 % of authors are engineers. It also shows that 27.0 % of papers have a single author and women single authors represent a 12.1%.

Table 1. Author data (1998-2002)

		%
Total authors	943	
Total engineers as authors	707	74.9 based on 943 authors
Women authors	251	26.6 based on 943 authors
Women engineers as authors	147	20.8 based on 707 engrs. authors
Number of papers with a single author	99	27.0 based on 367 total papers
Women as single authors	12	12.1 based on 99 authors
Engineers as single authors	78	78.8 based on 99 authors
Women engineers as single authors	7	7.0 based on 99 authors

It is important to say that while Wankat collected data for all authors the work done by Osorio and Osorio collected data only for the first author of each article.

An important piece of information reported by Wankat is about the financial support received by authors to conduct their research. Table 2 shows the results.

Table 2. Reported sources of support

		%
No of papers supported	180	49.0 based on 367 total papers
NSF	119	66.1 based on 180 papers
Other U.S. govt. agency	18	10.0 based on 180 papers
Corporate	23	12.8 based on 180 papers
Private foundation	28	15.6 based on 180 papers
State	4	2.2 based on 180 papers
Univ/Dept/College	43	23.9 based on 180 papers
Non-US Govt. agency	5	2.8 based on 180 papers
Others	17	9.4 based on 180 papers

According to the data it can be concluded that some authors received multiple sources of support for the same research project. Also, the author comments that after the National Science Foundation (NSF) the Fund for the Improvement of Postsecondary Education (FIPSE) and NASA were the two other U.S. government agencies providing more support to the authors.

Finally, Table 3 shows very similar results in terms of the numbers of reference sources cited by the authors.

Table 3. Reference listed

	Sources cite	avg./article
Wankat	5,903	16.1
Osorio & Osorio	5,398	16.3

3. WHA ARE THE TOPICS OF THE ARTICLES PUBLISHED?

Based on the work of Osorio and Osorio (2002) Table 4 presents the type of articles published in EJE and EEJE. In their paper a type of article "describes the nature of the paper" and a definition

for each type is made. According to Table 4, 64% of the articles fall in one of the first five type of documents: description of project; review of topic; research report; description of program; or description of course.

Table 4. Type of Documents

		%
Total number of papers	331	
Description of project	52	15.7
Review of topic	43	13.0
Research report	40	12.0
Description of program	39	11.8
Description of course	38	11.5
Case study	31	9.4
Survey report	25	7.5
Survey of field	23	6.9
Opinion paper	12	3.6
Description of teaching methods	11	3.3
Program reports	10	3.0
Survey of topic	2	.06
Review of field	3	.09
Report of project	2	.06

Also in the paper by Osorio and Osorio (2002) each article in EJE and EJEE is assigned one principal subject. The most common subjects for articles published in these two publications are courses, programs, and assessment. They represent 55.6% of all topics recorded. The definitions of these terms were provided by the authors.

Table 5. Main Subject of articles

Main Subject		%
Courses	82	24.8
Programs	61	18.4
Assessment	41	12.4
Society	26	7.8
Freshman	18	5.4
Skills	16	4.8
Administrative	12	3.6
Teaching	12	3.6
Technology	12	3.6
Women & minorities	9	2.7
History	9	2.7
Faculty	8	2.4
Curriculum	8	2.4
Learning	7	2.1
Design	4	1.2
Professional	4	1.2
Literature	1	.04
Laboratory	1	.04
Total no. of papers	331	

Wankat (2004) used a similar approach by analysing each article and assigning them with keywords to describe their subject content. The data shown in Table 6. is taken from 367 articles. In this work multiple keywords or subject terms were given to a single article. The four first

keywords listed in this table - teaching, computers, design and assessments - were reported by the author as the most common topics of research.

Table 6. Subject (1998-2002)

Main topic of article		%
Teaching	94	25.6
Computers	66	18.0
Design	50	13.6
Assessment	36	9.8
Groups/teams	30	8.2
Internet/web	28	7.6
ABET	24	6.5
Learning	24	6.5
First year	21	5.7
Curriculum	20	5.4
Laboratory	19	5.2
Gender/women	13	3.5
Distance education	12	3.3
Communication/writing	11	3.0
Ethics	10	2.7
Experimental/hands on	9	2.5
Entrepreneurship	8	2.2
International/global	8	2.2
Retention	8	2.2
Programming	8	2.2

The author also indicates that the subject coverage of JEE "remains very broad". Keywords with less than 8 hits were not listed.

Also, in the work done by Wankat (2004) five additional characteristics of the articles published in JEE are explored. These characteristics are called "tabulated data for the content" of each article. Each article can have several of these characteristics.

Table 7. Content of articles (1998-2002)

No of articles 367
Content Discipline specific 28 or 7.6 %
Teaching methods (computer techniques, lecture, cooperative groups) 127 or 34.6
Data (presented) 226 or 61.6
Assessment used (surveys, grades, stud. eval.) 152 or 41.4
Educational and learning style theories (Kolb, Learn. Styles, MBTI) 28 or 7.6%

As indicated by Wantak these types of subject analyses of journals "allows us to determine some of the trends in engineering education". It appears that research on specific courses, programs and assessments as reported by Osorio and Osorio (2002) and research on teaching, computers design and assessments as reported by Wankat (2004) are some of the recent trends in the subject covered by the articles. Since these two works were developed under a set of different parameters it is advisable to read the original papers in order to reach a deeper understanding of them. As for other data collected about the articles published; for Osorio and Osorio (2002) the description of project; review of topic; research report; description of program; and description of course are the most common type of articles found. For Wankat (2004) the teaching methods; data (presented) and assessment used are the most common content found in the articles. Finally,

the study done by Whitin and Sheppard (2004) focuses on topics of papers published in JEE from 1996 to 2001. It is a substantial and complementary approach of Wanka's paper and it also a recommended reading.

4. HOW TO FIND THEM?

Published documents in engineering education are mainly articles in journals and articles in conference proceedings. There are also a good number of related materials published as monographs, and reports. Searching a library online catalog and a national catalog like *WorldCat* is an effective way of finding books, reports and other formats such as dissertations and audiovisual materials. A great portion of the current literature is published as articles in journals and articles in conference proceedings. The sources listed in this section are the core of databases where information about documents published can be found. This is not a complete list but it represents some of the major sources of bibliographic information for engineering education.

Compendex. Engineering Information, Elsevier, New York. It is the most comprehensive single engineering index; it includes papers in journals, conference proceedings and technical reports since 1969.

INSPEC. Institution of Electrical Engineers (IEE), London, UK. It covers mainly electrical and electronics engineering; computer science and control engineering; physics and astronomy; and information technology since 1967.

ERIC (Education Resources Information Center). Computer Sciences Corporation Lanham, MD. It is the most comprehensive index for education in the English language with more than 1.1 million bibliographic citations since 1966.

Cambridge Scientific Abstracts (CSA), Bethesda, MD. This information service provider has over 70 databases among them are: *ANTE: Abstracts in New Technologies and Engineering; Aerospace & High Technology Database; CSA Engineering Research Database; Civil Engineering Abstracts; Earthquake Engineering Abstracts; Environmental Engineering Abstracts; Engineered Materials Abstracts; Advanced Polymers Abstracts; Composites Industry Abstracts; Engineered Materials Abstracts, Ceramics; and Mechanical & Transportation Engineering Abstracts*. All of them are recognized as excellent sources for engineering information.

Web of Science. Thomson Scientific, Philadelphia, PA. It includes the *Science Citation Index* and the *Social Science Citation Index*. A selected list of journals are included in each citation index from which historical data about cited references can be obtained.

SciFinder Scholar. Chemical Abstracts Service (CAS), Columbus, OH. A major index for chemical sciences and engineering. It is the comprehensive index for this field and includes several thousand journals and conference proceedings.

Google Scholar, Google, Mountain View, CA. It covers all areas of knowledge published in journals, books, preprints, and reports. A Beta version is currently offered free of charge. A search done on "engineering education" produced about 28,000 hits. (Cited 01-25-2005).

Examples of subject specific engineering databases are:

Civil Engineering Database (CEDB, American Society of Civil Engineering, Reston, VA. It covers the publications of the society with abstracts since 1973.

Ergonomics Abstracts, Taylor & Francis, Philadelphia, PA. It has international coverage of the literature on human factors and ergonomics.

Examples of electronic journals collections databases are:

ScienceDirect, Elsevier, New York, NY. It contains an extensive collection of science, engineering and medical journals, nearly 1,800 in all.

EBSCO Academic Elite, EBSCO Information Services, Birmingham, AL. It covers over 1,500 journals in all academic areas.

Kluwer Online, Springer-Verlag New York, NY. It provides several hundred (650) scientific, technical and scholarly journals. It has recently merged with Springer-Verlag.

Springer Link, Springer-Verlag New York, NY. It has a sizable collection of journals on medicine, science, engineering, humanities and economics.

Table 8. shows a distribution of the type of documents about engineering education in the *Compendex* database. This data was obtained by searching 14 thesaurus terms of this database that are closely related to engineering education. The time span is from 1980 to 2004.

Table 8. Type of documents in *Compendex*

Type	Count	%
Journal article	17374	41.8
Conference article	23073	55.5
OTHERS:		2.7
Conference proceeding	555	
Monograph chapter	365	
Monograph review	3	
Report chapter	2	
Report review	72	
Dissertations	0	
Unpublished paper	104	
Total	41548	

As reported earlier by Osorio (1998) articles in conference proceedings are the most common type of document in engineering education. Considering the fact that a good number of conference proceedings are published as special issues of journals the 55.7 % reported here could be higher. In Osorio (1998) it was 69%. The coverage of book reviews in *Compendex* is not very

good, therefore, the low figures for monographs and reports in Table 8 does not represent the real numbers in these types of documents. A library online catalog or a universal catalog like *WorldCat* are better sources for finding out about monographs and other formats.
In spite of its deficiencies *Compendex* is a very good database for finding documents on this subject. Table 9 shows the results when the 36 journals listed in Table 11 were searched in three different databases about articles dealing with engineering education during the period of 1980 to 2004. In Compendex 37% more documents were found than in INSPEC. It is noted that the coverage of each database differs from each title and even within a database the coverage of a title is not always consistent, therefore, shortcomings in the databases creates in some cases significant gaps in coverage. Articles in journals indexed in *ERIC* for this subject is quite limited.

Table 9. Articles in journals (1980-2004)

Database	Count
Compendex	7094
INSPEC	5141
ERIC	1030

Similar searches were done to compare the coverage of articles from conference proceedings in the three databases. In this case data for the 33 conferences listed in Table 12 was collected. The scope of each conference was limited to documents related to engineering education. This was accomplished in *Compendex* by selecting 14 thesaurus terms related to engineering education. In *INSPEC* keywords related to the subject such as teaching, learning, education, instruction, etc. were used. The time period is also from 1980 to 2004.

Table 10. Articles from conference proceedings (1980-2004)

Database	Count
Compendex	19078
INSPEC	3803
ERIC	1

Therefore, *Compendex* is also the best source for finding articles in conferences. *ERIC* practically does not cover this type of document for engineering education.

As reported by Osorio (1998) several hundreds of journals published articles on engineering education. Initially, in 1998, this list was collected by searching four databases: *Compendex, INSPEC, ERIC* and *Ingenta* producing a core list of professional journals where articles on engineering education are indexed. The data for this list has been updated for this article covering the period 1980-2004 and dropping the *Ingenta* database. A substantial reduction in coverage in *Ingenta* in the last years was the reason for this decision. Table 11 shows the top 18 journals in the field. Top meaning the journals with large numbers of citations found.

Table 11. Journals in Engineering Education

IEEE Transactions on Education 1470
Chemical engineering education 806
ASEE Prism 781
International Journal of electrical engineering education 795
International Journal of engineering education 729
European Journal of Engineering Education 670
Journal of engineering education 436
Journal of professional issues in engineering education 343
Engineering Science and Education Journal (ceased 2002) 434
International Journal of mechanical engineering education 341
Computer applications in engineering education 304
Education for information 246
IEEE transactions on power systems 183
Communications of the ACM 176
International journal of technology design (ceased, 2002) 154
Quality progress 153
Transportation research 137
Journal of the operational research society 107

This list indicates how several professional engineering societies are directly involved in the production of documents on the subject. Among them are the Institute of Electrical and Electronics Engineers (IEEE), the European Society for Engineering Education (SEFI), the American Society for Engineering Education (ASEE), the Association of Computing Machinery, and the Operational Research Society (ORS).

The following conference proceedings list was also originally developed by Osorio (1998) and it has been updated for this article. The list was made by searching in *Compendex*, *INSPEC*, and *ERIC*. Also used was the hands-on knowledge the author has about other professional conferences supported by engineering societies and other organizations. It is important to say that hundreds of conferences dealing with all areas of engineering were found including papers in their programs about engineering education. This list is a representative sample of the most productive conferences in the field.

Table 12. Conference proceedings in Engineering Education

Annual Conference on Frontiers in Education
ASEE Annual Conference
ASEE Gulf Southwest Section Meeting
ASEE North Central Section Meeting
ASEE Illinois-Indiana Section Meeting
ASEE Northwest Section Meeting
ASEE Pacific Southwest Section Meeting
ASEE Southeastern Section Meeting
College Industry Education Conference
International Conference on Engineering Education
SIGCSE Technical Symposium on Computer Science Education
Annual Conference of Society of Technical Communication
Annual Meeting of the Human Factors and Ergonomics Society
ASME International Mechanical Engineering Congress
Biennial University/Government/Industry Microelectronics Symposium
Conference on Human Factors in Computing Systems
Congress on Computing in Civil Engineering
IEEE Conference on Decision and Control
IEEE International Conf. on Acoustics, Speech and Signal Processing, ICASSPO
IEEE International Conference on Microelectronics Systems Education, MSE

IEEE International Conference on Multi-media Engineering Education
IEEE International Conference on Systems, Man and Cybernetics
IEEE International Professional Communication Conference
IEEE SOUTHEASTCON
Industrial Engineering Research Conference
International Conference on Computers and Industrial Engineering
International Conference on Education in Manufacturing
Proceedings of the SPIE - The International Society for Optical Engineering, International Conference on Education in Optics.
SIGCSE Technical Symposium on Computer Science Education
World Congress on Engineering Education and Training
UICEE Annual Conference on Engineering Education.
International Conference on Engineering and Technology Education (INTERTECH)

Examples of other journals or conferences not included in Table 11 nor Table 11 are: The UICEE (UNESCO International Centre for Engineering Education) Annual Conference on Engineering Education; SEFI Annual Conference; *The Global Journal of Engineering Education*; and, the *Australasian Journal of Engineering Education*. Many other smaller publications are making a significant effort to be at the forefront of engineering education. These smaller but excellent publications are additional possibilities for places where authors can get their works published.

Finally, the ASEE Web page has made significant improvements in providing access to published documents in the field. Limited only to ASEE members are the full-text of the following publications: the *Engineering Education Journals* and *Prism* but other users are allowed to browse the indexes of these publications. The following conference proceedings are available as open access publications: ASEE Annual Conference (1996-2004); International Colloquium on Engineering Education (2002-2003); Engineering Research Council - ERC (1996-2003); Conference for Industry and Education Collaboration - CIEC (2001-2004); and Frontiers in Education (FIE) (2000-2004). The last two are not loaded on the ASEE servers and are dependent on the functionality of external links. A significant improvement in the searching capabilities of the ASEE search engine is also worthy of mention. This Web page also has a large amount of information about future conferences.

5. WHERE TO PUBLISH THEM?

In the previous three sections a great deal of information about the literature of engineering education has been discussed. In summary, the authors in this field can publish their work mainly in the proceedings of conferences. A good number of engineering societies are supporting this kind of activity as well as commercial publishers. The second most important avenue for publication are professional journals. There is a core list of refereed engineering education journals. Other forms of publications are less common but a good number of monographs and reports have been published from a variety of sources.

Data obtained from Osorio (1998) indicates that these are publishers that in the past have published books, reports, conference proceedings or journals related to engineering education:

Table 13. Publishers

Association for Computing Machinery (ACM), New York, NY.
American Institute of Chemical Engineering, New York, NY.
American Society of Civil Engineers, Reston, VA.
American Society for Engineering Education (ASEE), Washington, DC.
American Society of Mechanical Engineers (ASME), Fairfield, NJ.
Columbia University Press, New York, NY.
CRC Press, Boca Raton, FL.
Elsevier Science & Technology Books, San Diego, CA.
Government Printing Office, Washington, DC.
Institution of Electrical Engineers (IEE), Edison, NJ.
Institute of Electrical and Electronics Engineers (IEEE), Piscataway, NJ.
IEEE Computer Society, Piscataway, NJ
Institution of Chemical Engineers, Rugby, UK.
Institution of Mechanical Engineers, London, UK.
Iowa State University Press, Iowa City, IA
Manchester University Press, Manchester, UK.
MIT Press, Cambridge, MA.
National Academy of Engineering, Washington, DC.
National Academy of Science, Washington, DC.
National Science Foundation, Arlington, VA.
Oregon Institute of Technology Press, Klamath Falls, OR.
Oxford University Press, Oxford, UK
Plenum Publishing Corporation, New York, NY.
Society of Manufacturing Engineers (SME), Dearborn, MI.
Society for Computer Simulation international, San Diego, CA.
Springer Verlag, New York, NY.
SUNY-Albany Press, Albany, NY.
Tempus Publications, Hamburg Educational Partnership, Hamburg, Germany.
Wiley & Sons, Hoboken, NJ.

Although this is not a complete list a variety of professional societies, academic, government and commercial publishers can be identified as active publishing partners in engineering education.

6. CONCLUSION

The results of works done about the literature of engineering education indicates that this is a robust and active field. The sections on authorship and subject coverage presented in this paper demonstrate a sophisticated level of complexity in the field of engineering education similar to other well known areas such as mathematical sciences education and science education. Therefore, it is necessary to recognize the importance of engineering education as a whole and independent body of knowledge. The interrelation of engineering education to other subjects is also well documented here. This conclusion is supported by the findings of Whitin and Sheppard (2004) who has stated: "As such, the body of work represented by the *Journal* shows an enterprise that is growing in size, in complexity of the work it is undertaking, and its ability to present this work in a reflective and convincing manner." In relation to the role play by JEE they said "to play a role in the broadening of engineering education culture by helping to bring the scholarship of engineering education to the same level of respect and recognition in the faculty reward system as traditional scholarship in engineering sciences." These reflections are also applicable to the whole production of research in engineering education.

The following comments are related to engineering education and its sources of publication:

Compendex is the most comprehensive index for engineering but it has significant gaps in the coverage of some core journals for engineering education. For example: the *International Journal of Engineering Education*; the *International Journal of Mechanical Engineering Education*; the *European journal of Engineering Education*; and the *Computer Applications in Engineering Education* are not included. Some other journals have several gaps in several years or are not covered cover to cover.

INSPEC, an index with a more specific subject coverage (electrical, control engineering, computer science, physics and information technology) indexes some of the journals and conferences in this field. The combined coverage of *Compendex* and *INSPEC* is good but is not complete.

ERIC is the major English language education index but it has poor coverage of engineering education. Basically, it does not include major journals and conference proceedings in this subject. Therefore, it is not recommended unless the motive to search on *ERIC* is to search for a specific topic in the literature of general education such as assessment methodologies, pedagogical principals, teaching methods, etc.

The major lack of coverage in index databases (*Compendex*, *INSPEC* and *ERIC*) is the indexing of articles published in conference proceedings. Compendex just recently (December 2004) finally included the proceedings of the ASEE Annual Conference. But Compendex nor *INSPEC* does not index any of the ASEE sectional conferences. Major national and international conferences such as the Annual Conference on Frontiers in Education and the International Conference on Engineering and Technology Education (INTERTECH) are also missing. Less known journals or conferences have little chance to appear in these databases.

Conference proceedings in engineering education is the most common format for researchers in the field to publish their findings. Therefore, it is important to attain a more complete level of coverage for this format. Also troublesome is the inconsistencies and gaps for the coverage of articles in journals and the complete absence of other smaller but important publications.

Monographs, textbooks, reference sources in engineering education are not that common. Most monographs on the subject are proceedings of conferences. There is a potential for growth in publishing monographs specifically about engineering education since it already appears to be a sizeable and acceptable knowledge in this field.

7. WHERE TO GO FROM HERE?

As indicated by De Petro (2002) one of the critical components of importance in maintaining the current vitality of the field is the identification, analysis and recording of the engineering education periodicals and proceedings.

As was mentioned before the American Society for Engineering Education has made considerable progress in the last few years by making several of its publications easily available in one place. But the lack of bibliographic record of a great portion of the literary production is still troublesome.

Following the example of the National Science Digital Library - a multi-institutional project funded by the National Science Foundation - the author would like to propose the development of an Engineering Education Gateway.

This gateway initially could be a bibliographic center for all the documents not included in the now available databases. It would also include the full-text of those documents that are made available from their sources free of charge. Further developments for this gateway would be the inclusion, for example, of databases with significant teaching materials of importance to engineering courses. There is also a considerable interest in the library and information community to identify open access projects that could be funded by external sources. Therefore, a project of this nature would be well received by libraries and it would need for its development the support of the engineering education community.

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