

METHODOLOGICAL ANALYSIS OF CDIO PAPERS

Le Li^{1,2}, Jens Bennedsen¹

¹Aarhus University, School of Engineering

²Soochow University, Department of Electronics and Information Engineering

ABSTRACT

Since 2005, there have been ten annual CDIO conferences. In this article, we analyze the development of the articles from 2005 to 2013. We have found 577 articles from the CDIO website from 2005 to 2013 (in the knowledge library). Out of the 577 papers in the knowledge library, 421 papers were selected for investigation.

We used bibliometric analyses and statistics to inspect the developmental process of the research in the CDIO area. We analyzed the features of the papers including authors, institutions, references, references to other articles presented at CDIO conferences and references from another CDIO article to this one from 2005 to 2013.

We compared the number of papers from the knowledge library with the number of papers shown in the conference programs from the CDIO conferences (except the conference in 2008, because we cannot find the conference program). The number of papers from the CDIO website and the CDIO conference programs are very close in 2005, 2007, 2010, 2011, 2012 and 2013. By contrast, the number of papers at the web-site and in the conference proceedings in 2006 and 2009 are quite different. Consequently, for 2006 and 2009, we could not find a sufficient number of papers to perform a statistical analysis.

We categorized the papers used in this study according to the year they were published. Furthermore, we examined the tendency of the development of the CDIO field through the analysis of the above mentioned paper features in each year.

We found the general growth of the number of published papers over time. The papers with multiple authors exceed those with single authors.

Additionally, the number of references in the published papers is relatively high. Moreover, the number of citations from the CDIO conference papers that were cited by the other papers shows a steady growth until 2011, and rapidly reduced from 2012 (Normally, the peak of the citation is shown in the second year of the publication of the paper.).

This result suggests that the website of the CDIO and the CDIO conference provide good platforms for scientific communication. However the interdisciplinary research and collaborations between institutions in the CDIO field need to be further strengthened in the future.

KEYWORDS

Biibliometric analyses, articles, reviews, CDIO development, Standards: 9,10

INTRODUCTION

Over the years, CDIO has developed from a small community, where everyone knew each other, to a community with over 100 members. With the CDIO focus on sharing ideas and generally inspiring each other, the growth puts even more focus on the conferences for face-to-face meetings and the knowledge library for inspiration between the meetings.

In other engineering societies, there is a growing interest in becoming more scholarly. One example is SEFI, where Wankat, Williams and Neto (2013) evaluated the two journals associated with SEFI (European Journal of Engineering Education and Journal of Engineering Education). They focused on author data, citation data and reference data. They concluded: “Both journals followed similar trends. They progressed from opinion essays, reports and descriptive papers to research papers”. Others (Malmi et al., 2013) have studied the more research oriented papers at the SEFI conferences.

Within the CDIO community, the question of becoming more scholarly has also been discussed. Some of the reviewers for previous conferences have expressed their concerns about the quality of the papers for the CDIO conferences. Do they have an appropriate review of literature? Do they have data to support the conclusions? Many papers seem to be a description of (elements of) a successful CDIO implementation at one institution. One response to this problem is the different categories of papers for the 2014 conference: Advances of CDIO, CDIO Learning Objects and CDIO Implementation, where the first category requires a scholarly approach and the other two are focused on helping others with the implementation of CDIO in their own institution.

This article analyzes the papers in the knowledge library (that is the papers presented at the annual CDIO world conferences) available at www.cdio.org. It has the same focus as the article by Wankat et al (2013), namely author, citation, reference and collaboration data and analytical trends in these different categories. As written before, this article looks at the development in the papers from 2005 to 2013.

RELATED WORK

CDIO is a rather young community. This year is the tenth international conference, so it seems reasonable to expect a development towards a more scholarly approach to the conference papers. Other young areas have gone through the same development phase; one example is computer science.

Valentine (2004) analyzed 444 objects (papers, workshop reports and panels) dealing with traditional CS1/2 topics from the SIGCSE conferences (SIGCSE, 2013) from 1984 to 2003. He used a six-fold taxonomy to classify the type of papers:

- Experimental (the author made an attempt to assess the “treatment” with some scientific analyses),
- Marco Polo (“I went there and I saw this”),
- Philosophy (“the author made an attempt to generate debate on an issue, on philosophical grounds, among the broader community”),
- Tools (“things helping education – not all software tools, but also rubrics”),
- Nifty (“small elements used in teaching such as nifty assignments”) and

- John Henry¹ (“every now and then a colleague describes a course that seems so outrageously difficult (in my opinion) that it is suspected of telling us more about the author than about its pedagogy”).

The general conclusions from Valentine’s research were:

- 21% of the papers presented (94 out of 444) fell into the experimental category (i.e., a kind of research paper).
- The portion of Experimental papers has been on the rise since the mid-nineties.
- The Marco Polo papers dropped from approximately 35% in 1984 to 19% in 2003 (a statistically significant drop).
- The total number of entities presented increased during the period.
- The percentage of first year entities remained almost the same throughout the period.

However, as noticed by Randolph, Bednarik, and Myller (2005), Valentine’s findings should be seen with a fair amount of skepticism. Their rationale for this skepticism is the lack of methodology used to conduct Valentine’s review (e.g., there were no estimates of reliability about his categorizations).

Within the broader area of engineering education research (EER), analyses have been carried out as well. Williams and Neto (2012) carried out a taxonomical analysis and citation analysis to the first 2011 number of IEEE Transactions on Education (21 papers) and from the two 2011 numbers of the ASEE published Advances in Engineering Education (22 papers). As they write, “In the former approach, seven taxonomical dimensions are used to characterize the papers and in the second the references cited in the 43 papers were studied so as to analyze how the researchers were informed by previous studies.” (p. 37). One of the taxonomical dimensions is “research purpose” (what is the goal of the research). They use three categories:

- Descriptive (description of a tool, technology or system),
- Evaluative (assessment of a tool, method or situation).
- Formulative (development and/or refinement of a theory, model, standard, or process, or proposition of a new concept.)

They find that the vast majority of papers fall into the descriptive category (86% in IEEE Transaction on Education, 82% in the Advances in Engineering Education)

RESEARCH DESIGN

This research is based on the papers presented at the international CDIO conferences from 2005 to 2013. The papers are categorized on the basis of 6 topics:

- The number of papers. We collected the names of all the papers we could find in the knowledge library. The number of papers was used to analyze the trend in CDIO research.

¹ John Henry was an American worker who worked as a steel-driver for the Chesapeake & Ohio Railroad. The folktale says that he was the strongest and fastest worker who had ever drilled holes using a hammer and a steel spike. One day a salesman came with a steam-powered drill and claimed that it could do better than any man. John Henry competed, won, but died due to strain (American Folklore, 2006).

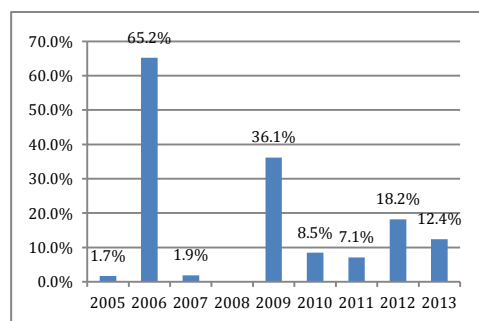
- Authors. We collected the names of the authors and the number of the authors per paper. We calculated the average number of authors per paper. This helped us to know the collaboration over the years.
- Institutions. We collected the number of institutions per paper and also calculated the average number of institutions per paper. This was another way to analyze the collaboration in CDIO research.
- References (out-going). The references were used to support the papers. In almost all of the articles, we could find the references at the end. We counted the number of references per paper.
- References to other CDIO conference papers (out-going). The number of references in the article where the author(s) gave the clear indication of reference to another CDIO conference paper.
- The in-coming references from CDIO conference papers. We collated the number of CDIO conference papers which had been cited by the other CDIO papers. As stated earlier, from analyzing the references, the CDIO references and the in-coming references, we can find the connection of CDIO papers, the development tendency of CDIO and the influence of CDIO conference in the CDIO research.

From the conference programs, we have a number of expected papers, except for the conference in 2008, where we cannot find the program. Table 1 and Figure 1 show the data from the CDIO website and conferences. We used the RSD (Relative standard deviation) for the data analysis. The number of papers included on CDIO websites and in conferences is very similar in 2005, 2007, 2010, 2011, 2012 and 2013, although they are not identical. However, in 2006 and 2009 the situation is quite different; there are very few papers we could find at the CDIO website. So be careful about conclusions from these two years.

Table 1. Number of papers from the website and the proceedings (2005-2013)

Figure 1. Difference in numbers of papers at cdio.org and in the proceedings

Year	Included from website	Included in conferences proc.	Relative standard deviation
	A	B	$C= (A-B)/(A+B) ^* 100\%$
2005	30	29	1.7%
2006	8	38	65.2%
2007	53	55	1.9%
2008	20	Not available	Not available
2009	38	81	36.1%
2010	77	65	8.5%
2011	125	144	7.1%
2012	91	63	18.2%
2013	78	100	12.4%
SUM	520	575	5.0%



The number of papers in this research is 577 (the number of papers found on the cdio.org knowledge base). Of those, 57 papers were without indication of which conference they were related to, giving a total of 520 papers. Of those, 99 were excluded; 421 were selected for review.

The excluded papers fell into five categories:

- There was only a presentation available at the website (39 in total).
- The authors were not stated on the paper (3 in total).
- The paper was not in English (1).
- The papers were not at the website at all (52 in total). 51 papers were found as a result of references from other papers on the CDIO website.
- Only the abstract was available (4 in total).

The data in the Table 2 show the number of papers on the CDIO website from 2005 to 2013.

Table 2. Papers on the CDIO website (2005-2013)

Year	Mis- sing papers	Only pres. available	Without authors	Only ab- stra ct	Trans lation	Valid papers	All pa- pers	Valid pa- pers(% papers)
2005	2	1				27	30	90.0%
2006	7					1	8	12.5%
2007	2	3				48	53	90.6%
2008²	11	2				7	20	35.0%
2009	9	18	1			10	38	26.3%
2010	5	12				60	77	77.9%
2011	10	1			1	113	125	90.4%
2012	4	1	2	4		80	91	87.9%
2013	2	1				75	78	96.2%
SUM	52	39	3	4	1	421	520	81.0%

Figure 2 shows that from 2005 to 2013 the number of papers both on the website and in the conference program has rapidly increased.

From analyzing the data in Figure 3, it can be seen that in the years 2005 (90.0%), 2007 (90.6%), 2010 (77.9%), 2011 (90.4%), 2012 (87.9%) and 2013 (96.2%) there is a high portion of papers having the information we need (number of authors, institutions, references, reference from CDIO, the cited references from CDIO conference papers) So for these years, we have a reasonable number of papers from which to perform our analysis (and also a high number of paper compared to the expected number - see Table 1 and Figure 3). However, in 2006 (12.5%) and 2009 (26.3%) the number of paper was low compared to the expected number, so be careful to conclude on these years. In 2008 we do not know the number of papers to expect.

FINDINGS

This article found the authors, institutions, references, CDIO references and in-coming references from 2005 to 2013. The papers available at www.cdio.org provide hard data and we

² The 2008 conference program is not available; in order not to influence Figure 2, we used the average number of all the papers: 71.9.

analyze the information of the papers to narrate the history and present conditions in the development of CDIO research. We used the method of bibliometric research on a yearly basis.

Figure 2. The papers on the CDIO website versus conferences (2005-2013)

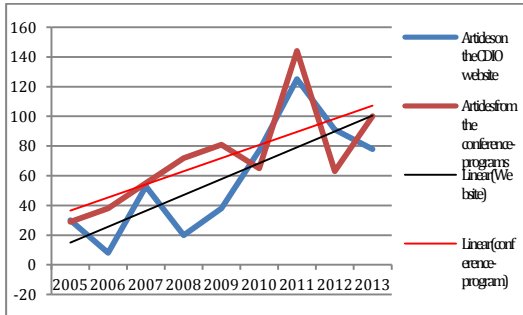
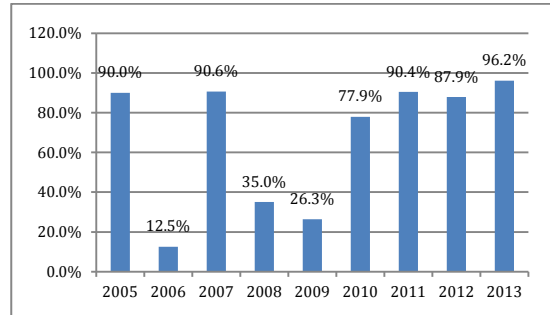


Figure 3. The percentage of the included papers



The number of papers

From Figure 2, showing the number of papers for each year on the CDIO website, it can be seen that there have been changes in the number of papers, but in general a growing number until 2011. In 2012 and 2013, a drop in the number of papers can be observed.

Authors

Figure 4 shows that the average number of authors per paper is 3.1, and the number is very similar from 2005 to 2013. The largest average number of authors is 3.4 in 2008, the lowest is 2.9 in 2010 and 2013.

The percentage of papers written by two authors is 29.0%, by three authors 24.9% and by four authors 12.8%. Only 17.6% of the papers are written by a single author. Therefore, the papers written in collaboration by several authors are more than the papers written by single authors. The results are shown in Table 3.

Figure 4. The average authors of per paper

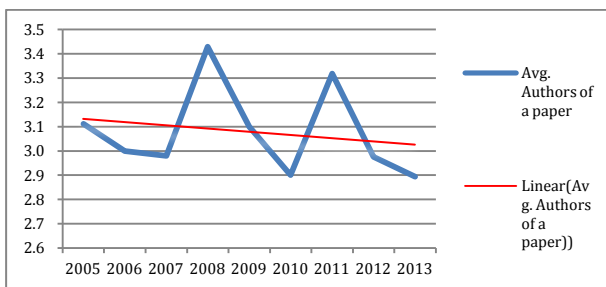


Table 3. The number of papers grouped by number of authors

#Authors	#Papers	% Papers
1	74	17.6%
2	122	29.0%
3	105	24.9%
4	54	12.8%
5	21	5.0%
6	22	5.2%
7	10	2.4%
8	5	1.2%
9	3	0.7%
10	3	0.7%
13	1	0.2%
23	1	0.2%

Institutions

The data in Figure 5 show a decrease in the average number of institutions per paper. Although the number of papers has increased, the average number of institutions per paper has decreased, and the average number is 1.5. The largest number of institutions is 7. The data from Table 4 show that 78.6% of the papers have authors from one institution (331 papers) and 12.6% from 2 institutions (52 papers). The numbers from 3 to 5 institutions are 4.0% (17 papers), 3.1% (13 papers), 1.4% (6 papers), respectively. Only one has authors from 7 institutions.

Figure 5. The average institutions per paper

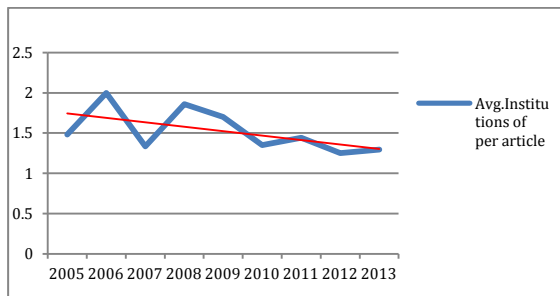


Table 4. The number of institutions and papers

The number of institutions	#Papers	The percentage of the papers
1	331	78.6%
2	53	12.6%
3	17	4.0%
4	13	3.1%
5	6	1.4%
7	1	0.2%

References

Figure 6 shows that the average references per paper are 11.6. The numbers of references is almost the same from 2005 to 2013. The highest average reference per paper is 17.3 in 2008, and the lowest average number of the references is 7.4 in 2005. Figure 7 shows the number of papers with 1-5 references, 6-10 references and 11-15 references are 101, 130 and 80, respectively. This means that 73.9% of the papers have 1-15 references. The number of references is kept at a stable high level, suggesting the website and the conference provide a good platform for scientific communication.

Figure 6. The average references per paper

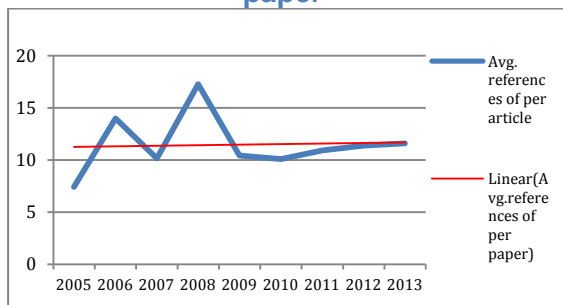
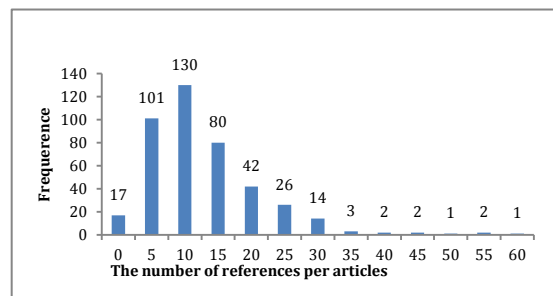


Figure 7. The distribution of papers wrt number of references



References to other CDIO conference papers

Figure 8 shows a remarkably increasing average number of references from CDIO conferences per paper. The continuous growth of citations mean that these topics attract more attention from the CDIO community. The fast increasing body of citations confirms the im-

portance of these topics and also shows the continuity of research on these topics. Naturally, one would expect to see a growth, since the number of articles grows each year.

2005 was the first year for a CDIO conference, so we have situated data from 2006 to 2013. The data in Table 5 shows that 225 (57.1%) of the papers are without reference to CDIO conference papers. 71 (18.0%) of all the papers have one reference to other CDIO papers, which is the highest proportion. There are 36 (9.1%), 20(5.1%), 22(5.6%), 6(1.5%), 7(1.8%) papers, which cite 2 to 6 references, respectively. There are only 7(1.9%) papers to have more than 6 references, which come from papers of CDIO conferences.

Figure 8. The average number of references to other CDIO conference papers

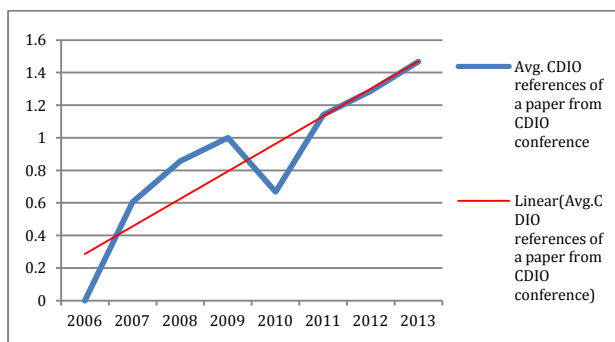


Table 5. The number of references to other CDIO conference papers and its percentage

The number of references	The number of papers	% Papers
0	225	57.1%
1	71	18.0%
2	36	9.1%
3	20	5.1%
4	22	5.6%
5	6	1.5%
6	7	1.8%
7	3	0.8%
8	2	0.5%
11	1	0.3%
16	1	0.3%
All	394	1

The in-coming references from CDIO conference paper

So far, of the 421 papers, 148 papers have been cited; a total 268 of citations. The average citation number is 1.6. The the most frequently cited paper is “The CDIO Syllabus v2.0: An Updated Statement of Goals for Engineering Education” , it has been cited 27 times.

In Figure 9, the result shows that there are 6 citations per paper in 2006 (but all 6 citations are to the same paper). There are 2.7 citations per paper in 2008. The average citations are 1.2, 1.15, 1.5 and 1 in 2005, 2007, 2009 and 2010, respectively. Normally, the peak of the citation is in the second year of the publication of the paper. Thus there are only 3 papers published in 2013 to be cited once in 2013, and the average citation per paper is 0.04. Similarly, for the papers published in 2011 and 2012, the number of cited references is just 0.5 and 0.26 until the end of March 2014. In addition to the above reason, another reason that we have described at the beginning of this article, that is, for the papers published in 2006, 2008 and 2009, there are still a lot of papers have not been included on the website. Therefore, from Figure 10, we can identify the decrease of the citation number in these 3 years.

Figure 9. The average in-coming references per paper from CDIO conference papers

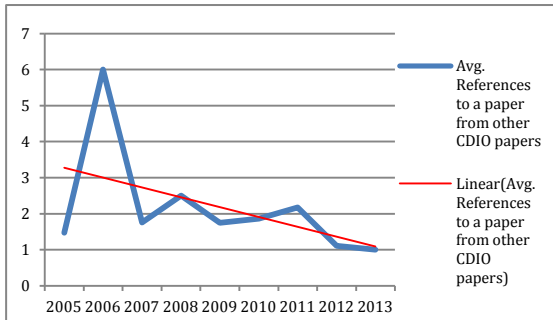
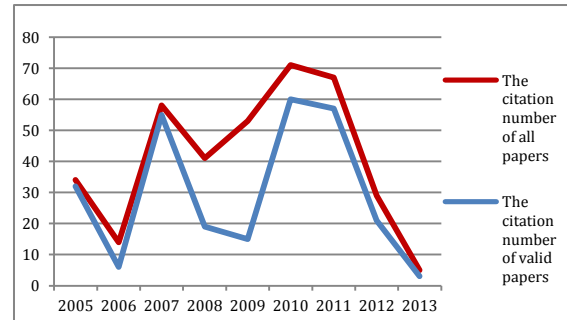


Figure 10. The citation number of valid papers and all papers were created



On the other hand, as we described in the “research design”, the number of papers in this investigation is 577, but we only selected 421 papers in this study. We found that a part of the excluded papers have been cited from the CDIO website papers, some of them coming from the references of the CDIO papers. We can still see the number of papers that have been cited from the excluded papers (Table 6). The number of in-coming references is 67, and the number of citations is 104 in total. From Figure 10, the red line of the total number of citations shows us that the general trend steadily increased until 2011. From 2012, the number of citations has rapidly been reduced.

Table 6. The number of in-coming references

Years	2005	2006	2007	2008	2009	2010	2011	2012	2013	Without year	All
Valid papers	32	6	55	19	15	60	57	21	3		268
Excluded papers	2	8	3	22	38	11	10	8	2	6	104
Sum	34	14	58	41	53	71	67	29	5	6	372

DISCUSSION

Lister (2008) concludes that “Twenty-first century academia needs to bring teaching and research together, to form a scholarship of computing that is an integrated, sustainable, ecological whole.” (p.3). The same needs to happen within the CDIO community, that is the rationale for this article.

We found 577 papers all in all, and excluded 156 papers due to incomplete information. Consequently we analyzed 421 papers. The number of papers available from the CDIO website from 2006 and 2009 is low compared to the expected numbers, so we ignored the influences of the two years. During the analyses of the available papers by authors, institutions, references, CDIO references and citations, we could find the development of the CDIO study. Such as the increasing number of the CDIO papers, 82.4% of the papers are written by multiple authors, the number of references and CDIO out-going references are both growing. The in-coming references from CDIO conference papers that could be found at the CDIO website increased steadily until 2011. It is in accordance with the norm that the peak of the citation is shown in the second year of the publication of the paper. The average number of

institutions was reducing and 78.6% of the papers came from single institutions. But most findings of CDIO papers are universal and extensive. They are not limited to one or a few institutions. The interdisciplinary research and collaboration between institutions in the CDIO field need to be further strengthened in the future. We find the CDIO website and conference provide a good starting point for scientific communication.

We will further investigate the dynamic development process of the CDIO research fields and reveal the tendency and hot points in the CDIO research. We hope that the results from this analysis can provide us with a potential orientation for the future study in the CDIO field.

CONCLUSION

The number of the CDIO conference papers was increasing in the past decade. The number of the references and CDIO papers references per paper is growing. The number of the CDIO citations is steadily increased until 2011. Most of the CDIO papers are finished by the collaboration of authors. Although most studies of the CDIO papers are universal and extensive, the average of institutions per paper is has decreased.

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BIOGRAPHICAL INFORMATION

Le Li, MA. Eng. is a lecturer at the Department of Electronics and Information Engineering, Soochow University. Her research focuses on the general area of electronics, information and computer science. She also researches in teaching methods of engineering education.

Jens Bennedsen. Ph. D. is a professor in engineering didactics. His research area includes educational methods, technology and curriculum development methodology, and he has published more than 40 articles at leading education conferences and journals.

Corresponding author

Jens Bennedsen
School of Engineering, Aarhus University
Finlandsgade 22, DK-8200 Aarhus N,
Denmark+45 4189 3090
jbb@iha.dk



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