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THE ROLE OF DEMOCRACY IN ENGINEERING EDUCATION: AN ANALYSIS OF SEFI CONFERENCE PROCEEDINGS

A Baier[1]

[a] Technische Universität Berlin, Germany, 0000-0002-4382-5788

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ABSTRACT

Introduction - The study is a first review of the role of democracy in engineering education within the conference proceedings of the SEFI annual conference.

Methods - The study aims at a systematic data collection and a first tentative analysis through a mixed-methods approach. For this, the retrieved data is analyzed with quantitative methods for a simple descriptive statistics and a simple qualitative analysis in which contexts the words democracy and/or democratic are used.

Results - The search string yielded 219 hits across 79 papers out of 1.824 papers in total, representing 4,3%. There are 67 papers which have only one match (66,7%) or two matches (19,0%). A first deductive coding of the matches identifies hits where the search term is used only in a peripheral or “accidental” manner which is the case for 55 hits (25,1%) in 47 papers (59,5%). There are 101 hits (46,1%) across 23 papers (29,1%) which address democracy in the context of higher education and learning.

Discussion - The study is an explorative study and only provides a first glimpse into the research field but as such it serves to identify future in-depth research. As a result of the high peripheral usage of the search term, the relative number of papers drops across all the annual proceedings from 4,3% to 1,75%.

[1] Corresponding Author
A Baier
Andre.Baier@tu-berlin.de

1 INTRODUCTION

Robert E. Doherty (1937), the electrical engineer and visionary third president of Carnegie Mellon University published in 1937 a paper titled "Engineering Education and Democracy". In a short summary preceding the text, the anonymous author writes "With a view to the future, an eminent educator here prescribes one form of engineering education intended to build engineers interested in assuming their places as effective citizens in our democratic government." Up until today, almost 100 years later, we see very little democracy within engineering education (Baier 2024) and even less democratic engineering education. Thus, within the context of higher education, particularly in engineering education, the role of democracy remains largely unexplored in theory and in practice.

This study was prompted by my experience with the European Society for Engineering Education (SEFI), an organization that brings together researchers and educators in engineering education. In 2024, I submitted a workshop proposal addressing democratic education within engineering education for the SEFI annual conference. The proposal was rejected due to the scores given by two reviewers. The local organizing committee acknowledged that no other curation of the topics took place. So it is not surprising that no other workshops addressed democratic education, despite the conference's theme, "Educating Responsible Engineers." This absence raises questions about the role of democracy in engineering education.

The overarching research question for this study is: What role does democracy play in engineering education? To operationalize this question it is put as follows: Where is democracy within the papers of past SEFI annual conference proceedings? And how is it addressed?

2 METHODS

2.1 Scope of Analysis

The SEFI annual conferences regularly attract hundreds of educators, researchers and students in engineering education presenting their papers. According to the principal decisions regarding the character and conduction of the conference the conference proceedings comprise among others research papers and practice papers, short papers, workshop descriptions and reports. Prior to the conference, the papers are peer-reviewed through a double-blind process which varies in detail from conference to conference.

The proceedings of the SEFI annual conferences are listed online on the SEFI website. The annual proceedings prior to 2017 have only been published as a single large PDF file on the SEFI website. From 2017 onward, proceedings are published on the SEFI website and in addition they are available on a dedicated publishing platform both as full collections and as single papers with an individually assigned DOI. Six out of the eight recent proceedings are hosted on the Zenodo platform (2017-2021 and 2024). The proceedings from 2022 and 2023 were published on two different platforms.

2.2 Document Selection

The data set for this study is limited to the SEFI annual conferences which have published a comprehensive conference proceedings as well as the individual papers with a DOI on a publishing platform. Accordingly, only the eight SEFI annual conferences from 2017 until the most recent edition in 2024 are included. The data set only includes the peer reviewed papers, so keynotes etc. are not considered.

2.3 Search Strategy

A consistent search and retrieval process is needed as only two proceedings are published on a platform which offer a full-text search and the remaining six proceedings are published on a platform which allows searches only within titles and abstracts rather than full texts. First, the full collection was searched and then the retrieved individual papers were collected from the publishing platform. The search string for each conference proceeding was *democ* as this includes all possible variations such as “democracy” or “democratic” as well as compound words which are rather uncommon in English. The search string is limited to *democ* as other terms like participation and collaboration are only derived from the term democracy or only address a specific aspect of democracy like freedom, equality and solidarity.

2.4 Data Extraction and Processing

The Identified papers are collected in a single folder. Next, the metadata of each paper is extracted and collected in a single row of a structured spreadsheet. In an additional sheet, the citekey is connected to each direct quote which includes the search string along with the surrounding relevant text as it was deemed necessary. In addition, this sheet contains the codes of the qualitative content analysis for each hit, see below. The spreadsheet is provided as open data.

2.5 Descriptive statistics

The collected data is analyzed in a quantitative manner by counting the occurrences of the search string in each paper which allows to identify how relevant the term is in the overall paper. Next, the number of papers which include the search string is set in relation to the total number of papers for the respective annual conference. This allows to identify possible trends across the years. Furthermore, the number of papers is analyzed with regard to the authors of the papers as this allows to identify whether the term is only used by few recurring authors or by a broad range of authors. Lastly, it is checked how authors are related with each other and what role institutions might play, that is to check whether authors from specific institutions might be more prone to use a word which matches the search string.

2.6 Qualitative content analysis

The qualitative content analysis described by Mayring (2008) is acknowledged for its scientific rigour, its extensive methodological approach and thus widely used. However, this study has a limited scope due to its explorative nature and thus it uses a simplified version of the qualitative content analysis described by Mayring (2008). A first semi-deductive coding is done to identify whether the hits to the search string *democ* are used only in a peripheral way, for example as part of a country’s name or as title of a book or paper in the references and others. The remaining hits to the search string actually address democracy within the concrete context of an engineering education, that is for example through describing forms of democratic teaching, suitable learning activities, assessments and evaluations. A second inductive coding assigns each quote one or several descriptive labels which capture its meaning. These labels are typically referred to as codes and they are refined through a second coding which aims at a harmonisation of similar codes. Codes that address related issues are later grouped to comprehensive categories which reflect broader patterns. This inductive approach of a content analysis is done in order to capture the full extent of how the term democracy is used within the papers in particular and within engineering education in general.

3 RESULTS - DESCRIPTIVE STATISTICS

3.1 Total and relative number of papers

For the eight most recent SEFI annual conference proceedings from 2017 to 2024, the search string *democ* yielded 219 hits across 79 papers out of 1.824 papers in total, representing 4,3%. On average each conference proceedings included 228 papers with 9,9 papers. The lowest number of relevant papers is 2 for the annual proceedings of 2017 while the highest number of papers is 23 for the year 2023. Over the years there has been a slight but consistent increase of papers in total numbers as well as in relative numbers which match with the search term. See Table 1 for further information.

3.2 Total and relative number of hits per paper

Across the years each of the 79 papers which resulted in at least one hit of the search term had 2,3 hits on average. However, from year to year the number of average hits per paper varies significantly from 1,0 in 2020 to 4,4 in 2023. The lowest number of matches per paper is 1 and the highest number of matches for one paper is 61 followed by 19, 12 and 9 hits, see Table 1. Across all years, 52 papers have only one match of the search term that is 65,8% of all papers. A total of 2 hits have 15 papers (18,9%), three papers have 3 hits and two papers have 4 hits. All other numbers of hits occur only once.

3.3 Published papers per year

There are three years which clearly show a much higher number of papers in which the search string was found, that is the years 2017, 2023 and 2024. For this, the qualitative analysis in chapter 4.1 shows that the increase in 2017 is due to the wording of a key area for this conference. The qualitative analysis below for the years 2023 and 2024 shows that the increase is due to occurrences of the search term in the papers themselves, see Table 1.

3.4 Affiliation of Authors

The authors of the papers come from 87 different organisations. Authors from 66 organisations only published one paper containing the search term, while authors from 21 organisations published at least twice such papers. The top three organisations are Aalborg University whose affiliated authors published seven papers, TU Berlin with six papers and KU Leuven with five papers. Authors from Chalmers University, TU Eindhoven and University of Cape Town published four papers each, while those from Tampere University, Universitat Politècnica de Catalunya, University College London, University of Texas at San Antonio, University of Twente and Virginia Tech published three papers each. Authors affiliated to the following universities published two papers: Budapest University of Technology and Economics, EPFL, Grenoble Alpes University, Istanbul Technical University, TU Delft, TU Dublin, TU Hamburg, Universidad Politécnica de Madrid and University of Johannesburg.

Table 1. Papers containing the search string.

Year	Papers in total	Papers with *democ*	% Papers with *democ*	Number of hits in total	Lowest number of hits	Highest number of hits	∅ hits per paper
2017	188	2	1,1%	6	1	5	3,0
2018	168	4	2,4%	5	1	2	1,3
2019	219	17	7,8%	40	1	9	2,4
2020	175	5	2,9%	5	1	1	1,0
2021	176	9	5,1%	11	1	2	1,2
2022	281	7	2,5%	10	1	3	1,4
2023	339	23	6,8%	101	1	61	4,4
2024	278	12	4,3%	41	1	17	3,4
Total	**228**	**9,9**	**4,3%**	**219**	1	61	**2,3**

3.5 Publishing Authors and Network of Authors

The papers of the SEFI annual conference proceedings list a total number of 243 authors, be it first or co-authors. Due to different approaches towards the listing of authors this is not further considered for analysis. There are 218 unique authors who published a paper. A vast majority of 199 unique authors (91,3%) published only one paper which includes the search string while 19 authors (8,7%) published at least twice such a paper. A total of 14 authors (6,4%) published two papers which matched the search string. Three authors (1,4%) published three papers, these are the following: André Baier published three papers across three annual conferences from 2017 to 2023 and accounts for 3 papers out of 6 papers of TU Berlin. Hannu-Matti Järvinen and Ulla-Talvikki Virta of Tampere University published their 3 papers across three annual conferences from 2020 to 2023 and account for all 3 papers of Tampere University. Joel Alejandro Mejia published three papers all in the annual conference of 2023 and accounts for all 3 papers of the University of Texas at San Antonio. The highest number of papers per author is four. Corinne Shaw, published these four papers in three succeeding annual conferences from 2021 to 2023 and accounts to four papers by the University of Cape Town. The publishing network of Corinne Shaw includes four different authors including Zack Simpsonon an author from the University of Johannesburg who also published one paper independently with another co-author. All other authors don't have a significant network in the data set.

3.6 Short presentation of the three papers with the highest number of hits

The highest number of hits have the following three papers:

André Baier (2023) of TU Berlin published a first quantitative and qualitative analysis on how the terms democracy an democratic are used in the standard curriculum as well as in the regular study programs of TU Berlin. The analysis shows that both terms hardly occur. This paper has 61 hits.

Vero Estrada-Galiñanes (2024) of EPFL published a paper with 17 hits. The paper describes a course design and its implementation since 2019 which facilitates a “hands-on introduction to technologies for human self-organization” advocating a broad decentralization.

Anton Schaefer (2023) of TU Berlin published a paper with 12 hits. The paper describes the design of a metaphorical toolbox on dismantling the underlying structures of technology and society and its use within a module.

4 RESULTS - QUALITATIVE CONTENT ANALYSIS

In the following, if the number of referred papers is five or below, they are directly listed if it is deemed helpful to list them. For all other codings please see the whole coded spreadsheet provided through a permalink/data repository after the publication.

4.1 Peripheral and “accidental” hits

A first deductive coding identifies hits where the search term is used only in a peripheral or “accidental” manner. Overall, 55 out of 219 hits (25,1%) use the search term *democ* in such a way. There are 47 out of 79 papers (59,5%) coded as such. Hits are considered peripheral in the following cases:

A number of papers have hits only in their introduction or in their reference list. Other papers have only one hit where the search term is used in an enumeration with other terms. If these are the only hits of a paper they are coded as “reference-only”, “intro-only” and “listing-only”.

In cases where the search term only appears in the reference list it is safe to assume that they are appearing accidentally in the paper in the sense of an unintentional use of the search term. The code “reference-only” is applied to 21 hits (9,6%) which are included in 19 papers (24,0%). Just in comparison, the code “reference” is assigned eleven times (5,0%) in cases where there are also hits other than in the intro, reference list or in a listing.

There are 9 hits in 9 papers (4,1% respectively 11,4%) where the search term appears only in the introductory chapter. These hits are coded with “intro-only” as a use of the terms democracy and/or democratic in the introductory chapter indicates that they play only a peripheral role in the whole paper.

The search term appears ten times in an enumeration with other terms which are coded with “listing-only”. This code is assigned to 8 hits (3,7%) and 7 papers (8,9%). Two of these papers are also coded “intro-only”. In comparison, only three other hits are coded with “listing”.

The SEFI annual conference of 2019 had as one of its key conference areas “Strong demand for democratic involvement in educational processes”. The assigned code for this is “key conference area” which is applied to 16 hits (7,3%). The naming of the key conference area accounts to a total of 16 hits out of 40 hits for this annual conference. For this year, there are 11 out of 17 papers which have only this one hit which makes it an accidental use of search term. However, Table 1 shows that the annual conference of 2019 sticks out in the number of hits as well as paper which include the search term in comparison to the preceding and following years. This suggests that the naming of key conference areas has an impact on the papers that are submitted and if it is only the impact of assigning a key area..

Three hits are coded with “country”. All three hits refer to the Democratic Republic of Congo and come from two papers (Finelli 2023, Mejia 2023]. Both papers are written by authors affiliated with two different organisations located in the United States of America. There is no apparent connection or relation between the authors, organisations and the Democratic Republic of Congo.

The code “conference title” was assigned in the case of two hits which refer to conference title which contained the search term. Both hits were in the same paper but it also contains another hit which is not deemed peripheral or “accidental” so that the paper is not considered as such (Valtins 2024).

4.2 Use of the search term in title, abstract, keyword and/or heading

A total of 5 papers (6,3%) use the search term in the title, abstract, keyword and/or a heading, this accounts for 18 hits (8,2%).

The three papers with the highest number of hits presented above in chapter 3.6 also use the search term in their abstract (Baier 2023, Schaefer 2023, Estrada-Galiñanes 2024]. Two of these papers the search term also occurs as a keyword (Baier 2023, Estrada-Galiñanes 2024) and/or in the title of the paper (Baier 2023, Schaefer 2023).

There are only two other papers where the search term appears in such a central part of a text. Isabell Blanckaert (2019) of KU Leuven uses the term in a heading “Workflow and democratic involvement” of a chapter which essentially describes a selection process that is not based on first come first serve, instead it ensures an involvement of the students and transparency. Jeanette Engzell and Charlotte Norrman (Engzell 2023) of Linköping University use the search term in the abstract of their paper which describes the use of podcasts in higher education in order to provide a mix of methods which cater to the needs of a diverse student body.

4.3 Equality, Access, Diversity, Inclusion and Interdisciplinarity

The search term is used to address a number of issues which can be categorized under the broad term of equality. A total of 24 hits (11,0%) are coded as such which occur in 17 papers (21,5%). As the two papers presented in the preceding paragraph show, the use of the search term is often used to describe equal access and inclusion which also is considered as granting a comprehensive access to knowledge. This accounts to 19 hits in the equality category (8,7%) in 13 papers (16,5%). One hit in one paper addresses equality within the context of academia by advocating to close the rising gap between the disciplines and promoting interdisciplinarity. The remainder of 4 hits occurs in 4 papers which address equality only in broad and general terms.

4.4 Democratization, Decision Making and Collaboration

Directly linked to codes of the preceding sub-chapter is the question of how decisions are taken. Across 6 papers (7,6%) there are 15 hits coded accordingly (6,8%). They address a broad range of decision making such as how students make decision in their team work and how to equip them with the necessary skills. Similar to this, but on a different level are 20 hits (9,1%) across 9 papers (11,4%) where either the term democratization is directly used by the authors or where the wording and context imply an immediate call for action of individuals, groups, organisations and societies to advocate democracy and to act more democratically. Other usages in this category include among others collaboration with 8 hits (3,7%).

4.5 Learning: Higher education, course design, outcomes, activities, surveys

There are 101 hits (46,1%) across 23 papers (29,1%) where the search term is used in a direct context with learning. This category consists of the following five codes: 1) The code “higher education” is assigned in cases where the search term is used in a comprehensive sense where for instance the goals of education are addressed. This code is assigned to 25 hits (11,4%) in 6 papers (7,6%). 2) The code “course design” is assigned to 15 hits (6,8%) contained in 8 papers (10,1%). Here the design of a course is either done in a democratic manner, it implements a democratic student-centered design of learning or the course as a whole has at least one of its focus points on democracy and democratic action. The learning outcomes of a course as well as the related competences are coded as such and show 12 hits (5,5%) in 4 papers (5,0 %). In contrast to the course design, the description of single activities is coded with “learning activity” which has 28 hits (12,8%) in 11 papers (13,9%). Only the hits in one paper are coded with all three that codes, that is course design, learning outcome and learning activity (Schaefer 2023). The search term is used in three surveys which haven been addressed in three papers, where two papers have one hit each as it is an item (Virta 2020, Virta 2023). The other paper is the above described survey on the use of democracy in the curriculum of TU Berlin (Baier 2023).

5 DISCUSSION AND CONCLUSION

This explorative study provides a first overview of how democracy is addressed in SEFI annual conference proceedings from 2017 to 2024. While the term *democ* appears in 4,3% of all papers, a closer qualitative analysis reveals that many occurrences are peripheral, that is 55 out of 219 hits (25,1%) and 47 out of 79 papers (59,5%). As a result of the high peripheral usage of the search term, the relative number of papers drops across all the annual proceedings from 4,3% to 1,75% or to 32 out of 1.824 papers.

However, it remains still unclear to which extent these 32 papers are actually promoting democracy within engineering education. Thus, there is continued in-depth theoretical research needed which identifies what types of democratic education actually take place. The comprehensive literature review on democratic education by Edda Sant might provide a first set of codes for such deductive coding as part of a qualitative analysis.

Overall, this explorative study gives only a first glimpse on the role of democracy in engineering education which should be expanded towards the leading journals like the EJEE and JEE. And yet, there is a much higher need for creative, playful and democratic educational design research through which new activities, courses and study programs are created, tested and implemented which focus engineering education on democracy - not as an add-on but fully integrated into engineering education and profession. A small start for this is Incorporating the term democracy in a key conference area as happened in 2019.

At last, an honorable mention goes to the paper by Søren Rosenlund Frimodt-Møller (2019) of Aalborg University who compares the work of an engineering team with the work done by an orchestra or a rock band. This philosophical paper ties together the democratic collaboration with the creative process of solving concrete problems on these two microcosms all the while reflecting on what is happening on societal level.

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