This is an electronic reprint of the original article.

This reprint may differ from the original in pagination and typographic detail.

Malmi, Lauri; Adawi, Tom; Curmi, Ronald; de Graaff, Erik; Duffy, Gavin; Kautz, Christian; Kinnunen, Päivi; Williams, Bill

How authors did it – a methodological analysis of recent engineering education research papers in the European Journal of Engineering Education

Published in:

European Journal of Engineering Education

DOI:

[10.1080/03043797.2016.1202905](https://doi.org/10.1080/03043797.2016.1202905)

Published: 01/01/2018

Document Version

Peer reviewed version

Please cite the original version:

Malmi, L., Adawi, T., Curmi, R., de Graaff, E., Duffy, G., Kautz, C., Kinnunen, P., & Williams, B. (2018). How authors did it – a methodological analysis of recent engineering education research papers in the European Journal of Engineering Education. *European Journal of Engineering Education*, 43(2), 171-189.
<https://doi.org/10.1080/03043797.2016.1202905>

This material is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of the repository collections is not permitted, except that material may be duplicated by you for your research use or educational purposes in electronic or print form. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone who is not an authorised user.

How authors did it – a methodological analysis of recent engineering education research papers in the *European Journal of Engineering Education*

Lauri Malmi^a , Tom Adawi^b , Ronald Curmi^c, Erik de Graaff^{cd}, Gavin Duffy^e , Christian Kautz^f, Päivi Kinnunen^a and Bill Williams^g

^aDepartment of Computer Science, Aalto University, Espoo, Finland; ^bDepartment of Applied IT, Chalmers University of Technology, Göteborg, Sweden; ^cMalta College of Arts, Science and Technology, Paola, Malta; ^dDepartment of Development and Planning, Aalborg University, Aalborg, Denmark; ^eDublin Institute of Technology, Dublin, Ireland; ^fCenter of Teaching and Learning, Hamburg University of Technology (TUHH), Hamburg, Germany; ^gESTBarreiro, Instituto Politécnico de Setúbal and CEG-IST, Universidade de Lisboa, Lisbon, Portugal

ABSTRACT

We investigated research processes applied in recent publications in the *European Journal of Engineering Education (EJEE)*, exploring how papers link to theoretical work and how research processes have been designed and reported. We analysed all 155 papers published in *EJEE* in 2009, 2010 and 2013, classifying the papers using a taxonomy of research processes in engineering education research (EER) (Malmi et al. 2012). The majority of the papers presented either empirical work (59%) or were case reports (27%). Our main findings are as follows: (1) *EJEE* papers build moderately on a wide selection of theoretical work; (2) a great majority of papers have a clear research strategy, but data analysis methods are mostly simple descriptive statistics or simple/undocumented qualitative research methods; and (3) there are significant shortcomings in reporting research questions, methodology and limitations of studies. Our findings are consistent with and extend analyses of *EER* papers in other publishing venues; they help to build a clearer picture of the research currently published in *EJEE* and allow us to make recommendations for consideration by the editorial team of the journal. Our employed procedure also provides a framework that can be applied to monitor future global evolution of this and other *EER* journals.

KEYWORDS

Engineering education research; taxonomy; research methods; theory

Introduction

Engineering education research (EER) has emerged as an independent field of research from a tradition of developing engineering education practice that goes back over a hundred years (Borrego and Bernhard 2011). In general, EER can be characterised as a field which seeks to (1) build deep understanding of student learning in engineering sciences, (2) identify theoretical underpinnings for innovations in engineering education and (3) evaluate these innovations to build empirical evidence and better understanding of their impact on students' learning processes and learning outcomes. Thus EER aspires to study the complex interactions between the central actors in the learning process, that is, students, teachers, teaching organisations and external stakeholders, as well as their relation to subject content. Due to the considerable breadth of these aims, it is to be

expected that EER would need to apply a broad range of research methodologies and theoretical frameworks.

EER is gradually building its own profile, drawing on research traditions from natural, engineering and social sciences. There is no established tradition for how EER is carried out, and probably could not be, due to the breadth of research topics in the field. This is well demonstrated in a recent analysis by Jesiek et al. (2011) who analysed over 2000 papers published in major engineering education journals and conferences from 2005 to 2008. They identified 38 different research areas or contexts in EER within the published papers.

While there have been many reviews of *what* is being researched within EER, and *who* are the people working in the field, a less covered aspect is *how* research is carried out, that is, what kinds of theoretical frameworks are being applied, in what kind of settings empirical work is carried out, how data is collected and analysed, as well as how results are reported. Building a big picture of the *how* aspects of EER contributes to its development by allowing us to recognise the variety of approaches, learn from the methodological work and theoretical frameworks of others, and thus further enrich the field. Moreover, such a methodological analysis can support research-training activities by pointing out possible areas of improvement both in the choice and use of methodologies as well as the way research is reported. Both Ph.D. students in EER and more senior researchers can benefit from access to the results of such analysis.

In this paper, we present and discuss the results of a study where we analysed the research process reported in 155 papers published in the *European Journal of Engineering Education* (EJEE), in 2009, 2010 and 2013. EJEE is the leading journal of the field in Europe and has a somewhat different profile than the leading US journal, the *Journal of Engineering Education* (JEE). Lohmann (2003) wrote: 'The Journal of Engineering Education serves as an archival record of scholarly research in engineering education'. In his Editorial, 11 years later, de Graaff (2014) wrote: 'Therefore, EJEE will continue to invite and publish case studies and descriptions of innovative practice that maybe do not contribute to a higher impact factor, but that are appreciated in the field of practice.' Our goal in this paper is to investigate how this vision is related to the quality aspects of research processes reported in the papers and we pursue this by taking analytical snapshots of papers published in three recent years.

Quality issues in EER have been addressed in many papers within the last 10 years, during which EER has started identifying itself as an independent research field. Educational research methods are not so familiar to researchers with background from engineering or natural sciences (Borrego 2007), and therefore several important papers have been discussing such methods in the EER context. Leydens, Moskal, and Pavelich (2004) and Borrego, Douglas, and Amelink (2009) discussed quantitative, qualitative and mixed-methods approaches in EER covering various data collection and analysis methods and measures to build trustworthiness of the results. Borrego (2007) addressed the same topics, specifically focussing on transferability of results, theoretical frameworks, operationalisation and measurement of constructs, qualitative and mixed-methods approaches, and interdisciplinary collaboration. Case and Light (2011) and Baillie and Douglas (2014) complemented the above by thorough discussion of the concepts of 'methodology' and 'epistemology' in a qualitative research context. Case and Light also gave illustrative examples of studies using different methodologies, for example, case studies, grounded theory, action research and phenomenography.

Quality issues were further discussed by Bernhard and Baillie (2013), when they sketched quality criteria in EER, covering awareness of different research traditions, using theory to inform research, setting research questions, being consistent in the study, including epistemology and ontology with methodology, showing richness in meaning of results, contributing to theory and discussing various aspects of validity in the research.

In this paper we address many of these quality aspects in studies published in EJEE, and contrast them with other similar findings in EER literature. We discuss related work in more detail in Section 2, and we briefly present the taxonomy used in our analysis in Section 3. The data collection and analysis methodology are set out in Section 4. Results are presented and contrasted with literature in

Section 5 while in Section 6, we discuss some broader issues. Finally, we conclude with a number of recommendations for EJEE and the field as a whole.

2. Related work

During the past 15 years, many analyses of the EER literature have been carried out with a common goal: to build a big picture of the field and summarise what kind of work has been published in different venues. These bibliometric analyses have focussed on several areas. There has been great interest in *authors* of EER papers, addressing questions concerning their affiliations, gender, countries of origin, publishing activity and various forms of collaboration (Chou and Chang 2010; Jesiek et al. 2011; Osorio 2005; Osorio and Osorio 2002; Wankat 1999, 2004; Wankat, Williams, and Neto 2014; Williams, Neto, and Wankat 2014; Williams, Wankat, and Neto 2015; Williams et al. 2014; Xian and Madhavan 2013, 2014). Citations have also been widely explored, investigating numbers of references, widely cited papers and authors, which sources are being used, and how the research links to other disciplines (Barry, Purchase, and Sanborn 2011; Chou and Chang 2010; Osorio 2005; Wankat 1999, 2004; Wankat, Williams, and Neto 2014; Williams and Neto 2012a, 2012b; Williams, Neto, and Wankat 2014; Williams, Wankat, and Neto 2015; Williams et al. 2014). A third natural area of interest, the actual topic or target of research, such as students' conceptions, teaching and assessment methods, use of educational technology, curriculum issues, recruitment, or faculty members, have been surveyed in many papers (Borrego 2007; Chou and Chang 2010; Jesiek et al. 2011; Osorio 2005; Osorio and Osorio 2002; Wankat 1999, 2004; Whitin and Sheppard 2004). Increasing attention has also been devoted to the gender and inclusiveness perspectives found in EER journals (Beddoes, Borrego, and Jesiek 2009; Beddoes and Borrego 2011). Additional explored aspects include funding sources of research (Osorio 2005; Wankat 1999, 2004), and where the research has been published (Osorio and Osorio 2002; Osorio 2005).

In this paper, we focus on *how the research process has been carried out*. As a framework we use the principles presented by Shavelson and Towne (2002), which stipulate that quality research needs to:

- pose significant questions that can be investigated empirically.
- link research to relevant theory.
- use methods that permit direct investigation of the question.
- provide a coherent and explicit chain of reasoning.
- replicate and generalise across studies.
- disclose research to encourage professional scrutiny and critique

We are interested in looking for information about research questions, applied theoretical frameworks, research designs, data collection and analysis methods and how explicitly these have been reported. More specifically, for this special issue paper, we aim to augment the big picture of EER in Europe. We therefore analyse research processes reported in papers published in a few recent years in the leading European journal in EER, EJEE. Our main research question is:

- (1) What theoretical frameworks, research strategies, data sources, analytical methods and reporting practices are found in papers published in the EJEE volumes 34, 35 and 38 and at what frequency do these occur?

We augment the results by addressing the following questions:

- (1) What is the nature (see Section 3) of the analysed papers?
- (2) How do our results compare with other similar analyses of EER papers?
- (3) Are there differences between research reported by European authors (based on their affiliation information) and non-European authors?

We did not find any previous research concerning theoretical frameworks in EJEE papers. Such analyses, however, have been carried out for papers published in JEE (Wankat 1999, 2004), IEEE *Transactions on Education* (IEEE ToE) and *Advances in Engineering Education* (AEE) (Williams and Neto 2012a, 2012b) and the SEFI Annual conference (Malmi et al. 2013). We return to their findings more closely after we have presented our results in Section 5.

The methods of data collection and analysis reported in EER papers have also mainly focused on papers published in venues other than EJEE. Wankat (1999, 2004) analysed data collection methods in JEE, Barry, Purchase, and Sanborn (2011) analysed them in ASEE Civil Engineering division conference papers, and Malmi et al. (2013) in SEFI conference papers. Only de Graaff and Kolmos (2010) have analysed data collection and analysis methods in EJEE papers where in a total of 101 papers published in 2008–2009 only 53% reported some research data.

de Graaff and Kolmos also classified the reported data analysis methods, splitting the papers into six categories: development cases (presenting how a (teaching) case was implemented, 17%), qualitative descriptive (6%), qualitative enhanced (11%), quantitative simple (descriptive statistics, 15%), quantitative complex (3%) and mixed (2%). We found no other similar analyses of EJEE papers. However, there are several works concerning data analysis methods reported in other venues. Malmi et al. (2013) used a similar classification as de Graaff and Kolmos when analysing SEFI EER papers. Chou and Chang (2010) investigated almost 10 years of JEE papers exploring also trends in the applied methodologies. Koro-Ljungberg and Douglas (2008) also analysed JEE papers, but focused specifically on qualitative research; Williams and Neto (2012a) analysed what kind of quantitative methods had been applied in IEEE ToE papers. We contrast our results to their findings later.

The taxonomies defined in Malmi et al. (2010, 2012) take a perspective that research designs can be considered at two levels. The overall design, which is called *research framework* in Malmi et al. (2010) and *research strategy* in Malmi et al. (2012), capture the choice of research questions and how they are generally approached, while data sources and analysis methods concern the concrete analysis methods used in processing collected data. A similar conceptualisation is presented, for example, by Case and Light (2011), when they present *emerging methodologies* in EER. The only previous work concerning how common these research designs are in EJEE is the analysis of Osorio and Osorio (2002), who reported that 15% of EJEE papers in 1998–2000 were surveys and 13% were case studies.

Only few papers have analysed how research has been reported. These include Koro-Ljungberg and Douglas (2008) and Barry, Purchase, and Sanborn (2011) who analysed research questions in JEE and ASEE papers in Civil Engineering division as well as Malmi et al. (2013) who analysed them in SEFI conference papers. The latter two works also analysed the extent to which methodological discussion had been included in the papers. To our knowledge, no such analysis has been carried out for EJEE papers.

When looking at the big picture of analysing how research has been carried out, we note that except for the works of Williams and Neto (2012a, 2012b) who used an earlier version of our taxonomy (Malmi et al. 2010) as their analysis tool, previous literature presents only some narrow views into the research process. Wankat (1999, 2004) reported on the use of educational theories and data sources. Osorio and Osorio (2002) had some results concerning the overall research design while Barry, Purchase, and Sanborn (2011) also reported about most common data sources and some aspects of reporting. de Graaff and Kolmos (2010) investigated only data collection and analysis methods. Chou and Chang (2010), on the other hand, looked at data analysis methods only, as did Koro-Ljungberg and Douglas (2008).

A recently published EER taxonomy (Finelli, Borrego, and Rasoulifar 2015), however, captures a large share of our taxonomy (see Section 3), which however was not available when this work was carried out. Moreover, their taxonomy does not cover the reporting aspects and nature of contribution, which are explained below. We thus claim that our approach gives the most holistic picture of research processes reported in EER papers.

3. Methodological taxonomy

The methodological taxonomy was originally presented in Malmi et al. (2012). Its overall goal is to capture central features in research settings, research processes and how they have been reported in published papers. The taxonomy combines work from three earlier classification schemes. Malmi et al. (2010) developed a taxonomy to classify computing education research literature. From this work we adopted three dimensions, though in a slightly modified form, which describe the theoretical foundations of the paper, the overall research design and the data sources. We left out the categories for the overall purpose of the research, which is not relevant here, and the data analysis method. For the latter, we preferred to use a coarser classification scheme inspired by the work of de Graaff and Kolmos (2010). To present the general character of the paper, we adopted the nature dimension from Simon et al. (2008), but decided to combine its 'experiment', 'analysis' and 'study' subclasses into one class that we call *empirical paper*, because their subclasses overlap with our research strategy dimension. Finally, we included a dimension of how various aspects are reported in papers because this aspect is not well covered in previous research.

Our taxonomy categorises research papers in six dimensions. They are in principle independent of each other. We, however, acknowledge that some research paradigms tend to use certain methods for data collection and analysis.

The *explanatory framework* dimension describes the theoretical or conceptual foundations, on which the paper is based. Examples could be cognitive load theory (Sweller 1988) or Bloom's taxonomy (Bloom 1956). We list here theories, models, frameworks, taxonomies and other formal constructs, as they are reported by the authors, with the limitation that these should be widely known in the EER community. Thus, we omit work that is based, for example, on a single reference and has no name. Moreover, we exclude technical tools and purely methodological references, for example, grounded theory, phenomenography or statistical tests. We list all works we identify; however, not all papers have an explanatory framework.

The *research strategy* dimension captures the general research design. Here we count, for instance, experimental research, survey research, case study and phenomenography. We also include *constructive research*, as defined in our previous research (Malmi et al. 2010, 6), into the pool of research strategies: 'Research that aims to demonstrate and/or evaluate the feasibility of a proposed idea (concept implementation; proof-of-concept research). Revolves around the development of, e.g. software, technology, a teaching approach, or an evaluation instrument.' We list all research strategies we identify, while noting that not all papers have an identifiable strategy.

The *data source* dimension lists all data sources that have been used in the research. Examples include examinations, course grading data, submitted assignments, questionnaires, interviews, reflections or software log data. Often a paper reports several data sources, but in some cases, for example, in some position papers, there is no data source. To augment this dimension, we also report the *scope* of data collection as a whole. This implies that we differentiate whether the research has been carried out at a group, institutional or multi-institutional level.

The *data analysis* dimension describes how the collected data has been analysed. As the pool of possible analysis methods is very large, we deliberately use a coarse classification. (A) The *quantitative simple* category is used for papers that report either descriptive statistics, correlations or comparison of means. (B) More sophisticated statistical analyses such as MANOVA, Factorial, Cluster analyses, etc. are categorised as *quantitative complex*. (C) *Qualitative simple or unspecified* methods category is assigned to cases where qualitative data have been analysed but no clear method and/or analysis process is reported. For instance, papers where the authors have listed items into some categories but there is no discussion or further analysis on the relationship between the categories were placed into this category.¹ (D) *Qualitative enhanced* methods denote any qualitative methods with a clearly specified analysis process, such as phenomenography or grounded theory. Many papers apply several analysis methods, but some have none (e.g. position papers). Finally, we do not consider authors' reflections on observations, such as 'lessons learned', a method, even though a

paper might include substantial argumentation. Reflections can, however, be considered a data source.

The *reporting* dimension covers how clearly various aspects of the research have been reported, including explanatory framework(s), research strategy, research questions, methods and discussion on validity/reliability/generalizability/trustworthiness of the research. We categorise them as explicitly presented (e.g. highlighted or titled), implicitly included within the paper among other text, or missing, if we cannot identify them in the paper.

Finally, the *nature* dimension presents the general character of the paper, described as one of four different categories: (A) *Empirical* papers clearly include parts for data collection, analysis and reporting results; (B) *Case reports* essentially describe some educational setting, such as a new teaching or assessment method, learning resource, educational software or some educational development project. The reported case must have always been implemented in practice, and it may or may not be accompanied with a simple evaluation study. Note that here case report does *not* mean the same as *case study*, which is a research strategy; (C) *Theory papers* discuss theoretical aspects of teaching and learning; (D) *position papers/proposals* present a position or some novel idea, technology, resource, etc., which has not been implemented yet. All papers are considered to have some nature.

4. Data collection, analysis and validity of results

The data consist of all 155 papers published in EJEE in years 2009, 2010 and 2013 (volumes 34, 35 and 38). We excluded all editorials, introductions to special issues/sections, letters to the editor and any announcements. EJEE does not have columns or short papers. Special issues or special section papers were included as they are a normal practice in scientific journals, even though the papers within them may differ considerably in character from regular papers.

The choice of the data set allows us to compare and contrast the findings with our parallel pilot study (Malmi et al. 2013) where we analysed 62 papers from the leading European EER conference (SEFI EER track) from around the same years (2010–2011). Our results represent a snapshot of types of research that have been published in EJEE in recent years. Extending the analysis to year 2013 allows some reflections on potential trends. We acknowledge that a longer time period covering, for example, 10 years of publications would better support such an analysis. However, such work was out of scope, given the resources available to us.

All authors had previous experience in analysing papers using the taxonomy. This prior experience is a salient factor that enhanced consistency in the analysis process and results. Malmi et al. (2013) describe in more detail the procedures we have used over the years to enhance the reliability of our data analysis process.

To increase consistency in the classification work, we divided the analysis of the data pool among the authors by forming four pairs of researchers and each dimension for the whole dataset was analysed by the same pair. In practice, all papers were first analysed individually and then discussed in the pairs. The classification was based on analysing the whole paper, not certain parts only, such as the abstract, titles or keywords. The decisions were made based on the discussions and final agreement among the pairs. Because of the dialogical nature of the analysis, we do not see the point in calculating the inter-rater reliability.

As we analysed the papers, we used the principle of face validity. That is, if the authors reported they had used a certain framework or method, we accepted this as it was reported rather than making our own interpretation of what the framework would be. Likewise, we did not check whether the method was correctly applied.

The selection of which explanatory frameworks were included was decided by looking not only at the references but by identifying evidence that theoretical constructs had been used in defining research questions, guiding research design and/or interpretation of results. Overall this was sufficient but there were a few problematic cases, which are explained in Section 5.1 with the results.

If a research strategy was explicitly reported, we recorded it. Otherwise we took a holistic view of the research design, looking at, for example, whether there were treatment/control group settings or exploration of survey data. Constructive research was identified when the overall focus of the paper was presenting an innovation, and empirical data were mainly used for showing the feasibility of the idea. The line between case studies and constructive research was not clear cut.

Data sources were typically mentioned explicitly in the sections explaining research settings and results. The scope of the collection was obvious in most cases, too. Quantitative analysis methods were simple to classify. *Qualitative enhanced* methods were identified by face validity (like grounded theory) or by elaborated explanation of how categorisation was carried out. If such information was absent or unclear, the paper was categorised *qualitative simple/unspecified*.

Finally, reporting was considered explicit if it was indicated with typographical methods such as using titles, lists or emphasising text. It was considered implicit if the aspect could be easily found by reading the relevant part of text, and if nothing was identified after a close reading of the text, the corresponding reporting aspect was regarded as 'None'.

The nature of the paper tended not to be explicitly reported because the journal does not identify which published papers are research reviews, research papers or position papers. The first of these is easy to identify. The main approach to differentiating the last two was that position papers/proposals typically posed new ideas that had not been implemented in practice. The split between case reports and empirical papers was sometimes less obvious, and the decision was based on the extent and overall quality of the reported empirical research.

We acknowledge that for some individual papers, decisions could be one way or another. However, we emphasise here that our goal is to provide a big picture of EER papers. The magnitude of results is significant (e.g. 27% vs. 59%), not small differences among the categories (like 63% vs. 66%). We are confident that our analysis procedure provides results that adequately reflect the big picture.

5. Results

In this section we present the results in each category separately and contrast them with some findings in related work. Broader observations are discussed in Section 6.

5.1. Explanatory framework (EF)

Engineering education research claims to be an interdisciplinary field, which combines work from engineering sciences, education, psychology and other social sciences. Therefore, one would expect EER papers to build on previous theoretical work in these fields. We deliberately chose to use a fairly loose definition for EFs because we consider that the most important question to be investigated in this respect is recognising whether EER researchers are building on previous theoretical or conceptual work regardless of what is the nature of the applied concepts.

Our results support our expectation. Of the $n_{\text{all}} = 155$ papers², close to three-quarters (111, i.e. 72%) applied some explanatory framework that we could identify. This is comparable with our previous analysis of 62 SEFI EER papers where we identified that 66% of the papers in 2010 and 79% of the papers in 2011 used some theoretical framework (Malmi et al. 2013). Also the findings of Williams and Neto (2012a, 2012b) concerning 43 papers in IEEE ToE and AEE in 2011 fit well with this; they found that in over 70% of the papers some theoretical constructs were used. Ten years earlier, Wankat's analysis of 597 JEE papers in years 1993–2002 gave considerably lower numbers (27% of papers that addressed some form of teaching), though he counted only educational theories or learning styles.

While these analyses captured any theoretical concept in EER, it is worth noting that in a narrower area similar results appear. Brown et al. (2015) carried out a systematic literature review in six EER journals in 2009–2012 identifying 71 papers related to students' or teachers' motivation. Of these, 28%

had clearly integrated the theoretical framework into the study, that is, it was described explicitly and integrated into design, methods and discussion. Another 20% used the framework only in some of these ways, and the rest did not make any explicit connection to theoretical literature and concepts. The share of papers with a theoretical framework was thus comparable to our findings and clearly more than in Wankat's study, thus creating evidence that the use of educational theories is indeed increasing in the field.

Further evidence is shown in recent work of Wankat, Williams, and Neto (2014), who investigated links to reference disciplines in JEE and EJEE in the time span from 1973 to 2013. They analysed papers, categorised as research papers, to identify explicit references to other disciplines, which underpinned the research. These were typically found in background and methodological sections. In their data set the number of such references increased from 0 in 1993 (in 20 research papers) to 11 in 2013 (18 papers) for EJEE and from 3 in 1993 (in 37 papers) to 17 (in 7 papers) in 2013 in JEE. Note that their analysis did not cover all issues in 2013. We consider this development a very positive trend because applying theoretical research work from other fields is very likely to deepen our understanding of teaching and learning of engineering topics.

Another aspect, which has not been addressed in the previous literature, is the richness of theoretical concepts being used. We counted in total 128 different explanatory frameworks. Our previous analysis with SEFI EER data (Malmi et al. 2013) identified 71 unique theoretical constructs in a data set of only 62 papers. This richness demonstrates the broadness of the field as already shown in the work of Jesiek et al. (2011), who identified almost 40 different research areas or contexts in EER within their wide bibliometric analysis of published papers. It may also set considerable challenges for researchers in the field because theories set up their own concepts, vocabularies and how research is reported. Hence, capturing the breadth of applied theories in the field may be outside the scope of many researchers' resources.

Notes concerning the analysis process. While the big picture is not affected, we note that our detailed numeric results here must be treated with care because there is considerable difference in the granularity of the frameworks. Some more general frameworks include specific ones: for example, *social constructivism* may either be counted as a separate framework or included in the category *constructivism*. (In this case, we chose the latter.)

In practice, the decision to include or exclude a certain term in our list of explanatory frameworks proved difficult at times. Many papers mentioned more or less specific teaching methods (such as problem-based learning (*PBL*) or *formative assessment*) as the theoretical basis. Others referred to institutional aspects or agencies (such as *accreditation* or conceive, design, implement, operate (*CDIO*)). To the extent that these terms (or the entities for which they stand) appeared to serve as a conceptual guide for the research questions or methods chosen in the respective study, we counted them as explanatory frameworks as well even if they were not primarily known as theoretical models in the learning sciences. However, if they only seemed to serve as keywords for the paper without serving as a theoretical basis for the design of the research work (like *assessment* in a few instances) we did not count them as an EF.

A somewhat related, specific problem concerns the interpretation of the term *PBL*, which can denote *problem-based learning* or *project-based learning*. While an explicit mention of *problem-based learning* was most frequent among these (eight instances), there were four papers that explicitly referred to *project-based learning*, and two more that used the term *PBL*, but did not specify what is meant by it. In addition, there were also some cases that claimed to apply *problem-based learning* but our interpretation of the text led us to categorise them as drawing on *project-based learning*. We acknowledge that there might be other similar misinterpretations in the data, but due to the breadth of the available EFs, we generally took the stand that we report what the authors have written, that is, we applied face validity here.

The diversity of the EFs is demonstrated by the observation that only five EFs were used at least five times. These were *Constructivism*, *Formative assessment*, *problem-based learning*, *Threshold concepts* and *Variation theory of learning*. It is interesting to note how the number of occurrences of

those frameworks are influenced by EJEE Special Issues. Formative assessment occurs mostly in the special issue on assessment (Vol. 38 no 6). Three of the five instances of threshold concepts and four of the instances of variation theory occur in the same single issue (Vol. 34 no 4).

In order to identify possible trends that may be overlooked in this (rather fine grained) first-order analysis, explanatory frameworks were then clustered in a second round into broader categories. The guiding principle in this second-order analysis was to group frameworks with similar explanatory power and applied to comparable realms of 'the reality of engineering education'. For example, we grouped all frameworks that may serve as guiding principles for the development of degree programs, departments or universities into the category '(models for) higher education institutional development'. This included frameworks focusing on themes such as accreditation, internationalisation or quality assurance. In some cases, the second-order categories included different frameworks that could lead to widely differing educational practices. As a somewhat extreme example, we clustered different explanatory frameworks into a category most appropriately labelled 'Models for societal development, social justice or the economy', thereby combining frameworks that emphasise the well-being of a country's industry or that of its citizens. Even though one may argue that there is overlap between the clusters, we assigned each explanatory framework from our first-order analysis to a single unique cluster.

As a result of this re-categorisation, we identified 19 clusters consisting of between 1 and 21 specific explanatory frameworks. The clusters are shown in [Table 1](#) in order of the summed occurrences of the constituting frameworks. (In cases of ties, we have listed the clusters consisting of fewer individual frameworks first.)

As a result of this analysis, a somewhat more coherent picture (albeit consistent with our first-order findings) emerges: Of the 197 citations (in total) of any explanatory framework, more than half (111 or 56%) invoked a framework belonging to the five most frequent clusters. The subsequent eight clusters accounted for more than another third (72 or 37%) of the citations, leaving only a small share (14 or 7%) to the remaining six clusters. It is evident that the specific numbers are dependent on the choice of the specific clusters, which is somewhat arbitrary. However, the procedure chosen here allowed us to identify some of the most important topics or themes to which the explanatory frameworks cited here can be assigned.

These are, first of all and somewhat predictably, models or theories of learning, which we distinguished as either theories emphasising more the cognitive development of the individual or others that depict learning as an inherently social process (again ignoring some overlap between the two

Table 1. Categories of explanatory frameworks. Number of EFs denotes the number of distinct frameworks in the category. Numbers in the remaining columns denote the number of all references to the frameworks in the category in the specified papers.

Cluster	Number of EFs	Vol. 34	Vol. 35	Vol. 38	Total
Theories of learning and cognitive development	21	16	13	7	36
Models for learning as a social process	15	12	8	6	26
Models underlying specific types of science/engineering curricula	7	7	7	5	19
Models for societal development, social justice or the economy	14	3	8	5	16
Models for assessment	4	2	1	11	14
Theories of motivation and models of student attitudes	8	0	6	5	11
Models for knowledge management and technology-supported learning	10	2	4	5	11
Theories of gender	8	4	5	1	10
Higher education institutional development	6	5	4	0	9
Models for creativity, decision-making and problem-solving	8	3	1	5	9
Models of the engineering process	8	2	0	7	9
Taxonomies of content and learning goals	4	3	0	4	7
Theories of cross-cultural psychology and communication	3	1	2	3	6
Sociological models for scientific research	3	0	4	0	4
Learning styles model	1	0	1	2	3
Epistemologies for the social sciences	3	2	1	0	3
Personal and social competencies	2	0	2	0	2
Theories of group development	1	0	0	1	1
Theories of self-development and personal growth	1	1	0	0	1

clusters). The third most frequently cited cluster consisted of various educational models that each support specific types of science or engineering curricula (most importantly theoretical underpinnings of *Problem-Based* or *Project-Based Learning*). The remaining two in the group of the first five clusters were models or theories focusing on the development of society as a whole, including those aiming to foster social justice, or on the development of the national economy, and models of assessment. The following group of six clusters focused on the themes 'motivation and student attitudes', 'knowledge management and technology-supported learning', 'gender', 'institutional development', 'creativity, decision-making and problem solving' and more general models of the engineering process.

While the occurrence of these themes as well as their relative frequencies (to the extent that our somewhat crude analysis can accurately reflect differences between them) seems unsurprising, a salient feature remains: Even though most authors in EJEE have been basing their work on some explanatory framework, they tend to choose very specific frameworks rather than relating their work to those most well known or most firmly established. This outcome may be interpreted as a typical feature of a new academic field.

5.2. Research strategy

We recall here that research strategy denotes the overall research design instead of a detailed data collection and analysis method. Some other overlapping terms used for this concept include research approach, research framework or research methodology.

We identified some research strategy in 131 out of $n_{all} = 155$ papers (85%). No strategy was found in only 24 papers, which were mainly position papers or proposals. In six papers we identified two research strategies. These results are in line with our former analysis of SEFI papers, which identified 71% of papers with some research strategy (Malmi et al. 2013). This is also well in line with the study by Williams and Neto (2012a) who identified 95% of papers in IEEE ToE and 55% of papers in AEE using some strategy. They used the taxonomy by Malmi et al. (2010), which uses the term research framework but essentially means the same as our research strategy.

The most common strategies in our data pool included *constructive research* (28%), *case studies* (22%) and *survey research* (19%). Other strategies included experimental research, phenomenography and grounded theory, each of which were used only in 3–4% of papers. Action research and ethnography were identified only once. Ten years earlier, Osorio and Osorio (2002) analysed EJEE papers in 1998–2000 and identified 13% of papers as case studies and 15% as surveys. Other comparisons are not possible due to their different categorisation scheme.

Interestingly, here our results differ considerably from the results of SEFI papers where two most common strategies were *case studies* (26%) and *surveys* (21%), and there were very few *constructive research* papers. It seems that the SEFI EER track does not solicit many papers that present innovations in engineering education. It may be the case that such papers are presented in other SEFI tracks. In EJEE, presenting educational innovations is much more common, which is in line with the journal policy (de Graaff 2014). It is worth noting that in the analysis by Williams and Neto (2012a) *case studies* were clearly the dominant strategy covering 3 out of four cases for IEEE ToE and about a quarter of papers in AEE.

5.3. Data source

Research published in EJEE heavily emphasises empirical research and our study correspondingly revealed a rich selection of different data sources – 11 in total – which are presented in Table 2. In 152 papers there was at least one data source, 37 had two sources while 6 papers used three data sources. Only three papers did not have any data source at all.³ The most common data source was *questionnaire* (77 mentions) followed by *interviews* (29) and *literature* (23). *Reflection* was identified as a data source if reflections were part of the input for analyses.

Table 2. Different types of data sources. One paper could have several sources. Percentages are counted from the total number of mentions.

Source type	Number of sources	Percent
Questionnaire	77	38.9
Interview	29	14.6
Literature	23	11.6
Exams	15	7.6
Documents	12	6.1
Observation	12	6.1
Focus Group	9	4.5
Instrument	6	3.0
Reflection	6	3.0
Database	2	1.0
Project reports	2	1.0
Website	2	1.0
No data	3	1.5
Total	198	100

Questionnaires, interviews and literature were the most common data sources in our SEFI EER papers analysis too (Malmi et al. 2013). It seems somewhat surprising that natural student data such as grades, *exam results*, *submissions* or *project work* are not used more often as they would be very easy to access. On the other hand, Wankat (2004) reported that the most common assessment data in his JEE data pool were surveys (20%), student evaluation data (12%) and grades (9%). Also Barry, Purchase, and Sanborn (2011), when analysing ASEE Civil Engineering division conference papers, reported the same three as the most common assessment data: 35%, 18% and 22%, in the corresponding order. A possible explanation could be that Wankat (2004) and Barry, Purchase, and Sanborn (2011) researched mostly US specific papers, whereas EJEE and SEFI present more European and multinational research with possibly different research topics. In the US tradition, there is considerable emphasis on evaluating the impact of educational innovations on learning outcomes while the European tradition also emphasises researching student conceptions, attitudes and motivation, for which questionnaires and interviews are obvious tools.

5.3.1 Scope of data collection

There were four categories for scope of data collection (*group*, *institutional*, *multi-institutional*, and *none*). Forty-three per cent ($n = 66$ out of $n_{all} = 155$) of data concerned groups, 28% ($n = 44$) institutions and 25% ($n = 39$) multiple institutions. In six papers we did not categorise any scope.

The scope of data collection is thus fairly balanced and studies on all *levels* are frequently carried out. In the 2013 EJEE issues, *group level* studies were more common than *multi-institutional* studies, whereas in the 2009–2010 issues the situation was balanced. The SEFI data (Malmi et al. 2013) are from years 2010 and 2011 and also show a balance between the three scopes.

5.4. Data analysis

We had six categories for data analysis – *none*, *quantitative simple*, *quantitative complex*, *qualitative simple/unspecified*, *qualitative enhanced*, *other/description*. Fifteen papers applied two methods, 135 applied one method and 5 papers did not have any method. The most common method was *quantitative simple* (86 mentions) followed by *qualitative simple/unspecified* (45). Only a small number ($n = 15$) of papers used mixed methods. The summary results are presented in Table 3. Note that we consider quantitative complex to exclude quantitative simple, that is, if the method in a paper is deemed complex, we never list that the paper has a simple method, too. The same applies to qualitative enhanced and qualitative simple/unspecified.

The analysis methods in the papers analysed seem to be underdeveloped. Only a small share of papers used *quantitative complex* methods or *qualitative enhanced* methods. Their share of the total

Table 3. Methods in papers. One paper could use several methods. Percentages are counted from the total number of identified methods. Note that there were 15 mixed-methods papers, for which two methods were counted.

Method	Number of identified methods	Percent
Quantitative simple	86	50.6
Quantitative complex	9	5.3
Qualitative simple	45	26.5
Qualitative simple/unspecified	11	6.5
Other/description	14	8.2
None	5	2.9
Total	170	100.0

number of papers that have any analysis method is thus only 14% (20 out of remaining 141). The rest of the papers were deemed descriptive/other/none. This is in line with the analysis of de Graaff and Kolmos (2010), who analysed 101 papers in EJEE papers published in 2008–2009, and found that only 3 papers used *quantitative complex* methods and 11 papers *qualitative enhanced* methods.

In SEFI EER papers the share of advanced methods was significantly more, 35% (Malmi et al. 2013). Williams and Neto (2012a) also reported that 33% of papers in IEEE ToE and 23% of papers in AEE used some advanced quantitative methods. They did not, however, report on qualitative methods. Overall, these results are somewhat worrying because one would expect that journal papers, due to their length, would allow more elaborate analysis methods than is possible to present in short conference papers. EJEE has the least usage of advanced methods. In spite of this worry, there seems to be a good share of both qualitative and quantitative research, although the latter is more common. Mixed method studies are scarce, which is line with the SEFI paper analysis.

We can contrast these results also to JEE papers. Chou and Chang (2010) investigated 437 papers published in 2001–2009 and present a fairly detailed description of data analysis methods. In the beginning of the decade, over half of the papers did not present research data; thereafter the share of such papers has had a clear decreasing trend, reaching a 10–20% level at the end of the decade. The papers reporting research data had a strong emphasis on quantitative methods, averaging over 50% over the decade. Moreover, papers with plain descriptive statistics had a decreasing trend, while papers with inferential statistics increased in numbers. Qualitative analysis and mixed-methods papers also showed a clear increase after 2005, thus demonstrating the increasing methodological richness of the journal. This was also investigated by Koro-Ljungberg and Douglas (2008), who analysed two years (2005–2006, 48 papers) in JEE focussing specifically on qualitative research. They identified 19% papers as qualitative, with a rich selection of methodologies, 12% as mixed-methods studies, 62% as quantitative and the remaining 6% as non-empirical work.

5.5. Reporting

How clearly research is reported has great significance for both readers and reviewers. Explicit reporting of the goals of the work, research questions, research methods, results as well as limitations makes it much easier to judge the value of contribution of the paper. One would expect that the authors would invest much effort in this area. Unfortunately our results do not support this.

When we analysed how the research had been reported, we found that only 28% ($n = 43$ out of $n_{all} = 155$) of the papers reported explicitly their research questions or goals. Implicitly these were reported more often (41%, $n = 63$), and almost one-third (32%, $n = 49$) did not report any research questions that we could identify. For the SEFI EER data set the results were similar (37% explicit, 31% implicit and 32% none) (Malmi et al. 2013). Barry, Purchase, and Sanborn (2011) found in their research that only 22% of papers stated formal research questions. Koro-Ljungberg and Douglas (2008) found that only 40% of the papers in JEE in 2005–2006 contained either research questions or hypotheses.

In the methodology section, we looked for an explanation of the research paradigm (e.g. experimental research, survey research, ethnography, mixed methods, etc.) and motive for choosing the particular research method and procedures adopted (Crotty 1998). Although the majority of papers did describe the methods adopted (sometimes in a 'methodology' section, assuming the two terms to be interchangeable) relatively few addressed the underlying reasoning, that is, what led to a particular method being adopted rather than any other. Seventy-one per cent ($n = 110$) of the papers did not address methodology. Methodology was implicitly presented/discussed in 16% ($n = 24$) and explicitly in 14% ($n = 21$) of the papers. Similar results were found regarding the discussion of validity, reliability, generalizability and trustworthiness issues in the papers. In 67% of the papers ($n = 104$) we found no discussion of these issues. In 8% ($n = 12$) they were discussed implicitly and in 25% ($n = 39$) explicitly. These findings are fully in line with our analysis of SEFI EER papers, where 66% of papers did not discuss methodology and 63% did not discuss validity, reliability, generalizability and trustworthiness issues. Interestingly, Barry et al. reported on the contrary that 86% of papers did include discussion of methods.

Reasons for these observations could include the following. Firstly, not all papers published in EER forums are actually presenting empirical research. Examples include curriculum papers and literature studies, which aim at summarising work in some area. In addition, 12% of papers in our data set were deemed position papers or proposals, which often do not present empirical work, or its role is small. Such papers typically do not have research questions, while they, of course, could present an explicit goal for the work – often this is found implicitly within the abstract and/or introduction. These papers generally do not discuss methodological issues and the same holds for limitations because these aspects are equally not relevant in these contexts compared with presenting empirical research.

We acknowledged this and reanalysed reporting practices only in papers presenting empirical work. Unfortunately, the big picture did not change. Therefore we conclude that in many papers the quality of reporting could be enhanced. Considering some simple guidelines would be helpful: checking that the central aspects of the research process, research questions, theoretical framework, research strategy and methodology as well as limitations are explicitly addressed in the paper. Highlighting with titles or typographical methods is very helpful. Moreover, all this would also help to crystallise the paper contribution, which makes it easier to 'sell' the results to the readers. Some journals actually request such emphasis. For example, JEE requests that the abstract of empirical contributions has the following structure: Background, Purpose, Design/Method, Results and Conclusions. For research reviews, the abstract should include Background, Purpose and Scope/Method.

5.6. Observations on reporting trends

The time span in our data set covers a total of 18 EJEE issues in years 2009, 2010 and 2013. This allows some observations of possible trends. However, we cannot make any strong conclusions as yet. Using Fisher's exact test, we found only that reporting research questions/goals had improved. In 2009 47% ($n = 23$ out of $n_{2009} = 50$) did not report any research questions or goals while in 2013 such papers were only 8% ($n = 4$ out of $n_{2013} = 53$), and the share of implicit reporting had increased from 22% ($n = 14$ out of n_{2009}) to 54% ($n = 34$ out of n_{2013}), (Fisher's test = 28.1, $p < .001$). There were changes in other reporting aspects as well, but they were not significant. Figure 1 presents the full data.

5.7. Author background

EJEE is a global journal when we consider the background of authors. The 155 papers in the three issues had 420 authors, of whom 219 had indicated a European affiliation in the paper. A majority of the papers ($n = 87$) had at least one author with a European affiliation. We compared the set of papers with at least one European author with papers that had no European authors and investigated

Figure 1. Reporting research questions (left), methodology (middle) and validity/reliability/generalizability/trustworthiness issues in the different volumes of EJEE (Vol. 34 = 2009, Vol. 35 = 2010, Vol. 38 = 2013). Gray bars indicate explicit reporting, black bars implicit reporting and hatched bars cases where these aspects were not reported.

possible differences in all dimensions of our taxonomy. We found none that were statistically significant (Fisher's exact test, all p -values $> .05$). This can be considered a highly positive result, which shows that the journal is consistent in its criteria of accepting papers. An author's geographical location has no effect on review results concerning the research process. We did not analyse the extent to which there were differences in research topics between these groups.

6. Nature dimension and discussion

EJEE solicits papers with different characteristics. On its website it states that the journal 'welcomes *research papers as well as position papers and review articles* that debate and explore strategic, theoretical and methodological issues, methodological approaches (assessed best practice), and substantive topics'. Our results match with this call as we show below. In the introduction we quoted an editorial (de Graaff 2014) which states the EJEE continues to solicit case studies and descriptions of innovative practice. While the published papers do not explicitly indicate which papers fit into this category, we wanted to look closely at the differences between empirical research papers and these other types of papers. The Nature dimension in our taxonomy specifically addresses this split by identifying papers as *empirical papers*, *case reports*, *theory papers* and *positions papers/proposals*.

A clear majority of the 155 papers were empirical papers (59%, $n_{\text{emp}} = 92$ out of $n_{\text{all}} = 155$). The next largest group was case reports (27%, $n_{\text{cr}} = 42$), followed by position papers/proposals (12%, $n_{\text{pp}} = 19$). Only two papers were classified as theory papers.

As we anticipated, a closer look at the data revealed considerable differences between the empirical papers and case reports. The number of position papers/proposals and theory papers was small and they rarely reported on data collection and analysis. We therefore do not compare them with the other types of papers.

Research strategies had big differences between case reports and empirical papers. The three most common research strategies in case reports were constructive research (74%, $n = 31$ out of n_{cr}), case study (10%, $n = 4$ out of n_{cr}) and other ($n = 2$). For empirical papers the research strategies were survey research (30%, $n = 28$ out of n_{emp}), case study (32%, $n = 29$ out of n_{emp}) and constructive research (14%, $n = 13$ out of n_{emp}). Experimental research, action research, grounded theory, ethnography and phenomenography were only used in empirical papers. Statistical analysis indicated that the difference between these two groups of papers is statistically very significant, (Fisher's exact test

Table 4. Reporting in case reports and empirical studies.

	Case reports $n_{cr} = 42$			Empirical papers $n_{emp} = 92$			Fisher's exact test
	Explicit	Implicit	None	Explicit	Implicit	None	
EF	50%	14%	36%	52%	21%	27%	1.32, $p = .509$
Research strategy	7%	81%	12%	48%	49%	4%	49.2, $p < .001$
Research questions	2%	40%	57%	46%	46%	9%	48.1, $p < .001$
Methodology	5%	0%	95%	21%	26%	53%	26.8, $p < .001$
Validity/reliab. etc.	5%	7%	88%	39%	10%	51%	20.9, $p < .001$

= 67.46, $p < .001$), when we counted the primary strategy and left out the few cases with a secondary strategy. Correspondingly quantitative complex methods were used in 10% of empirical papers but never in case reports and qualitative enhanced methods in 11% of empirical papers and only once in case reports. The difference in the classes between the primary methodology (leaving out mixed method studies) was also statistically significant (Fisher's exact test = 13.74, $p = .008$). The following table presents the differences in the various aspects in reporting research, which also shows wide differences. Interestingly, there is no statistically significant difference between how explanatory frameworks have been reported (Table 4).

The observations between case reports and empirical papers thus show that empirical papers had more often some research strategy and a clearly wider set of strategies were applied than in case reports. They also used advanced analysis methods more often and the papers also scored better in reporting various aspects of research. This suggests that the papers do have a different purpose and thus reflect the journal policy. However, we recommend the journal to consider whether it would be beneficial to make this difference explicit in the instructions for authors and review criteria. Perhaps case reports could be solicited as a separate category, possibly as short papers presenting innovations or on-going work.

Again, our analysis for SEFI EER papers in 2010–2011 is fully in line with our results concerning EJEE. Sixty-six percent of them were empirical papers, 24% were case reports and 10% position papers/proposals. Borrego (2007) analysed 700 abstracts from engineering education coalition publications observing that the 'overwhelming majority (74%) describe the experience of the authors'. Barry et al. write that 78% of papers in their data pool were 'we just did this' papers. All these results demonstrate the split in the field where research papers and experience papers/practice reports/case reports are highly frequent. The number of research papers in EJEE and JEE has, however, been steadily increasing (Wankat, Williams, and Neto 2014). What the right balance might be would depend on the publication venue and on the readers' interest. For EER researchers, the most interesting papers are obviously found among research papers, but for engineering education practitioners the case reports could be more relevant.

To provide the reader with further insight into our findings, we have selected three exemplars of papers which we believe appropriately address the theoretical and methodological aspects included in our taxonomy: 'Think engineer, think male?' (Male, Bush, and Murray 2009), 'Learning to fly: first experiences on team learning of Icaros cooperative' (Juvonen 2013) and 'Issues of doing gender and doing technology – Music as an innovative theme for technology education' (Thaler and Zorn 2010). These three papers describe research in Australia, Finland and Austria respectively and present a range of methodological approaches, the first employing a statistical analysis of survey data, the second uses a grounded theory approach while the third applies ethnographic research.

6.1 Limitations

The data presented relate to three years – 2009, 2010 and 2013. The intention is to analyse more years so as to present a larger dataset but given that this analysis will take some time and being aware that

the special issue devoted to European Research was in preparation we felt that the data analysed for these three years present a valuable snapshot of research published in EJEE and allow us to point out some trends that are important to share with the engineering education research community.

Given that the author-introduced keyword system currently applied by the journal is unsystematic, we were not able to use these to classify the articles under study. For this reason we opted for the process described in Section 4. The procedure adopted was relatively manpower-intensive as it involved two researchers individually reading each paper, classifying various features and then discussing the characterisation with the other until consensus was achieved with respect to the classification. This type of analysis requires the researchers themselves to have sufficient experience of EER publications, is time-consuming and ideally would be facilitated by being part of a recognised and funded research project. However, by contrast with the US National Science Foundation which has shown willingness to support research of this nature (see for example Finelli, Borrego, and Rasoulifar 2015) within the European context, it is difficult to receive support for research of this type as it is not a good fit with the criteria defined for Horizon 2020 funding (EC 2013). For this reason, we have opted to present the data for the 3 years already analysed and aim to complete the intervening years in future work.

Finally, we recognise that when comparing our findings with those from other similar analysis papers, a direct comparison of the numerical results is challenging. Not all papers we have cited include detailed definitions of how various aspects of the research process or reporting were categorised. We have tried to interpret them the best we can.

7. Conclusions and recommendations

Our analysis has revealed some of the richness of EER papers in EJEE. Our findings are in line with and extend previous work that has analysed research processes in EER. Moreover, the field is developing rapidly. We identified some signs of trends but due to the limited size and time span of the data set it is premature to draw strong conclusions. However, the results can well be applied to provide some recommendations that we see as being particularly appropriate to the evolution of EER in the European context:

- Methodological richness in the field is valuable in that it can provide insights to engineering education practitioners and also contribute to the developing maturity of the field. Hence we would encourage authors to consider adopting more elaborate methods, both quantitative and qualitative, given of course that they are appropriate for the research questions posed. Institutions active in Europe such as SEFI and International Society for Engineering Pedagogy (IGIP) could contribute by organising methodological workshops or tutorials in connection with their major conferences.
- EJEE could consider special issues that focus on methodological aspects of the field.
- Doctoral consortia for EER researchers could invite methodological experts to give guidance in research designs.
- EJEE could consider adding a section in the instructions for authors, giving recommendations for how empirical papers should be reported. The review criteria for such papers could also be revised (and published on the website) to promote the message. However, promoting more elaborate review criteria alone is not likely to be sufficient to enhance the quality of empirical papers (Jolley et al. 2011; Willey et al. 2011). Raising the general awareness of these issues in the EER community takes some time.
- EJEE could consider establishing a new category of papers, for example, 'short papers' or 'innovations', which would cover most of the current case reports. The main purpose would be to solicit proof-of-concept of the innovations while not requiring rigorous empirical evaluation. This might clarify the different role of these types of papers and research papers which should be the main core in journal publications.
- EJEE or the SEFI EER working group could also set up a website as a resource which provides links to good examples of (1) how different theoretical frameworks have been successfully used in EER,

and (2) papers introducing or using different methodological approaches (e.g. Case and Light 2011; Jawitz and Case 2009). These could be a valuable source both for Ph.D. students in EER as well as for more senior researchers who wish to enrich their competences in EER.

Closing remarks

Finally we note that the analysis presented in this study applies to all the 155 original research papers published in EJEE during the three years analysed and only starts to examine the differences between work from European and other sources – an aspect we hope to investigate in future work. We plan to continue this analysis longitudinally as we believe the findings presented here can help scholars to have a clearer picture of engineering education research as published in the journal at present and we are confident that the procedure employed provides a taxonomical framework which can be applied to monitor future global evolution of EJEE and of European research published by it.

Notes

1. We acknowledge that this depends on how the authors have chosen to report on the methods used. Enhanced methods may have been used, but if the process is not visible in the papers, the method was deemed simple/unspecified qualitative analysis.
2. We use notation n_{all} and likewise n with other subscripts for denoting sizes of specific subgroups of the papers, if we analyse these subgroups further. Plain n is used as a generic denoter of group size at hand.
3. Interestingly, when de Graaff and Kolmos (2010) analysed data collection and analysis methods in EJEE papers (2008–2009, 101 papers), which partially overlapped our data pool, they identified only 53% papers with some research data. The difference is partially due to our interpretation that literature and reflections are considered data sources.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

Lauri Malmi is Professor of computer science at Aalto University, and Vice Dean of Education at Aalto School of Science. His main research areas include computing education research and educational technology, especially in the context of programming education. He has promoted international research training in various courses and doctoral consortia both in computing education research and engineering educations research. He has published over 100 international journal and conference papers.

Tom Adawi is Professor in Engineering Education Research (EER) at Chalmers University of Technology and Chair of the Nordic Network of Engineering Education Research (NNEER). His research interests include students' understanding of threshold concepts in science and engineering, the interplay between and the development of conceptual/mathematical understanding, the scholarship of teaching and learning, as well as theoretical and methodological issues in EER.

Ronald Curmi currently holds the post of Registrar at the Malta College of Arts, Science and Technology. For 12 years he was the Deputy Director at the MCAST Institute of Electrical and Electronics Engineering. His main interests include quality assurance in education, engineering education research, curriculum design and technology for teaching.

Erik de Graaff has been Associate Professor in the field of educational innovation at the Faculty of Technology Policy and Management of Delft University of Technology. Since 2011 he is Professor at the department of Development and Planning of Aalborg University, Denmark. He has contributed to the promotion of knowledge and understanding of higher engineering education with numerous publications and through active participation in professional organizations like SEFI, IGIP, IFEEs and ALE. He has published over 200 articles and papers and he has presented more than 70 keynotes and invited lectures on various topics related to PBL in higher education. Since January 2008 he is Editor-in-Chief of the *European Journal of Engineering Education*.

Gavin Duffy is a faculty member in the School of Electrical Electronic Engineering Systems in the Dublin Institute of Technology (DIT) since 2002. He now delivers modules on chemical technology, instrumentation, automation and control engineering and has been using project-based learning since 2005. His research activity is in the area of engineering

education and is a member of the CREATE research group at DIT. Current projects include spatial ability among engineering students, epistemological development and how engineering education research is conducted.

Christian Kautz is Associate Professor and Head of the Engineering Education Research Group at the Center of Teaching and Learning at Hamburg University of Technology. He has taught physics and introductory engineering courses at universities in the US and Germany. For the past 12 years, his research has concentrated on student learning in introductory engineering. An additional focus of his work is the development of instructional materials to foster conceptual understanding. He also conducts faculty development workshops for instructors in technical subjects at various universities in Germany and Switzerland.

Dr Päivi Kinnunen is a researcher at Aalto University in Finland. Her research interests relate to engineering students' first-year experiences, dropout phenomenon and pedagogical feedback loops.

Bill Williams originally trained as a chemist at the National University of Ireland and went on to work in education in Ireland, the UK, Eritrea, Kenya, Mozambique and Portugal. He lectures on technical communication at the Instituto Politécnico de Setúbal and is a member of the Centre for Management Studies of Instituto Superior Técnico, Universidade de Lisboa, Portugal.

ORCiD

Lauri Malmi <http://orcid.org/0000-0003-1064-796X>

Tom Adawi <http://orcid.org/0000-0002-4135-8784>

Gavin Duffy <http://orcid.org/0000-0003-3049-7030>

Päivi Kinnunen <http://orcid.org/0000-0002-8650-4925>

Bill Williams <http://orcid.org/0000-0003-1604-748X>

References

- Baillie, C., and E. P. Douglas. 2014. "Confusions and Conventions: Qualitative Research in Engineering Education." *Journal of Engineering Education* 103 (1): 1–7.
- Barry, B. E., K. Purchase, and M. J. Sanborn. 2011. "Rigorous Educational Research in Civil Engineering: What Does It Look Like and How Are We Doing?" Proceedings of ASEE, American Society for Engineering Education.
- Beddoes, K., and M. Borrego. 2011. "Feminist Theory in Three Engineering Education Research Journals: 1995–2008." *Journal of Engineering Education* 100 (2): 281–303.
- Beddoes, K., M. Borrego, and B. K. Jesiek. 2009. "Mapping International Perspectives on Gender in Engineering Education Research." ASEE/IEEE Frontiers in Education (FIE) Annual Conference, San Antonio, TX, October.
- Bernhard, J., and C. Baillie. 2013. "Standards for quality of research in engineering education." In Research in Engineering Education Symposium (REES 2013), Kuala Lumpur, 4–6 July 2013.
- Bloom, B. S. (1956). *Taxonomy of Educational Objectives, Handbook 1: Cognitive Domain*. New York: Addison Wesley.
- Borrego, M. 2007. "Engineering Education as a Rigorous Discipline: A Study of the Publication Patterns of Four Coalitions." *Journal of Engineering Education* 96 (1): 5–18.
- Borrego, M., and J. Bernhard. 2011. "The Emergence of Engineering Education Research as an Internationally Connected Field of Inquiry." *Journal of Engineering Education* 100: 14–47.
- Borrego, M., E. P. Douglas, and C. T. Amelink. 2009. "Quantitative, Qualitative, and Mixed Research Methods in Engineering Education." *Journal of Engineering Education* 98 (1): 53–66.
- Brown, P. R., R. E. McCord, H. M. Matusovich, and R. L. Kajfez. 2015. "The Use of Motivation Theory in Engineering Education Research: A Systematic Review of Literature." *European Journal of Engineering Education* 40 (2): 186–205.
- Case, J., and G. Light. 2011. "Emerging Methodologies in Engineering Education Research." *Journal of Engineering Education* 100 (1): 186–210.
- Chou, P. N., and C. C. Chang. 2010. "Research Characteristics and Patterns in Engineering Education: Content Analysis, 2000–2009." *World Transactions on Engineering and Technology Education* 8 (4): 462–470.
- Crotty, M. 1998. *The Foundations of Social Research: Meaning and Perspective in the Research Process*. London: Sage.
- EC. 2013. "Horizon 2020 – the EU's New Research and Innovation Programme." European Commission Press Release. http://europa.eu/rapid/press-release_MEMO-13-1085_en.htm.
- Finelli, C., M. Borrego, and G. Rasoulifar. 2015. "Development of a Taxonomy of Keywords for Engineering Education Research." *Journal of Engineering Education* 104 (4): 365–387. October 2015.
- de Graaff, E. 2014. "Research Versus Educational Practice: Positioning the European Journal of Engineering Education." *European Journal of Engineering Education* 39 (1): 1–6.
- de Graaff, E., and A. Kolmos. 2010. "Research Methods in Engineering Education Research." Proceedings of Joint International IGIP-SEFI Annual Conference 2010, Trnava.

- Jawitz, J., and J. Case. 2009. "Communicating Your Findings in Engineering Education: The Value of Making Your Theoretical Perspective Explicit." *European Journal of Engineering Education* 34 (2): 149–154.
- Jesiek, B. K., M. Borrego, K. Beddoes, M. Hurtado, P. Rajendran, and D. Sangam. 2011. "Mapping Global Trends in Engineering Education Research, 2005–2008." *International Journal of Engineering Education* 27 (1): 77–90.
- Jolley, L., K. Willey, G. Tibbits, and A. Gardiner. 2011. "Conferences, Reviews and Conversations about Improving Engineering Education." Proceedings of the Research in Engineering Education Symposium (REES 2011), Madrid.
- Juvonen, P. 2013. "Learning to Fly? First Experiences on Team Learning of Icaros Cooperative." *European Journal of Engineering Education* 38 (2): 186–193.
- Koro-Ljungberg, M., and E. P. Douglas. 2008. "State of Qualitative Research in Engineering Education: Meta-analysis of JEE Articles, 2005–2006." *Journal of Engineering Education* 97 (2): 163–175.
- Leydens, J. A., B. M. Moskal, and M. J. Pavelich. 2004. "Qualitative Methods Used in the Assessment of Engineering Education." *Journal of Engineering Education* 93 (1): 65–72.
- Lohmann, J. R. 2003. "The Editor's Page." *Journal of Engineering Education* 92 (2): 109–109.
- Male, S. A., M. B. Bush, and K. Murray. 2009. "Think Engineer, Think Male?" *European Journal of Engineering Education* 34 (5): 455–464.
- Malmi, L., T. Adawi, R. Curmi, E. de Graaff, G. Duffy, C. Kautz, P. Kinnunen, and B. Williams. 2013. "Methodological Analysis of SEFI EER Papers." Proceedings of SEFI 2013 Conference, Paper 87.
- Malmi, L., E. de Graaff, T. Adawi, R. Curmi, G. Duffy, C. Kautz, P. Kinnunen, and B. Williams. 2012. "Developing a Methodological Taxonomy of EER Papers." Proceedings of SEFI Annual Conference 2012, Tessaaloniki, 23–26 September.
- Malmi, L., J. Sheard, Simon, R. Bednarik, J. Helminen, A. Korhonen, N. Myller, J. Sorva, and A. Taherkhani. 2010. "Characterizing Research in Computing Education: A Preliminary Analysis of the Literature." Proceedings of 6th International Computing Education Research Workshop, Aarhus, 3–12.
- Osorio, N. 2005. "What Every Engineer Should Know about Engineering Education." Proceedings of the American Society for Engineering Education (ASEE) 2005 Illinois-Indiana Sectional Conference, DeKalb, IL.
- Osorio, N., and M. Osorio. 2002. "Engineering Education in Europe and the USA: A Analysis of Two Journals." *Science and Technology Libraries* 23 (1): 49–70.
- Shavelson, R. J., and L. Towne, eds. 2002. *Scientific Research in Education*. Washington, DC: National Academies Press.
- Simon, Carbone, A., M. de Raadt, R. Lister, M. Hamilton, and J. Sheard. 2008. "Classifying Computing Education Papers: Process and Results." Proceedings of 4th International Computing Education Research Workshop, Sydney, pp. 161–172.
- SwellerJ. 1988. "Cognitive Load During Problem Solving: Effects on Learning." *Cognitive Science* 12 (2): 257–285.
- Thaler, A., and I. Zorn. 2010. "Issues of Doing Gender and Doing Technology – Music as an Innovative Theme for Technology Education." *European Journal of Engineering Education* 35 (4): 445–454.
- Wankat, P. C. 1999. "An Analysis of the Articles in the Journal of Engineering Education." *Journal of Engineering Education* 88 (1): 37–42.
- Wankat, P. 2004. "Analysis of the First Ten Years of the Journal of Engineering Education." *Journal of Engineering Education* 93 (1): 13–21.
- Wankat, P. C., B. Williams, and P. Neto. 2014. "Engineering Education Research in European Journal of Engineering Education and Journal of Engineering Education: Citation and Reference Discipline Analysis." *European Journal of Engineering Education* 39 (1): 7–17.
- Whitin, K., and S. Sheppard. 2004. "Taking Stock: An Analysis of the Publishing Record as Represented by the Journal of Engineering Education." *Journal of Engineering Education* 93 (1): 5–12.
- Willey, K., L. Jolley, G. Tibbits, and A. Gardiner. 2011. "Investigating Research Quality and the Review Process: Some Suggestions for Improvement." Proceedings of the SEFI Annual Conference, Lisbon, 2011.
- Williams, B., and P. Neto. 2012a. "Taxonomical Classification of Engineering Education Research Publications-an IT Perspective." In Global Engineering Education Conference (EDUCON), 2012 IEEE, pp. 1–7. IEEE.
- Williams, B., and P. Neto. 2012b. "Tracking Engineering Education Research and Development: Contributions from Bibliometric Analysis." *International Journal of Engineering Pedagogy (IJEP)* 2 (2): 37–44.
- Williams, B., P. Neto, and P. C. Wankat. 2014. "Taking a Snapshot: Four Bibliometric Indicators to Track Engineering Education Research Evolution." *Chemical Engineering Education* 17 (1): 2–3.
- Williams, B., P. C. Wankat, and P. Neto. 2015. "Globalization of Engineering Education Research: Citation Analysis of ASEE and SEFI Conference Papers." Proceeding of 43rd Annual SEFI Conference.
- Williams, B., P. Wankat, P. Neto, and C. Tiago. 2014. "Is Engineering Education Research Global? The Answer May Surprise You." Proceedings of 121th ASEE Annual Conference, Paper ID #8817.
- Xian, H., and K. Madhavan. 2013. "Studying Factors that Influence Scholar Retention in Engineering Education Research." Proceedings of 120th ASEE Annual Conference, Paper ID #7562.
- Xian, H., and K. Madhavan. 2014. "Anatomy of Scholarly Communication in Engineering Education: A Big-Data Bibliometric Analysis." *Journal of Engineering Education* 103 (3): 486–514.