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# Breaking Barriers With Qualitative Multi-Method Research for Engineering Studies: Pros, Cons and Issues!

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## ABSTRACT

The purpose of this article is to investigate how contemporary studies about engineering are breaking down boundaries of knowledge. This study uses a systematic literature review to show how the application of qualitative multi-method approaches may offer reliable results and provide greater emphasis to the dimensions of development, triangulation and complementarity. The article offers new insights on the role of qualitative researches for the engineering domain, an area which has been largely unaddressed in the literature.

**Keywords:** Engineering, Systematic literature review, Multi-method approach, Development, Triangulation, Complementarity, Qualitative research.

## RESUMO

O objetivo deste artigo é analisar como os estudos contemporâneos sobre a engenharia estão a quebrar as fronteiras do conhecimento. Este artigo utiliza uma revisão sistemática da literatura para mostrar como a utilização de abordagens qualitativas multi-método pode oferecer resultados fiáveis e dar maior enfase às dimensões de desenvolvimento, triangulação e complementaridade. O artigo discute as novas dinâmicas que as investigações qualitativas oferecem ao domínio da engenharia, área que que tem sido amplamente negligenciada pela literatura.

**Palavras-Chave:** Engenharia, Revisão sistemática da literatura, Abordagem multi-método, Desenvolvimento, Triangulação, Complementaridade, Investigação qualitativa.

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## 1. INTRODUCTION

Multi-method research is based on a methodological research strategy that includes more than one method of collecting data and or more than one method of analysing the data; such methods can be based on qualitative techniques, quantitative techniques or a mix of both (Mills *et al.,* 2010). A common misconception is that the various research strategies should be arrayed hierarchically, but the hierarchical view may be questioned, as the goal is to avoid gross misfits, when investigators plan to use one type of strategy but another is really more advantageous (Yin, 2003). The emphasis should be given to break down barriers, since there are preconceived ideas that certain areas of knowledge should necessary follow a particular research strategy. While researchers are adopting a variety of methods, the potential advantages of combining different qualitative methods remains largely unexploited (Monrad, 2013). Herein lies the relevance of this article, as it discusses the pros, cons and issues of using research methods in a complementary way. In this article we set up to describe two qualitative research methods that may help researchers to reduce potential bias when performing qualitative studies. Thus, the implementation of a multi-method research program may generate comprehensiveness and rich knowledge (Mills *et al.,* 2010), counterbalancing the weaknesses that inherent to individual methods (Wood *et al.,* 1999). Building on these suggestions, we perceived that the vast majority of academic research carries out a literature review. On this basis, we propose the discussion of a systematic literature review as a research method. Additionally, it also seems appropriate to discuss a case study methodology, as a complementary method to a systematic literature review. Complementing research methods may take a number of forms, in this specific case, one study is used to corroborate (or not) empirical findings. Hence, the overall aim is to enhance the validity of research findings.

## 2. THEORETICAL BACKGROUND

Epistemologically *hodos* is equivalent to the contemporary word of method. Firstly, hodos was defined as a journey or path. Combined with the prefix *meta-*, we get *methodos*, a "following after, pursuit, especially pursuit of knowledge, a plan or system of pursuing an inquiry" (Liddell *et al.,* 1940). Our modern-day understanding of method, especially the scientific method, strongly resonates with *methodos*, which emphasizes the methodical system

of generating and legitimizing knowledge (Thorpe & Holt, 2008). Method--ology has a particular meaning, as an "ology" is the study of a whole academic field, it is a stepping-back from a subject and a consideration of it at a broader level (Fisher, 2007). Fisher (2007) goes further stating that methodology is the study of methods and it raises all sorts of philosophical questions about what it is possible for researchers to know and how valid their claims to knowledge might be. Additionally, *research* in common parlance refers to a search of knowledge, and can be defined as a scientific and systematic search for pertinent information on a specific topic (Kothari *et al.,* 2004). At this point we are in condition to comment on the difference between research methods and research methodology. Research methods may be understood as all methods or techniques, thus, they refer to the methods that researchers use in conducting research operations, in other words, are all methods that are employed by the researcher during the course of addressing his/her research problem (Kothari *et al.,* 2004). The same authors also distinguish research technique as the behaviour and instruments we use in conducting research operations (e.g. recording data) and research method to the behaviour and instruments used in selecting and constructing a research technique. In practice, the two terms are taken as interchangeable. Research methodology is associated with a broader approach, i.e. including the assumptions, postulates, rules, and methods – the blueprint or roadmap – that researchers employ to render their work open to analysis, critique, replication, repetition, and/or adaptation and to choose research methods (Given, 2008), in other words, is the way to resolve our research problem. Methodological triangulation leads to more accurate, complete, and analytically satisfying representation of the social world (Elliott, 2005). Triangulation is a term that generally describes the use of multiple approaches to the study of a phenomenon (Denzin & Lincoln, 2000). Denzin (1978) include: (a) data triangulation, where data are collected at different times or from different sources; (b) investigator triangulation, where different researchers or evaluators independently collect data on the same phenomenon and compare the results; (c) methodological triangulation, where multiple methods of data collection are used; and (d) theory triangulation, where different theories are used to interpret a set of data. Within each type of triangulation there are various sub-types, for example, methodological triangulation can include various combinations of qualitative and quantitative research designs (Thorpe & Holt, 2008). Particularly, methodological triangulation is defined as more than one method which is used to gather data (e.g. interviewing, participant observation) (Mills *et al.,* 2010). Denzin (1978) also distinguished *within-methods* triangulation, which refers to the

use of either multiple quantitative or multiple qualitative approaches, from *between-methods* triangulation, which involves the use of both quantitative and qualitative approaches (Johnson *et al.,* 2007).
Quantitative approaches involve the generation of data of quantitative nature which can be subject to rigorous quantitative analysis in a formal and rigid fashion, while qualitative approaches to research are concerned with subjective assessment of attitudes, opinions and behaviours (Berg, 2004; Kothari *et al.,* 2004). Since the last decade of the 20th century, there has been a growing interest in the use of qualitative techniques in the social sciences (Benbasat et al., 1987). This interest has been sparked by a general dis--satisfaction and the limitation associated with the type of research information that is provided by quantitative techniques (Maanen, 1982). The dissatisfaction stems from several sources:

the complexity of multivariate research methods, the distribution restrictions inherent in the use of these methods (e.g., multivariate normality), the large sample sizes these methods dictate, and the difficulty of understanding and interpreting the results of studies in which complex quantitative methods are used (Benbasat *et al.,* 1987). Finally, methodological triangulation has received the most attention and it has become almost obligatory for qualitative researchers, in planning their studies, to demonstrate their commitment to methodological rigor by multi-method research designs, allegedly capable of validation through triangulation (Bloor & Wood, 2006).

## 3. METODOLOGY

This article follows a systematic literature review as a research method. This choice is appropriate because qualitative multi-method researches are still in an early stage of development (Monrad, 2013).
A truly comprehensive approach to produce a systematic literature review generally requires the use of more than one database (Reis *et al.,* 2014). However, we just used one database since our priority was transparency and easy reproduction of results (Buchanan and Bryman, 2009). On the 21st of October 2016 we conducted a research with the Scopus database, which is one of the largest abstract and citation databases of peer-reviewed literature, and we searched keywords related with our subject, as displayed in the table 1.

**Table 1.** Methodological approach

| Scopus Search | | "Multi-Method Research" or "Multimethod Research" | "Systematic Literature Review" | "Case Study Research" |
|---|---|---|---|---|
| Keyword | Title-abs-key | 407 | 8,710 | 2,831 |
| Language | English | 398 | 8,105 | 2,776 |
| Source type | Journals | 322 | 7,169 | 2,118 |
| Document type | Article | 281 | 3,082 | 1,922 |
| Subject Areas | Social Sciences and Engineering | 151 | 401 | 1,040 |
| Keyword | The terms used on the search | 35 | 123 | 150 |

The search returned 35 documents using the keyword "Multi-Method Research" or "Multimethod Research", 123 documents using "Systematic Lite--rature Review" and 150 documents using "Case Study Research". Besides the Multi-Method Research Methodology that is the core investigation of this article, additionally we selected two other different approaches, firstly a qualitative methodology centred on a content analysis of the literature (Combes and Nicholson, 2013) and then, in order to empirically corroborate the findings in the literature a case study methodology. Both techniques present advantages and disadvantages and, therefore, they must be seen as being "complementary" in gaining the overall understanding of a subject under investigation. The review process was based on the application of successive filters to exclude irrelevant papers and ensure viable results (Reis et al., 2015). According to table 1, we can observe that only articles written in English were deemed relevant in order to avoid wrong interpretations. To ensure the quality of the findings, the authors only considered articles from indexed scientific journals and, to guarantee the adequacy of the results, we selected subjects from social sciences and engineering areas. From a 11,948 documents, we excluded 11,640, remaining, at the end, 308 articles that will be the focus of further analysis in the next sections of this paper.

## 4. MULTI-METHOD RESEARCH

Multi-method research is an increasingly prominent technique (Ahram, 2013) as some scholars have become progressively aware of its benefits, through which the strengths of one method can offset the limits of another (Bennett,

2015). The justification for the relevance in choosing a multi-method re--search is briefly explained by the frequent recommendations in the literature:

> e.g., "Further work may employ a multimethod approach, using both empirical and simulated Closed Loop Supply Chain data to validate and deep our contribution." (Cannella *et al.,* 2016).

After careful analysis of the 35 articles, we realised that, frequently, the term mixed- and multimethod research is used indistinctively. Although, since the mid-1970s there has been a prominent discussion centred on the use of mixed methods, we believe that the future lies in dropping the terms "qualitative" or "quantitative" research, so that it is referred to simply as research (Given, 2008). This argument is being strengthened, when the multi-method approach is put in place. Nevertheless, Darlington and Scott (2002) admit that there are four common approaches to mixing/multi-methods:

(1) qualitative then quantitative approach - this design occurs when the findings of the qualitative research are used to develop the quantitative phase of the research; (2) quantitative then qualitative approach - when the findings of the quantitative research are needed to develop and make sense of the quantitative phase; (3) qualitative and quantitative concurrently, is when a mixed qualitative and quantitative designs do not always have to be interdependent, the purposes of a mixed-method study of this type would generally be triangulation, complementarity or expansion, or some combination of these; lastly, (4) mixing qualitative data collection approaches, just as it is possible to combine quantitative and qualitative methods in order to more thoroughly investigate a research problem.

Much of the methods used in the literature analysed in this study are mixed, with 49% of applications. The analysis showed that 34% of multi-method research is purely qualitative research. Additionally, we noticed that there are no purely quantitative investigations, and 17% of the articles do not refer to any explicit method (figure 1).

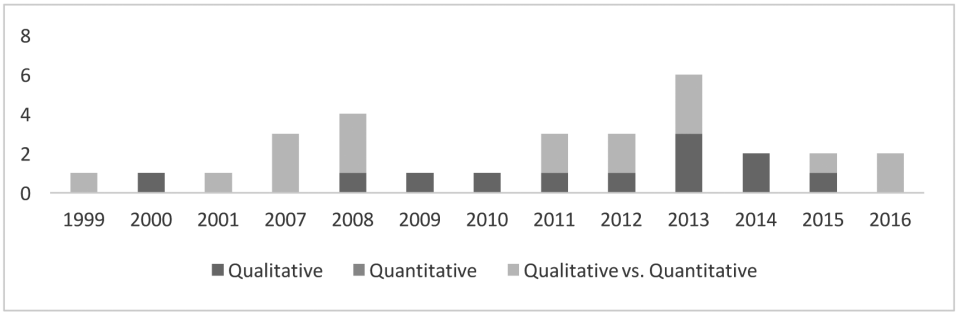


**Figure 1.** Multi-method research

Legend: x-axis – date of publication; y-axis – number of articles published

Thus, it is possible to conclude that multi-method research is mainly focused on mixed-researches (qualitative vs. quantitative), neglecting, partly, pure-methods. Hence, we recommend further investigations to use qualitative or quantitative research methods. Furthermore, Brones *et al*. (2014) article is an example of a pure multi-method research. These authors presented a study that explored the points of intersection of a specific research area, via a combination of multi--methods: a literature review and a field research. In their study, several data collection methods were combined and both research approaches, i.e., systematic literature review and case study were performed in an integrated manner. The systematic literature review was performed to better explain the general constructs and their relationships by merging bibliometrics and content analysis. The purpose of the case study was to understand how different constructs were related. Next, we explore what we call pure multimethod.

Since the combination of pure qualitative methods seems to be an adequate contribution to contemporary studies, and also suitable in the extent that fits with the dimensions of Darlington and Scott (2002), as a mixing of qualitative data collection approaches – this method searches for theoretical and empirical balance in the same investigation, as shown in some of the 35 selected articles (cf. Niehaves, 2011; Waitzkin *et al.,* 2008).

## 5. SYSTEMATIC LITERATURE REVIEW

An example of qualitative research is the systematic literature review method, which is turn can be part of a multi-method research approach. According to Fink (2005), a systematic literature review is an "explicit and reproducible method for identifying, evaluating and synthesizing the existent body of completed and recorded work produced by researchers". Overall, a systematic review is

a valuable tool to discover key theories, concepts, ideas and debates around multidisciplinary studies (Hart, 1998). A brief analysis showed us that, when we use the keyword "systematic literature review" (123 articles), just 6 of these articles mentions multi-method research. But, surprisingly, we also discovered that about half of the articles (55 to be more precise) made reference to case studies. This means that, although the multi-method approach is not explicitly recognized as a methodology in the articles, it is clearly put in practice. The reason for this is possibly associated to the fact that researchers use systematic literature reviews to help building conceptual models or developing protocols to conduct exploratory interviews when performing case study research (cf. Brones *et al.,* 2014). Therefore, it is legitimate to sustain that qualitative multi-method research naturally searches for a methodological balance. This means that a method assists to develop other methods, to triangulate data or to mutually complement it. Furthermore, several articles also mentioned that the conceptual models that emerge from systematic literature reviews may be empirically validated through case study research (Esposito & Evangelista, 2014; Naim & Gosling, 2011; Qu *et al.,* 2016).

Like we previously mentioned, the initial search was restricted to the subject areas of social sciences and engineering, but Scopus can automatically refine this restriction and assign minor subject areas for a more detailed analysis. Thus, titles may belong to more than one (minor) subject area. Figure 2 shows that 55,7% of the articles are related to the social sciences and 48,4% are related to engineering. In a multidisciplinary perspective, these minor subject areas are likely indication that exact sciences are increasingly interested in using qualitative methods, in particular in the areas of engineering.

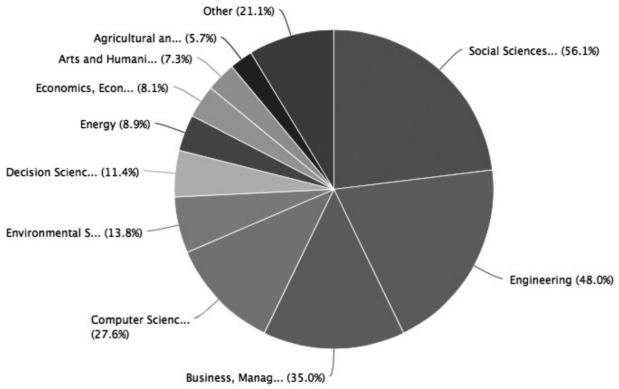


**Figure 2.** Documents by subject area – systematic literature review (source: Scopus)

The interesting aspect here is that most part of the minor subject areas also belong to the social sciences and engineering scope, confirming the perspective that qualitative methods are becoming more widely accepted.

## 6. CASE STUDY RESEARCH

Another example of qualitative research is the case study research, which can also be part of a multimethod research approach. Case study research offers the opportunity to explore and explain a phenomenon for which little or no empirical data exists (Yin, 2003). Additionally, the case study method enables the research to acquire an in-depth and holistic understanding of multiple aspects of a phenomenon as well as the interrelationships between the different aspects (Gummesson, 1991). A common criticism directed at qualitative research is that it fails to adhere to canons of validity (Given, 2008). Case study research may use multiple sources of data collection for triangulation purposes.

Sources of data collection may consist on e.g., interviews, direct observation or document analysis (Yin, 2003). A case study research that uses multiple sources of data collection as a form of triangulation prevents an exclusive reliance on a single data collection method and, thus, aids to neutralize any bias inherent to a particular data source (Given, 2008). A brief analysis showed that from a total of 150 case study research articles, just 3 articles employ multi-method research. As in the previous section, we also discovered that 35 articles made reference to systematic literature reviews, corroborating the view that the multi-method approach is not explicitly recognized as a methodology in those articles. The reason for this is that the literature reviews were being used to build conceptual models (Grimm *et al.,* 2016; Kickert, 2014) and triangulate data (Hilletofth, 2011). Similarly, most case study articles pertain to the social sciences and engineering fields. Figure 3 shows that 53,0% of the minor subject areas are related to the social sciences and 51,0% are related to engineering.

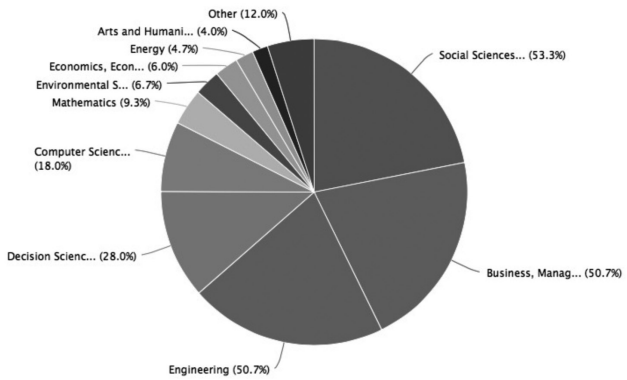


**Figure 3.** Documents by subject area – case study strategy (source: Scopus)

This analysis is in line with the previous section, it suggests that exact

sciences are increasingly interested to use qualitative methods, in particular in the areas of engineering.

## 7. PROS, CONS AND ISSUES

Yauch and Steudel (2003) that used both quantitative and qualitative methods, in two exploratory case studies, have contributed to the definitional debates to distinguish *triangulation*, which is aimed at corroborating data and reducing bias, from *complementarity*, which is aimed at deepening understanding. Similarly, Green *et al*. (1989) identified comparably dimensions that emerged from 57 evaluation studies that used mixed methods and identified five main purposes for combining methods:

(1) *triangulation*, seeks convergence, corroborating and correspondence of results from the different methods; (2) *complementarity*, seeks elaboration, enhancement, illustration and clarification of the results from one method with the results from the other method; (3) *development*, seeks to use the results from one method to help develop or inform the other method, where development is broadly construed to include sampling and implementation, as well as measurement decisions; (4) *initiation*, seeks the discovery of paradox and contradiction, new perspectives of frameworks, the recasting of questions or results from one method with questions from the other method; (5) *expansion*, seeks to extend the breadth and range of inquiry by using different methods for different inquiry components.

We used Green *et al.* (1989) dimensions in our study, and concluded that most part of the articles seek to apply results from one method to help develop the other (development), and pursue corroborating purposes from different methods (triangulation) (figure 4) – this information is fully corroborated by Darlington and Scott (2002, p.124).

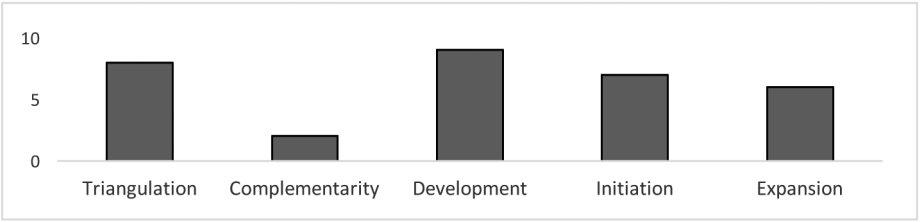


**Figure 4.** Combining methods (adaptation: Green *et al.,* 1989)

In addition, we performed the same exercise to pure-qualitative multi-method researches and we did not find significant differences. Evidence shows that the qualitative multi-method researches are undoubtedly *development*, e.g., the validity and reliability of a case study is strengthened by a literature review (theory triangulation) to develop interview protocols and data analysis coding systems (Denzin, 1989, Banerjee, 2014). Moreover, these qualitative articles also corroborate the seek for *triangulation*, e.g., as qualitative empirical research may validate and corroborate the findings on the literature review. A small difference is that, unlike the mixed multi-method studies (qualitative vs. quantitative), the pure-qualitative studies mentioned the dimension of *complementarity* in 50% of the pure-qualitative articles. This dimension has a greater weight for purely qualitative studies, unlike what is shown in figure 4.

Qualitative multi-method research differs from the mixed method studies (qualitative vs. quantitative) in the extent that it gives greater emphasis to the dimensions of complementarity, triangulation and complementarity. Thus, qualitative multi-method research has been shown to be a multidisciplinary research tool for development, triangulation and complementary purposes, with applicability to social sciences but also to exact sciences (cf. Gimpel *et al.,* 2012). Furthermore, contemporary investigations have shown that the bridge from social sciences and engineering methods is being diluted, although the number of studies are still incipient (3 studies in 35).

The next section explains how social sciences techniques are being applied to contemporaneous engineering studies. However, the use of this type of methodology is not free of limitations. As with qualitative research methods, qualitative approaches are difficult to generalize. This phenomenon occurs because generalization is difficult to obtain without the use of repeatable, quantitative metrics (Neufeld *et al.,* 2003). Moreover, some issues may rise when an investigator uses different methods in the same study: it may carry the risk to obtain contradictory findings, but this should not in itself be considered as a problem; it is, however, a clear indication that further work may be required to understand better what is happening (Darlington & Scott, 2002).

## 8. QUALITATIVE MULTI-METHOD RESEARCH IN ENGINEERING STUDIES

There are several plausible explanations for why engineering researchers appear to strongly prefer quantitative methods. One reason is because the majority of engineering education researchers are engineering faculty members, who were trained within the post-positivism perspective (Borrego *et*

*al.,* 2009). Conversely, with recent calls for expanding the scope and rigor of engineering research, the use of qualitative methods to answer research questions that cannot be answered through quantitative methods is taking an increasing significance (Koro-Ljungberg & Douglas, 2008).

Ljungberg and Douglas (2008) also remark that it is this growing diversity of approaches and perspectives that marks the field of engineering as vibrant and strong and that qualitative methods provide important insights that would not have been possible through quantitative approaches. The articles identified in the literature review that concern the engineering field use multi--method research (qualitative vs. quantitative), as we did not identify any pure qualitative multi-method article. Clearly, this is a gap in the literature. Qualitative multi-method studies are essential for the engineering sector.

Koro-Ljungberg & Douglas (2008) express the same concern and noticed that an incipient quantity of qualitative articles was published. Still, we believe that engineering research will follow the contemporary trend, with respect to an increase of purely qualitative multi-method studies (cf. figure 1). Researchers obstinately stay away from qualitative studies because it may appear easy and less rigorous than quantitative research, while quantitative research requires the use of statistical methods that can provide a sense of reliability (Yin, 2003). For that reason, Borrego *et al.* (2009) suggested that all research (quantitative and qualitative) should be evaluated with regard to four aspects of trustworthiness (table 2).

**Table 2:** Quantitative and qualitative research criteria (adapted: Lincoln & Guba, 1985; Tashakkori & Teddlie, 1998; and Chism et al., 2008)

| Quantitative Research Criteria | Qualitative Research Criteria |
|---|---|
| Validity: project and instruments measure what is intended to be measured | Credibility: establishing that the results are credible or believable |
| Generalizability: results are applicable to other settings, achieved through representative sampling | Transferability: applicability of research findings to other settings, achieved through thick description |
| Reliability: findings are replicable or repeatable | Dependability: researchers account for the ever-changing context within which the research occurs |
| Objectivity: researcher limits bias and interaction with participants | Reflexivity: researchers examine their own biases and make them known. |

Table 2 illustrates an intellectual exercise that may put in place the credibility of qualitative researches, along with quantitative studies. In fact, qualitative research can be just as difficult to conceptualize, and be as methodologically and theoretical challenging, if not more challenging, than quantitative

research (Koro-Ljungberg & Douglas, 2008). To strengthen our arguments a qualitative multi-method research is not free of data analysis, as many of contemporaneous researches use qualitative data analysis software (e.g., NVivo)[2] allowing investigators for handling large volumes of data, as an integrative process of coding and categorizing.

## 9. CONCLUSIONS

Characterizing a study as multi-method research is not a straightforward task (Small, 2011) as it is essential further investigation to find a consensual and multidisciplinary definition among academia. The results suggest that:

(1) multi-method approaches offer the possibility of leading to reliable results in engineering studies; (2) qualitative multi-method research is generally balanced, usually integrating theoretical and empirical studies; (3) qualitative multi-method research differs from other mixed methods in the extent that gives greater emphasis to the dimensions of development, triangulation and complementarity; (4) new developments show that engineering studies will probably follow the contemporary trend, with respect to an increase of purely qualitative multimethod researches.

One limitation of this study is associated with the incipient amount of multi--method research articles in the field of engineering, hence, the reason why most articles are qualitative is because they are mixed with social sciences articles. The search on Scopus did not make any distinction during the application of filters, the social sciences were selected in the same extent of engineering (cf. table 1).
This limitation may be mitigated with the cross-contributions of similar academic articles, which obtained identical results (Borrego *et al.,* 2009). Due to space limitations it is not possible to list all the references. References can be provided on request, by contacting the first author.
Further investigation is needed. In line with this article, we suggest that future research should focus on new trends of qualitative multi-method research. For instance, it would be interesting to find a consensual multidisciplinary concept/definition concerning the qualitative multi-method research.
With our timely contribution, we expect to instigate other researchers to promote the engineering education and the use of contemporaneous trends to investigate.

[2] http://www.qsrinternational.com/

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