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## **Creating a cross-comparative methodology to study engineering education and profession in Europe today**

### **(1) Introduction**

As comparative studies are developing inside Europe, very useful harmonised European statistical data is produced, but a methodology for a more accurate interpretation of the data, combining both qualitative and quantitative approaches, is still under construction. A pluridisciplinary consortium of seven countries<sup>1</sup> tried to develop such a methodology based on empirical experience during the WOMENG research project,<sup>2</sup> funded by the European Union from 2002 to 2005 under the 5th Framework Programme. This project was aimed at understanding when, how and why, women choose or do not choose to study engineering and have careers in engineering in Europe.

Methodology for the WOMENG project had to deal with at least three challenges: first with historically and socially constructed concepts as gender and engineering, second, with large scale cross-national comparison assumed as a research strategy, third with the collection and combination of different sets of data, gathered through different approaches. In addition, the WOMENG project was interdisciplinary and intercultural; this situation implied both translation and methodology issues.

From the beginning, methodology has been considered as a research strategy and as a major output of the WOMENG project, and designed in the perspective of possible transfers to other projects using international cross-comparisons. Through research experience, a methodological toolbox emerged from the project. Four connected steps have been identified and documented: designing research, doing fieldwork, reporting, analysing and interpreting. This paper will present a detailed description of those steps. Through that common work are emerging similar categories, similar configurations that allow new hypotheses, but don't deny the diversity of each specific setting. A complete presentation of WOMENG methodology is available in *Methodological Tools for Research in Gender and technology*.<sup>3</sup>

WOMENG results illustrate how an iterative cross-cultural mixed methodology allows fruitful comparisons that go far beyond the usual statistical comparisons. Anyway, further research in methodology for cross-national comparisons remains necessary: If the methodology for research design, fieldwork and reporting may be considered as rather well documented, which ensures comparability and commensurability, the methodology for qualitative comparative analysis needs further research.

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<sup>2</sup> WOMENG is the acronym of the project: "Creating Cultures of Success for Women Engineers", HPSE-CT-2002-00109, 5th FP, Specific Programme "Improving the Human Research Potential and the Socio Economic Knowledge Base". Report has been published by the European Commission: *Creating Cultures of Success for Women Engineers, WOMENG, project final report*, Brussels 2006, EUR n° 22028, ISBN 92-79-02412-4, v, 125 pages. Report is available at <http://cordis.europa.eu/documents/documentlibrary/2745EN.pdf>.

<sup>3</sup> *Methodological Tools for Research in Gender and technology*, edited by Dr. Y. Pourrat (Paris, 2005); see <http://www.womeng.net>. Another presentation of WOMENG methodology has been published in *European Journal of Engineering Education*, Vol. 31, No. 1 (March 2006), p. 23–33: Godfroy-Genin, Anne-Sophie and Pinault, Cloé, "The benefits of comparing grapefruits and tangerines: a toolbox for European cross-cultural comparisons in engineering education – using this toolbox to study gendered images of engineering among students."

## (2.1) Methodological challenge 1: Beyond case-oriented and variable approach

Two main traditions in cross-comparison have been identified by Ragin in 1987:<sup>4</sup> On one hand, a variable oriented-approach based on quantitative data from many countries, but vague and abstract. That methodology misses connections to the actual empirical process, social bases and specific phenomena, but allows comparisons between many different countries, which broadens the scope, but few general conclusions may be drawn out of that kind of study. On the other hand, a case-oriented approach, sensitive to both complexity and specificity, treats each case as a whole. The drawback of such a method is the difficulty in extending it to a large number of cases because attention to complexity across a large number of cases is very difficult. Another sensitive issue is the possibility of generalizing conclusions from a few cases.

From that statement Ragin proposed “to formalize qualitative comparative methods without departing from the general logic of case-oriented approach” (Ragin (1987), p. x) and recommended “examination of constellations, configurations and conjunctures” that will describe the causal complexity of the phenomenon. From Ragin’s conclusions we tried to go beyond a quantitative approach and to develop mixed methodologies.

## (2.2) Methodological challenge 2: Gender and engineering

Gender and engineering are two historically and socially built concepts, with original interactions between the two in each specific setting. This situation implies difference and similarities from one country to another. In that case, it was necessary to find a common definition of our research topic. How to ensure comparability through the definition of a common research object, common classifications, common scales of evaluations?

To avoid too much complexity, we decided to study women first, and through the situation of women and men, gender construction as far as possible.

“Engineer” is defined here as an academic degree confirmed by an accreditation board, at master’s level, in all scientific and technical areas, excluding agronomy, business and architecture, which are not considered as engineering disciplines in all European countries. As far as possible, existing ISCED and ISCO<sup>5</sup> international classifications were used to enable the use of existing data and facilitate further comparisons.

In the quantitative questionnaires, approval and disapproval were measured on a scale of 5, “1” meaning “strongly disagree” and “5” meaning “strongly agree”. Ambiguous translations and cultural variations were tracked down by the collaborative work of all partners.

Sampling philosophy is based on 3 assumptions:

1. To compare men and women situations with same methodology and sampling, we considered it was the best way to observe men and women interaction in gender construction.
2. Need for a larger sampling where women are a minority, because their situation is more diverse there.
3. To study reasons for choosing, it is important to study also reasons for not choosing engineering.

Because engineering is a very diverse field, the sampling needs also to take into account the various areas of speciality and the ranking of the diverse faculties and schools: 200 questionnaires were handed out in each country, as follows: 50 female and 50 male engineering students, 50 female and 50 male students who could have become engineers, but chose another speciality.

Compared to the national average proportion of women students in engineering, 50% of questionnaires were handed out in settings where the percentage of women students is low, 20% where it is the average, 30% where it is high. Sampling of non-engineering students is composed of 40% of students in Natural Sciences, 20% in Human and Social Sciences, 40% in Economics. Various area of speciality and various types of faculty are represented: old and new ones, large and small cities, etc. The same setting has been studied through qualitative and quantitative approaches.

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<sup>4</sup> Ragin, C., *The Comparative Method. Moving beyond Qualitative and Quantitative Strategies* (University of California Press: Berkeley, CA, 1987).

<sup>5</sup> ISCED = “International Standard Classification of Education” (1997 – UNESCO); ISCO = “International Standard Classification of Occupations” (1988, used by EUROSTAT).

In the professional sphere, three criteria were selected for an exploratory study of two companies in each country. The sampling includes at least one company in the energy sector,<sup>6</sup> one with “good practice” to attract and retain women engineers, and, if possible, one in the manufacturing sector.

### **(2.3) Methodological challenge 3: An iterative mixed methodological framework**

Mixed methodologies are still emerging, they have been thoroughly described by Cresswell<sup>7</sup> who reviews different mixed methodologies and points out their advantages and drawbacks. In our field, a mixed methodology offered the opportunity to use all the available data, both qualitative and quantitative, with heterogeneity due to the different countries.

In addition, the concurrent progress of qualitative and quantitative strategies enables the use of iterative approaches, and therefore the emergence of common cross-national research questions. Through this project, this methodology allows the emergence of common research questions.

The WOMENG methodology is iterative and uses three levels of data collection:

– I: An overall statistical framework, built from existing gendered national data, expressed in international classifications. When it was possible, this type of data was collected directly from EUROSTAT. These data were used as a reference and were a first source of correlation hypotheses.

– II: Specific quantitative data collected by the project on specific questions. The aim was to check hypotheses in a comparative context and to identify significant factors related to choosing engineering. These data were provided by WOMENG-designed questionnaires applied to specific samples in higher education, and by the collection of information about chosen companies for the professional sphere.

– III: Qualitative data from interviews, focus groups, participant observation and document analysis. The aim was to understand why and how specific situations may be explained from the inside, and to find reasons and explanations for results observed in data I and II.

Quantitative and qualitative methodologies were designed to allow mixed and iterative methodologies: some questions are common to questionnaires and interviews or focus groups, so common issues were addressed in the different sets of data. Here are some examples of mixed approaches:

There is a possibility either to identify relevant results in questionnaires and to check qualitative results for an in depth interpretation of those results, or to compare qualitative results to average results in questionnaires and to assess the representativity of case studies. For example, it was possible to know if the opinions of interviewed students represented a common usual view on the subject or a very specific and individual analysis of the situation.

Some tools have been experienced for combining qualitative and quantitative results, in order to maximise the potential of this mixed methodology:

– A cross-reference table for qualitative and quantitative methodology: for a given item in questionnaires, the corresponding questions in qualitative methodology are given.

– Qualitative data presentation to highlight most obvious results: answers 1 and 2 (completely disagree / disagree) are added and opposed to the addition of answers 4 and 5 (agree / totally agree) in percentage. Results are then compared country by country to the average result. When a national result is very different, further analysis is proposed, using qualitative results.

### **(2.4) Methodological challenge 4: large-scale comparison**

There is not much literature and experience for comparisons beyond three or four terms. For example, in a recent important book on international comparisons,<sup>8</sup> Lallement and Spurk selected almost no study including more than three to four terms. However, a comparison with six, seven terms or more raises specific problems.

The first and most obvious one is the quantity of data: tons of data are generated by that kind of project. Simply browsing results becomes difficult, there is a multiplicative effect related to the number of terms. In WOMENG, we collected data in seven countries, which means seven times the amount of data. We had in WOMENG c.a. 1400 questionnaires (200X7) with 600 items and 4 different samples

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<sup>6</sup> This sector is present in all countries.

<sup>7</sup> Cresswell J.W., *Research Design, Qualitative, Quantitative, and Mixed Methods Approaches* (2nd edition; London and Thousands Oaks: Sage, 2003).

<sup>8</sup> Lallement M., Spurk J. (eds.), *Stratégies de la comparaison internationale* (Paris: Editions du CNRS, 2004).

in data set 2; c.a. 40 different interviews or focus groups in each country (total  $40 \times 7 = 280$ ) representing 700 to 1000 pages of English summary.

For each set of data, the results are so numerous that browsing the database becomes a challenge: cross-cultural analysis means mastering seven hundred to one thousand pages of qualitative data, that must be added to the enormous volume of quantitative data.

Beyond the practical problem, this situation also means that direct access to the data, which is the usual research situation, is no longer achievable. Data for analysis and interpretation is always filtered by translations from English to national languages and back, by English summaries, and by the procedures to report on fieldwork results. Moreover, the data may be made more difficult to analyse by translation problems, by reports and summaries made by national researchers, and by our sometimes poor or unequal knowledge of national situations. This linguistic difficulty must be kept under control through various procedures in order to report in the same way and to provide information for analysis on a basis of mutual trust among the different researchers.

A second difficulty arises from the way of consulting the database. For some data, transversal reading always remains possible. When the amount of data increases, it becomes time-consuming for sometimes ineffective results. Our process in reporting and classifying results insisted on the linear process of the interview, which is useful for getting at the inner logic of each interview, but is not very convenient for addressing the same question in different settings. Because possibilities for analysis are so dependant of technical tools required to browse the database, especially for transversal reading (e.g. the same question in different settings), database design has to be integrated to research design. The technical process of collecting and reporting must be defined very carefully to avoid missing or mixing up data and the huge amount of data to be analysed must be considered from the beginning.

### **(3) Main practical problems: Timing, expansion, translation**

Because of the extent of the project, we encountered practical problems. Even if they have nothing to do with the epistemological problems raised by cross-comparisons, it may be very useful to mention the most important ones, as they can be underestimated and cause delay and management difficulties for the consortium.

In WOMENG, a crucial issue was the timing for handing out the questionnaire or doing interviews, which can be different from one country to another. The same problem exists with companies; they are not available for questioning at any time of the year. Sometimes, if the right moment is missed, the fieldwork may be delayed for months, especially with the structure of academic year and the seasonality of academic activities. A good planning needs to identify the *kairos*, but as the *kairos* is not at the same time in the different countries, this planning is not obvious. If you miss it, all the project is delayed, because all results are connected. Another problem is in finding equivalent settings for handing out questionnaires or carrying out interviews.

The other recurrent issue in such projects is the trend to uncontrolled expansion. Each partner tend to consider some issues as essential, but of course, each partner has its own essential questions, so many questions are essential at the end! The questionnaires tended to be too long, and some questions were inappropriate in some national contexts. Anyway, it seems impossible to avoid inappropriate questions in some contexts without missing important issues. A good example of those inappropriate questions are questions about salaries, about „women’s day”, or about sexual orientation. If they are very common in some European countries, they are very unusual and sometimes unsettling in some others. In that case, these issue will be studied in some countries only, and not in the others, because of the absence of data. A comparative study should not be the compulsory study of a list of questions even if comparability and common questions must be ensured. Another concern with the expansion process is the length of the questionnaires or interviews: some students or colleagues were afraid of filling them in or answering them because a whole hour was required. This may be the price to pay for the collegial design of common instruments. This collegiality limited the number of different research instruments, which was a good thing in itself, but lengthened each one that was designed. The design process could be improved in order to be less cumulative and more integrated.

Translation issues must be addressed also very carefully to avoid mistranslation and bias. The only way to address this issue is collegial design and testing of fieldwork instruments, even if the perfect translation remains an utopia. Research was designed in English, then guidelines were translated in

national languages, fieldwork was handed out in national languages, afterwards results were summarized and translated back to English. Even if partners were very careful, there were some translation problems. Slightly different meanings or connotations of words, that is an overall intercultural methodological challenge to interpret carefully. Despite a careful approach of translation, we had the surprise to discover that all engineering students in Europe did not consider themselves as very “emotional” except Greek ones, which was not coherent with the results for other items (“rational”, “practical oriented”, “scientific”, “friendly”, “collaborative”, etc.). The explanation was in the translation of „emotional” in Greek by something meaning „well tempered”. Recommendations for translation must be stressed and concern at first the source language: it should avoid ambiguity, stick to simple structure, avoid « faux amis » (words close to foreign words, but with another meaning). Each sentence must be discussed to avoid misunderstanding and key-concepts as « gender mainstreaming », etc. must be clearly explained.

#### **(4) WOMENG toolbox**

Finally, through research experience, a methodological toolbox emerged from the WOMENG project. Four steps may be identified:

Step 1: Designing research tools. The WOMENG project was structured in two parts: engineering education and the engineering profession and three main “Work Packages”: „Reasons for Choices” (WP2), “Success and Non-Persistence” (WP3), and “Organisational Culture and Social Change” (WP4). WP1 “Methodology” was responsible for designing common research tools and ensuring comparability. Each Work Package proposed specific questions in relation to its hypotheses; those questions were gathered and reviewed to ensure coordination, relevance and exactness in all national contexts. Several versions were produced and improved until a final version of methodological guide-lines was reached. Then the final version of guidelines was translated into national languages. Major translation problems were avoided thanks to the collaborative design, but some irrelevant questions in certain contexts remain.

Step 2: Fieldwork. Due to the number of different actors and contexts, fieldwork procedures must be described very clearly and cultural differences must be taken into account. (cultural bias, socially desirable answers, etc.). A crucial element is an accurate documentation of the research context through biographical data, identification of relevant samples, etc. Even if it is impossible to ensure perfect equivalence, we must make efforts to identify a common research setting and avoid obviously different methodologies and procedures.

Step 3: Reporting. The idea was to work as closely as possible with the original data, even if they were necessarily filtered by the translation into English, the summaries and the national reports. Complete transcription and translation of qualitative results would have taken too long, but, on the other hand, relying on national reports without any access to original data would have reduced the benefits of cross-comparisons with the risk of juxtaposing national studies without comparing them. So an intermediate methodology was implemented: each interview or focus group was summarized in English, question by question. The authors of the summaries were asked to quote important sentences, to identify general patterns and to stress national specificities. In the margin, a column was added for comments and first interpretation. To help interpretation, short national reports were written for first interpretation at national level and explanation of the specific contexts.<sup>9</sup>

Step 4: Analysing and interpreting. Through this methodology, relevant and comparable material has been produced, with appropriate documentation. We can combine all the data from set 1: statistical framework, set 2: questionnaires, information on companies, set 3: qualitative instruments, through an iterative mixed methodology. In fact, only few possibilities have been experienced to produce the WOMENG final report, and further research is needed for a more systematic exploitation of this material.

Analysis and interpretation represent a challenge due to the huge amount of data we have. The main difficulties must be mentioned:

1. Technical difficulties in consulting the results and lack of immediate, intuitive perspective due to the amount of results.

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<sup>9</sup> All this data is available to all researchers on the WOMENG web site <http://www.womeng.net>, then database. With the agreement of the WOMENG consortium, researchers may use the collected material for further research.

2. Epistemological difficulties in choosing meaningful comparisons and conceiving qualitative data comparison.

3. Methodological difficulties for qualitative data comparison. A more or less intuitive identification of recurrent ideas was attempted, but it may be possible to try coding or mapping the main concepts and their links as Ragin suggested (Ragin, 1987, see note 4).

## (5) Conclusion and perspectives

As far as we are able to consider the results of the project, the methodology for research design, fieldwork and reporting may be considered as well-known and our toolbox ensures comparability and commensurability. But if we consider the methodology for consulting the data, we still lack efficient technical tools, and our methodology for qualitative comparative analysis needs further research and development.

It appears crucial to keep in mind that these steps are connected, and that only a collegial process can ensure comparability, even if it is sometimes time-consuming. A mono-national approach would reveal itself to be completely inappropriate when doing fieldwork or interpretation in other countries. Only through collaborative work are similar categories emerging, similar configurations that enable new hypotheses to be formulated, but do not deny the diversity of each specific setting.

From a methodological point of view it must be stressed that an iterative cross-cultural mixed methodology allows a fruitful comparison that goes far beyond the usual statistical comparisons, within some limits: even if we tried not to compare oranges with apples, never forget we are comparing grapefruits with tangerines. Even if some similarities and a common culture allow a common comparative framework, European countries are too diverse to be similar and directly comparable. The aim was to catch at the same time diversity and unity of the European technological field: “In varietate concordia” as the European Union motto says.

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