Leveraging European SMEs and Start-Ups competitiveness through design

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Abstract: Firms are increasingly investing in design and involving firms operating in this field in their innovation process. This research is based on an ongoing research project consisting in a complete range of free training courses - held in the main European cities - which main objective is to discover how design-driven innovation can become the key to improve European Small and Medium Enterprises (SMEs) competitiveness, efficiency and sustainability. It starts from the results of a previous work, that aimed at taking a picture of the design European trends. Keep the same research objective, in this work more updated data has been considered and analysed. Furthermore, more insights have been evaluated through the analysis of statistics and feedback. Hierarchical Cluster Analysis (HCA) has been used as learning methodology, in order to explore data and discover some hidden relationships between groups (countries and course modules). From this analysis, some considerations have emerged. Firstly, focusing on the countries, more interest has been shown by participants coming from Poland, Italy, Bulgaria and Spain. Furthermore, the most followed courses are related to the connection between product and services, global future trends and business models and design seen as shaping products. On the other hand, Product Lifecycle Management (PLM), Additive Manufacturing and Life Cycle Assessment (LCA) were the less selected topics. Some considerations can be hidden behind these choices. Concerning the decision to select the Product&Service as a favourite choice, this could depend on the relevance that services are assuming nowadays. Concerning the design for shaping products, this choice could be related to the fact that this module represents the common meaning of design: the shape. About global and future trends and business models, companies have shown their interest in those topics because are considered highly relevant in order to understand the future challenges, implications and possibilities (related to the design topic) they have to face and how to address them. The less interest on the modules of PLM, additive manufacturing and LCA could be linked to the fact that those topics are seen more as supporting tools or methods by SMEs, helping them to improve design but not directly involved in the process itself. Finally, this work could be used by the European SMEs as benchmarking, in order to understand which design topics are covered by them and which not.

Keywords: Design; Design process; Design in Europe; Design driven innovation; training courses; SMEs; Hierarchical Cluster Analysis; HCA

1. Introduction

In the last decades, companies are facing numerous difficulties coming from the turbulent economic situation (financial crises, fiscal policies) and growing demand of customers asking for personalized products and services. These drastic changes urge companies to innovate in order to satisfy their customers, acquire new ones and gain leading positions on the market (Sorescu and Spanjol, 2008; Reid and Brentani, 2010; Bohlmann *et al.*, 2013). The academics propose different models how company can innovate through technology change, collaboration or simply changing the meaning of the existing product.

Design has recently gained much attention among practitioners and scholars as a source of innovation. Firms are increasingly investing in design and involving design firms in their innovation processes. This relevance is also highlighted by the scientific literature, that explores the contribution of design to product development and business performance (Robertson and Radcliffe, 2009). Design management is recognized as a rather young area, with blurred boundaries and often unclear or contrasting

perspectives. Indeed, the concept of design has changed and evolved over the years, starting from the design as "form of things", passing through the design perceived as "creative problem solving" (Robertson and Radcliffe, 2009) till the concept of design as "innovation of meanings" (Verganti, 2008).

In this context, SMEs should consider a differentiation strategy evaluating not only the product characteristics but also its meaning. Innovate the meaning of the product alludes to create products and services accordingly with the customers' needs, helping to ground a sense of purpose into an organization. In the meanwhile, nowadays there are some issue concerning the product because it is increasingly perceived as a commodity, as the primary needs of consumers have already been fully satisfied. What really makes sense to the company is the product seen as a system. Strategic design is then a mind-set that makes sense to company strategy through a product system, from the commodity to the user engagement. This study is based on an ongoing research project that consists in a complete range of free training courses provided by the European Commission and has the objective to discover how design-driven innovation can become the key to improve European SMEs competitiveness, efficiency and sustainability (*Design for enterprises A tool for SMEs development*, 2015). In the meanwhile, this research starts also from the results of a previous work, which main aim was to take a picture of the trends at European level with respect to the design, starting from the modules proposed by the course during its first year of deployment. Accordingly, the results of the analysis allowed understanding which were the knowledge - in terms of design - most requested by European SMEs. Keep the same research objective, in this research more updated data have been analysed through cluster analysis, in order to highlight the main connection between modules and countries. Furthermore, more insights have been evaluated through the analysis of statistics and feedback coming from the second year's activities. The paper starts, in section II, with a brief overview of the analysed project. The following section, section III, introduces the research approach, describing the statistical techniques supporting the analysis (Ward hierarchical cluster analysis) together with some motivations we found to use this technique and the dataset construction/sample. Section IV is dedicated to the discussion of the results. Finally, session V concludes the paper, presenting some thoughts about future research.

2.Relation to existing theories and work

The creation of effective learning environments plays an important role when it comes to organizational learning. In fact, it allows to (i) change individual and social interpretation patterns of reality, (ii) develop knowledge and competencies, and (iii) change the sociotechnical systems of organizations (Kriz, 2003). This work put more emphasis on the knowledge and competencies development. As previously mentioned, this research is based on an ongoing project, started in 2015, consisting in a complete range of free training courses focused on design-driven innovation. The courses are targeted on European SMEs and Business Development Intermediaries. Understanding new technologies, organizations and business cultural trends are the core of the courses. The training program focuses on design as the key feature in the strategies to develop a SME in the global market of today.

The full program is divided into modules. The modules are classified in four main categories. Following, the categories and the modules belonging to each category are described:

1. **Design - Tool of management**

a. *Global Future Trends and Business Models* - How Global Future Trends and Business Models influence product design and development.

b. *Product & Service - Its Design and Development* - How to design a company strategy for the new product development process.

c. *Design for Problem Solving* - How to foster creativity and product engineering, through systematic innovation.

d. *Communicating innovation through metaphors* - How to communicate Design-Driven Innovation.

2. **Added value design to your products/services**

a. *Design for Opening New Markets* - How to use design as a strategic asset.

b. *Design of Innovative Services* - How to design services to differentiate the offering of companies.

c. *Design for Future Products/Services* - How to explore new ideas and design products and services for the future market.

d. *Design for Shaping Products* - How the shape of a product can boost its marketability.

3. **Materials and Technologies**

a. *Design for materials* - How the use of innovative materials brings competitive advantage and opens new markets.

b. *Additive Manufacturing for Design* - How additive manufacturing revolutionizes the SMEs' approach to business and product design

4. **Effective Product Development**

a. *Lean design I&II* - Part I – How lean thinking enhances product design and Part II – How SMEs can improve the design process through waste elimination

b. *Tools for Product Lifecycle Management (PLM) I&II* - Part I – How digital tools support design, along the whole lifecycle of products and services and Part II – How SMEs can evaluate costs and benefits of an investment in PLM tools

5. **Design for Sustainable Products/Services**

a. *Design for Life Cycle Assessment (LCA) I&II* - Part I – How to use LCA for developing greener

products and Part II (Simulation game) – How to put in practice the LCA methodology in an SMEs

The modules are then presented during a first face-to-face event. In addition, at the end of the training program, a module called "Project Work" is planned, to be run on distance, where each participant is asked to develop a case study in one field of his interest.

3.Research Methodology

The idea of this work is to analyse the collected data using the Cluster analysis. In this way we aim to explore and visualize data using something quite different respect to traditional statistical method, such as histograms or similar. Cluster analysis is an exploratory technique and it is used to recognize whether the dataset is actually composed by distinct subgroups (clusters), each group representing objects with substantially different properties. This also means that objects in the same cluster are more similar than other objects assigned to other clusters (Murtagh and Legendre, 2014) (Szekely and Rizzo, 2005).

The particularity of the method is that the algorithm is able to explore data in an unsupervised way, meaning that the algorithm is able to search for similarities inside the data without having any previous knowledge about how they are labelled or which features they represent. Central to the construction of the method is therefore the definition of the degree of similarity (or dissimilarity) distance between the different objects. So depending on this notion, different procedures could be implemented such as the partitioning method (k-means or k-medoids) and the hierarchical method (Hastie, T. *et al.*, 2008)

In this work, we focus on Hierarchical Cluster Analysis (HCA), which is a method of cluster analysis that seeks to build a hierarchy of clusters. We develop an agglomerative approach, which is a "bottom-up" approach: each observation starts in its own cluster, and pairs of clusters are merged as one moves up the hierarchy. In order to develop our method, we make other two choices:

- In order to decide which clusters should be combined, a measure of dissimilarity between sets of observations is required. In this sense, we use the Euclidean distance in order to compute the distance between two different objects.
- We need to fix a linkage criterion, which specifies the dissimilarity of sets as a function of the pairwise distances of observations in the sets. Among the different possibilities, we choose to apply Ward's method. Ward suggested a general agglomerative hierarchical clustering procedure, where the criterion for choosing the pair of clusters to merge at each step is based on the optimal value of an objective function. Usually, the objective function is the error sum of squares, and this is known as Ward's method or more precisely Ward's minimum variance method. Ward's minimum variance method minimizes the total within-cluster variance (Szekely, G. J. and Rizzo, M. L. 2005).

Figure 1: The histogram is representing the distribution of Modules within the different European Countries.

The data set we want to explore is reflecting the relationship between Modules and European Countries. In particular, for each country participating in the Project, we have collected how many people have chosen a specific Module of the program. The total data set is composed register the entries for 12 European Countries and for 13 Modules.

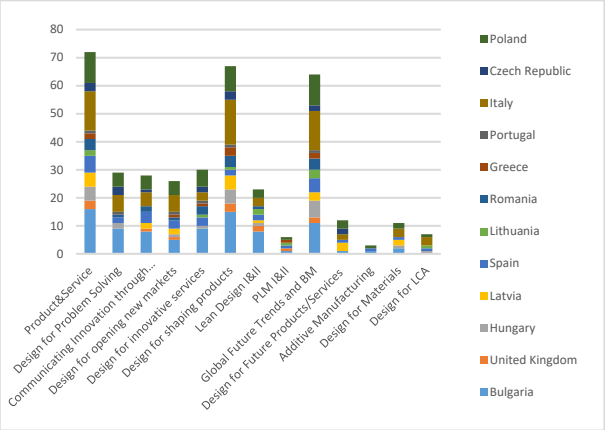

Figure 1 shows how the courses are distributed, highlighting the involvement of each country. In Table 1 and Table 2, the number of participants divided respectively per country and courses are reported.

Table 1: Number of participants per country

Country Id Number	Country	Number of participants
1	Bulgaria	86
2	United Kingdom	13
3	Hungary	23
4	Latvia	23
5	Spain	32
6	Lithuania	11
7	Romania	20
8	Greece	10
9	Portugal	6
10	Italy	75
11	Czech Republic	16
12	Poland	63

Table 2: Number of participants per courses

Course Id Number	Course	Number of participants
1	Product&Service	72
2	Design for Problem Solving	29
3	Communicating Innovation through Metaphors	28
4	Design for opening new markets	26
5	Design for innovative services	30
6	Design for shaping products	67
7	Lean Design I&II	23
8	PLM I&II	6
9	Global Future Trends and BM	64
10	Design for Future Products/Services	12
11	Additive Manufacturing	3
12	Design for Materials	11
13	Design for LCA	7

The aim of the application of a machine learning technique, such as the cluster analysis, is to explore data and to eventually discover some hidden patterns existing in the dataset. In particular, we are searching for correlations between modules and countries that are not immediately visible from pure numbers of participants. A machine learning techniques is indeed able to explore data more in depth, automatically and autonomously searching for existing groups of entities inside the dataset.

To reach this goal, we apply HCA in both the two space dimensions (countries and courses).

- **Case A** starts assuming that modules are variables. In this way, we have 13 variables and for each of these, we collect 12 observations (where we know that each observation is actually a European country). We want to group observations into specific sets, through the application of the HCA. Grouping observations mean grouping Countries, in order to understand if particular relationships exist among them.
- **Case B** reconsiders the data set assuming European countries as variables of the data set. In this way, we have 12 variables (which is the number of the European countries participating in the project) and we are collecting 13 observations for each of them. These observations are actually the different 13 modules. We want to group these observations into specific sets, through the application of the HCA. Grouping observations mean in this case grouping modules, in order to understand if particular relationships exist among them.

Furthermore, other statistical analyses have been performed (see 4.2 Courses Statistics) regarding mostly the number of participants - divided per categories (SMEs and Business Intermediaries) and course typology (Short or Full) - and their feedback. The data analysed belonging to the second year's activities. During the second year of the project, the consortium has been working mainly on the collection of the first Survey results;

4.Findings

4.1 Results of data analysis

The cluster analysis has been performed using the statistical software R (R Core Team, 2014). To analyse Case A, a dataset where variables are representing different European Countries have been used. Therefore, clusters are now composed of different European countries.

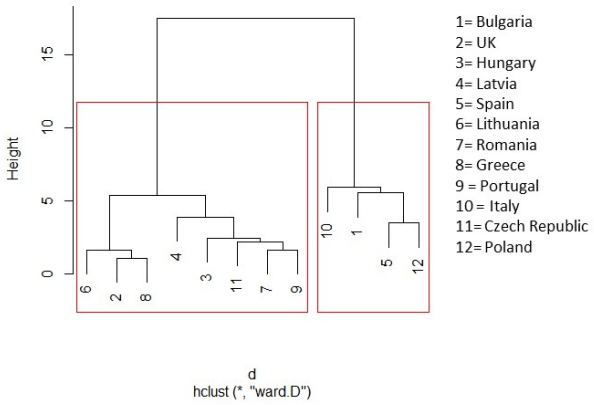

Figure 2: HCA result for the case A. The dendrogram is representing the different 12 countries clustered in a hierarchical way. The red boxes are representing the different clustering we can obtain when the distance (height) is equal to 5.

Two main clusters have been identified setting height equal to 5, starting from the left:

- Cluster A1: composed by Lithuania, United Kingdom, Greece, Latvia, Hungary, Czech Republic, Romania and Portugal.
- Cluster A2: composed by Italy, Bulgaria, Spain and Poland.

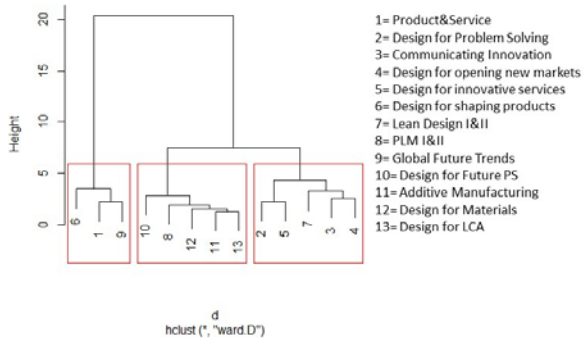

Figure 3: HCA result for case B. The dendrogram is representing the different 13 modules clustered in a hierarchical way. The red boxes are representing the different clustering we can obtain when the distance (height) is equal to 5. Fig. 3 reports the dendrogram which results from the application of the HCA. The dendrogram is representing the hierarchical clusterization of the different 13 Modules. The height axis is representing the value of the Euclidean distance between

different observations. We have decided to fix a threshold on the height equal to 5. With this values, we can obtain 3 different clusters, each of them containing some modules.

In particular, starting from the left:

- Cluster B1: composed by Design for shaping products, Product&Service and Global Future Trends and BM;
- Cluster B2: composed by Design for future Products/Services, PLM I&II, Design for materials, Additive Manufacturing and Design for LCA;
- Cluster B3: composed by Design for Problem Solving, Design for innovative services, Lean Design I&II, Communicating innovation through metaphors and Design for opening new markets.

4.2 Courses Statistics

During the second year's activities (from September 2016 to August 2017) 21 courses were delivered in 17 Countries.

The target was to have 40% of SMEs participants and 60% Business Intermediaries participants. This target has been achieved, as shown in Table 2.

Table 2: Number of Participants

Country	Number of participants	SMEs participants		Business Intermediaries participants	
		SHORT	FULL	SHORT	FULL
First Year courses	106	27	21	42	16
Second Year courses	448	120	73	156	99
Total	**554**	241		198	115

Generally, participants could be classified into 3 different categories on the basis of their knowledge on Design Driven Innovation:

Table 3: Participants classification

Basic	Intermediate	Advanced
About 55% of total participants	About 40% of total participants	About 5% of total participants

At the end of each course, participants are asked to answer a Satisfaction Survey (both for the short and full course).

Courses feedback

This section shows the feedbacks for the full and short courses. Participants can be categorized as SMEs participants and Business Intermediaries participants. In this analysis the total number of participants is the sum of those two categories. Concerning the full courses, the overall reply rate of the survey is 96% for SMEs and 98% for Business Intermediaries, with only few participants (about 10) that were not able to compile the satisfaction survey. Table 4 shows the feedback that comprise the full courses organized in Gdynia (Poland), Zagreb (Croatia), Huddersfield (United Kingdom), Sofia (Bulgaria), Debrecen (Hungary), Riga (Latvia), Ljubljana (Slovenia), Kaunas (Lithuania) are reported.

Table 4: Full courses reply rate

Total number of participants	SMEs		Business Intermediaries	
	N° of participants	Reply rate	N° of participants	Reply rate
172	73	96%	99	98%

In figure 4, the percentage rates of the training full course are shown.

Figure 4: Percentage of rates of the training full course

In Table 5 the feedbacks that comprise the short courses organized in Gdynia (Poland), Reykjavik (Iceland), Sofia (Bulgaria), Lisbon (Portugal), Thessaloniki (Greece), Prague (Czech Rep.), Cluj-Napoca (Romania), Kaunas (Lithuania), Chisinau (Moldova), Saint-Etienne (France), Montebelluna (Italy), Jaen (Spain), Liverpool (United Kingdom) are reported.

Table 5: Short courses reply rate

Total number of participants	SMEs		Business Intermediaries	
	N° of participants	Reply rate	N° of participants	Reply rate
276	119	97%	157	98%

In figure 5, the percentage of rates of the training short course are shown.

Figure 5: Percentage of rates of the training short course

5.Discussion

In this section, the discussion of the research results and conclusions are presented. The discussion has been structured following the two main analysis, focusing the cluster analysis on Case A (courses) and Case B (countries).

Case A: HCA Respect to the countries

- Cluster A1 is the largest cluster in terms of number of observations (countries). The countries belonging to this cluster have some commonalities. In particular, they have a similar number in terms of participation and also analogous choices (concerning the kind of courses). As interesting example is the case of Romania (7) and Portugal (9): in fact, despite they have different number of participants (respectively 20 and 6), they have been coupled immediately because of their similar choices. Basically, this cluster could be divided into two sub-clusters, composed by the following countries:
  - A1.1 Lithuania, United Kingdom and Greece (with similar rate of participant, between 10 and 13);
  - A1.2 Latvia, Hungary, Czech Republic, Romania and Portugal (with almost the same rate of participant. Portugal has been coupled because of the communalities in the courses selection).
- Cluster A2 contains 10-1-5-12 (Italy, Bulgaria, Spain and Poland). These countries have been grouped for two main reasons: starting with Poland and Spain, those countries have the lowest number of participants of the cluster (respectively 63 and 32); after that Bulgaria (86 participants) and Italy (75 participants) have been paired. Here, the type of modules selected by the participants represents a key driver for this cluster analysis. All of them, in fact, present a similar choice in terms of module typology.

Case B. HCA Respect to the modules

- Cluster B1 is composed of the following courses Design for shaping products, Product&Service and Global Future Trends and BM, which are effectively the most chosen courses. Indeed, the number of participants for these courses are respectively 67, 72 and 64. Therefore, we can categorize this cluster as the "most followed";
- Cluster B2 is composed by the courses with following id numbers 10-8-12-11-13, and are respectively Design for future Products/Services (12 participants), PLM I&II (6 participants), Design for materials (11 participants), Additive Manufacturing (3 participants) and Design for LCA (7 participants). From the cluster analysis, Additive manufacturing and Design for LCA belong to the same cluster. The main reason is surely related to the low number of participants choosing these modules and also to the fact that these courses have been selected by the same countries (Poland and Spain);
- Cluster B3 is composed by the courses identified with the following id numbers 2-5-7-3-4, and are respectively Design for Problem Solving (29 participants), Design for innovative services (30 participants), Lean Design I&II (23 participants), Communicating innovation through metaphors (28 participants) and Design for opening new markets (26 participants). As is it possible to infer, this cluster is characterized by courses that are followed by quite the same number of participants. An interesting analysis that has to be made is related to the first level of coupling. In fact, 2 and 5 (Design for Problem Solving and Design for innovative services) are firstly coupled together and the same happens for 3 and 4 (Communicating Innovation through Metaphors and Design for opening new markets. It means that participants that chose one of these courses are (i.e. Communicating Innovation through Metaphors) will more likely choose the other belonging to its sub-cluster (in that case Design for opening new markets).

6. Conclusions

The methodology and the approach proposed by the team and applied showed a great efficiency. All the key parameters set to monitor and evaluate the advancement of the project are confirming, and in some case exceeding, the expectations. However, thanks to the high number of courses organized, the interviews done to some participants, the feedbacks collected during the training and gathered from the follow-up surveys and, most of all, to the experience of trainers involved, there are some suggestion for further increase the efficiency of the program. One of the most important factors for success is the commitment of Enterprise Europe Network (EEN) local representatives in cooperating with the team (and in particular with the communication team) during the preliminary phase of organization. The support for a focused communication campaign on local SMEs and intermediaries, the official communication done through their main channels (local press, Newsletter, website) and the direct contact with their associates increased both the number of participants and the rate of participants/registered people. A higher role for local EEN members and some small budget to support the courses could be a further way for increasing more and more the effectiveness of the training course in the future.

From August 2016 to August 2017 a total of 21 courses in 17 countries have been delivered, including 8 full courses and 13 short courses. According to them, it is possible to extrapolate a list of achievements:

- during this second year's courses 448 people participated to our courses. Considering also first year's courses more than 550 people from SMEs and business intermediaries have been trained (from April 2016 up to August 2017).
- participants find the courses very useful and interesting.
- as for the first year, many participants to the short course would like to participate also to the full one, in these cases they will be informed to participate only to the second day of the kick-off event of the full course;
- the platform is used with no significant problem, a FAQ section and a General forum where added to improve the experience;
- both the trainers and the on-line support received a high score.

Furthermore, from the analysis of the cluster analysis results, some considerations have emerged. Firstly, focusing on the country, more interest to this topic has been given by participants coming from Poland, Italy, Bulgaria and Spain. These countries have the higher rate of participation and, consequently, they are also the most interested in the topics proposed by the courses. The majority of the participants coming from these countries followed the Product&Service, Design for shaping products and Global Future Trends and BM courses. This last result is aligned with the overall result of the research. In fact, these three courses are the most followed by the whole participants. Concerning the other countries of the sample (countries belonging to the cluster A1), they have a similar number in terms of participation and also analogous choices (concerning the courses typology). In this case, the less followed courses are PLM I&II, Additive Manufacturing and Design for LCA. Some considerations can be hidden behind these choices. In fact, concerning the decision to select the Product&Service as a favourite choice for the majority of the participants this could depend on the relevance that services are assuming nowadays. In fact, this module helps the participants to define design as a process, with many players involved, to manage the development process, for being effective, to improve the design process, adopting reference models, and to manage the intellectual capital generated by the design process. Concerning the Design for shaping products module this choice could be related to the fact that in this modules the most common meaning of design is represented: the shape. Following this module, participants have the chance to understand the drivers to shape the form of industrial products, to control all the variables that contribute to the final appearance of products and to manage and balance the different drivers of the form. Therefore, from the analysis of the results, the topics described by these two modules are those considered important in terms of adding value to the SMEs business. On the other hand, the choice to consider less the modules of PLM I&II, Additive Manufacturing and Design for LCA could be linked to the fact that SMEs consider those topics more as supporting tools, methods and technologies helping them to improve their design but are not directly involved in the design process itself. Concluding, further research could take into consideration this last assumption, trying to understand better why these topics are not considered as relevant as the others. It could happen that a specific company is not still ready to understand how to exploit the topic addressed by some of the modules proposed (especially the less followed). Therefore, more training could help them to get more awareness and to improve their business using also different knowledge.

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