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Smartness of Learning Ecosystems and its Bottom-up Emergence in six European Campuses

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Abstract. Each year a considerable amount of money is spent in the production of several national and international University rankings that may deeply influence the students' enrollment. However, all such rankings are based almost exclusively on numerical indicators weakly related to the quality of the learning process and do not consider the perceptions of the "end users", i.e. the learners. Recently, as part of the activity promoted by the ASLERD (Association for Smart Learning Ecosystems and Regional Development), we have developed an alternative approach to benchmark learning ecosystems. Such novel approach is based on: a) the detection of the degree of satisfaction related to the levels of the Maslow's Pyramid of needs, and b) the detection of indicators related with the achievement of the state of "flow" by the actors involved in the learning processes. In this paper we report on the first implementation of such benchmarking approach that involved six European Campuses and more than 700 students. The critical analysis of the outcomes allowed us to identify: a) the set of the most relevant indicators; b) a "smartness" axis in the plan of the first two principal components derived by applying a Principal Component Analysis (PCA) to the spaces of the selected indicators.

Keywords: Learning Ecosystems, University ranking, Benchmarking, Smartness, Maslow's Pyramid, Flow, Principal Component Analysis

1 Introduction

Since the beginning, universities have established as places for a privileged transmission of knowledge and know-how. For centuries the choice to attend one university rather than another has been linked to the personality of the “magister" who was allowed to operate in a favorable context that in return facilitate the development of what are usually known as “schools of disciples” [1]. In order to survive universities had to attract the relatively few available students and talents, and spread their fame well beyond their territory of reference. With the massification of the higher education, universities have assumed a different social role and became drivers of local economies, regardless of the quality of the educational processes and that of the overall faculty [2-4]. The abundance of suppliers and, as well, the changes in the social conditions have shifted the parents’ focus, with few exceptions, from *quality* to *proximity* [5]. Meanwhile the universities have assigned, with only few exceptions, an increasing relevance to the establishment of systems of relations, at the expense of educational quality and meritocracy [6]. Universities, in addition, are progressively organizing themselves as enterprises that deliver *services*. In this context, the potential *student* became a potential *customer* to be attracted and inserted into the process that transforms *raw materials* into the *products* needed by the *market*. The multiplication of suppliers, together with the growing adoption of marketing techniques, have made the scenery increasingly opaque and the students’ choices more difficult and doubtful. Therefore, in recent years, many university rankings were produced either at global or at national level, in order to “support” students and parents in their choices.

Unfortunately, none of such rankings can be considered “neutral” because all are built upon the underlying model’ assumptions from which indicators and indices are derived and, then, suitably combined in order to produce rankings [7]. Potential rankings’ target - i.e. students and their parents - are usually not in the conditions to identify the underlined models and, thus, are not able to critically evaluate the actual reliability of the methodology. As an example. As an example, recently, the two rankings of the Italian universities [8,9] have been critically analyzed and it has been shown [10] that they:

a) are based exclusively on *process* and *product* indicators (that aims at detecting: the quality of the research and of the delivered process, the level of internationalization and, in part, the capability to connect the educational process with the productive environment);

b) use indicators strongly correlated among themselves that would require a different and more appropriate statistical treatments to determine the best space of representation;

c) are correlated with the territorial rankings (i.e. smart cities rankings).

In addition the analysis of the correlations among indicators has shown that macro-analysis of comparable quality can be obtained by considering only a subset of the initial indicators. This, in turn, would enable an optimization of the ranking process, i.e. a reduction of data retrieval efforts and, as well, of the associated costs.
Moreover it is of outmost importance to emphasize that students' opinions are scarcely taken into account in the elaboration of such rankings. As an example, in one of the two Italian rankings [8] students were considered only as a normalization factor and for their propensity toward international mobility; in the other one [9], apart from being used as normalizing factor, students were considered as a product destined to the labor market and influenced the benchmarking on the basis of their performances. These latter, in fact, are actually related to the measure of effectiveness and efficiency of the overall process having among its goals the satisfaction of the territory's expectation. In this second ranking the only exception was represented by the possibility granted to the students to give their opinion on the integrated quality of the offer (*product*) and of the learning courses (*process*).

The international "landscape" is not that different from the Italian one [7]. Let's consider as example two of the most popular university classification systems: Topuniversities [11] and U-Multirank [12]. The first one ranks universities by assigning 60% of the score to the *research "quality"* (reputation and number of scientific papers citations), 10% to the *level of internationalization* (students and teachers), 10% to the *outcomes of the process* (reputation of former students in their working environment) and 20% to the *staff/student ratio*. We can certainly state that this ranking does not put the students and the educational process at the center of the evaluation. The second system, U-Multirank, supported by the Erasmus+ initiative, monitors the quality of the universities on the basis of:
a) *effectiveness and efficiency of the process* (percentage of graduates and percentage of non-employees);
b) *research "quality"* (total number of publications produced and citations) and the level of interdisciplinarity;
c) *knowledge transfer* (industrial relations, patents, spin-offs) with emphasis on the regional level of engagement: internships, local funding, job placement, joint research at local level;
d) *international propensity* (courses given in English or activated in collaboration with foreign universities, percentage or foreign students and teachers, students' propensity toward mobility).
Also in the case of U-Multirank one may expect that indicators and indices are affected by correlations but they have not been investigated by their authors. U-Multirank, however, has the merit not to propose itself as a ranking, but rather as an informative tool, although, similarly to the other ranking' methods, does not consider students' expectations and/or perceptions.
Although some of the dimensions considered by the evaluation approaches described above may be related, to some extent, to the attractiveness of the learning

environment, they are inexorably linked to a top-down and *productive* vision. This perspective considers universities as *factories* that have to place efficiently their *products* (innovative knowledge and human resources) into the *productive context* within the time-frame allocated to the process. All this without submitting the *productive chain* to meaningful quality control, as quality, in principle, is expected to be guaranteed solely by the propensity towards the internationalization and the worldwide recognition of research).

Actually, as speculated in the past, the smartness or attractiveness of an ecosystem does not depend exclusively on its ability to run “all gears” in an effective and efficient manner. It, rather, depends on its ability to create an environment able to meet the individuals’ basic needs and keep them in a state of positive tension in which their skills are stimulated by adequate challenges, to favor the achievement of the self-realization [13]. Only under such conditions, individuals will ”live” and feel as active actors of their territory and, as well, will be encouraged to innovate and contribute to both the the economic development and the social well-being. Accordingly we need a different approach to monitor and evaluate learning ecosystems: a *bottom-up approach*, that fully involves students and, possibly, all other categories contributing to the success of the educational process. This approach should be based on a different framework of reference and, at the same time, should be considered complementary to the top-down evaluation approaches discussed up to now, since it represents a complementary perspective.

2 The Bottom-Up Evaluation Model and Test-beds

The framework of reference - from which our bottom-up approach to measure the ”smartness" of a learning ecosystems has been derived - has been inspired by the Maslow’s Pyramid [14] and by the definition of the Flow state [15]. Accordingly, provided that basic individual’s needs [14] are satisfied, all individual actors of the learning process - in particular students - are candidate to achieve a state of flow [13], i.e. a state where challenges are exciting and adequate to the skills owned by the individuals, which, in turn, are expected to be improved due to the challenges.

While referring the reader for a detailed description to previous publications [16, 17], here we resume briefly the procedure we developed. First internal and external elements composing a learning eco-system - infrastructures, services, social life, challenges, skills, etc. - and data typologies (subjective and objective, qualitative and quantitative) have been mapped onto the Maslow's Pyramid of needs, slightly redefining its inner layers. Afterwards, using such mapping as guidelines, a questionnaire aimed at collecting the opinions of all actors operating within the learning eco-systems have been elaborated. The questionnaire (see Appendix A) was designed to collect both numerical indicators and textual opinions on all levels of the

Maslow's pyramid of needs and, as well, parameters strictly related to the achievement of the state of flow.

According to the definition of ecosystems' smartness [13,16,17], this latter can be fully determined only when data are collected from all actors of the educational processes - students, teachers, technicians, etc.. However, due to the difficulty to involve all such categories in a trials of reasonable dimensions, and considering that all learning ecosystems should be centered around students and their needs, some members of the ASLERD [20] decided to start a trial phase considering only samples of university students. The goal was *to extract a measure of the ecosystems' smartness as perceived by the students*.

The questionnaire was pre-validated by the local campus research coordinator. Observations were collected and the questionnaire adapted accordingly to the coordinators' requests. Once a full agreement was achieved, the final version of the questionnaire was implemented in an electronic form and made available for anonymously filling through an instance of the LIFE on-line environment [21]. This environment has been chosen because: a) it allows easily to create dedicated instances of the same questionnaire, b) automatically generates histograms and offers an integrated facility to analyze the frequency of the words used in answering the open questions. A more in depth text analysis of the answers given to the open questions, however, is beyond the scope of this paper and will be left for future works.

The dissemination strategy used to inform students about the questionnaires differed from campus to campus, depending on the level of collaboration offered by the local administrative services. When possible the questionnaire was announced on the university website; otherwise a group of students was involved to attract colleagues studying in the same Campus. The questionnaires was left open until no more significant statistical variations of the collected data have been observed.

The total number of students involved was around 700 distributed as follow among the six universities that participated in the trial for the academic year 2014-2015: 81 from the University of Rome Tor Vergata, 51 from the Polytechnic of Turin and University Politehnica of Bucharest, 47 from the University of Craiova, 150 from the Politehnica University of Timisoara and 320 from the Aalborg University. The difference in the number of participants among the universities is deemed not to have any influence on the comparative study since for a number of participants equal to or greater than 40 the numerical outcomes of the survey tend to stabilize within a variability range that does not exceed few tenths of percent.

Between 50% (Alborg) and 90% (Bucharest and Craiova) of the participants were bachelor students; while the remaining student were attending a master course. A large part of the students was attending scientific courses, except in Aalborg and Rome Tor Vergata universities where the students had a more heterogeneous background. It is important to stress that the questionnaire was intended to test general aspects (see Appendix A) not strictly related to the subjects dealt with by any specific course.

Table 1. Mean values of the indicators produced by the questionnaire reported in Appendix A (the scale ranges between 1 and 10). In brackets the corresponding standard deviation.

Indicator/University	Rome	Bucharest	Craiova	Aalborg	Turin	Timisoara
Infrastructures	5,86 (0,23)	6,37 (0,27)	5,98 (0,34)	7,12 (0,13)	5,64 (0,27)	7,14 (0,17)
Food services	5,94 (0,22)	7,47 (0,29)	4,91 (0,42)	7,07 (0,12)	6,22 (0,29)	5,67 (0,21)
Environment	6,35 (0,25)	7,30 (0,29)	5,20 (0,39)	6,50 (0,13)	6,53 (0,29)	6,36 (0,19)
Info/admin services	5,91 (0,20)	6,75 (0,30)	7,08 (0,30)	6,93 (0,12)	5,82 (031)	7,00 (0,18)
Mobility	6,40 (0,24)	7,61 (0,27)	7,67 (0,31)	7,39 (0,12)	6,82 (0,24)	7,82 (0,17)
Safety	6,24 (0,26)	7,35 (0,26)	7,62 (0,33)	8,92 (0,09)	7,47 (0,25)	7,68 (0,16)
Support to social interactions	5,28 (0,22)	7,14 (0,28)	7,30 (0,33)	6,83 (0,12)	6,04 (0,29)	6,98 (0,18)
Satisfaction	6,85 (0,20)	6,65 (0,26)	7,18 (0,26)	7,35 (0,10)	6,7 (0,25)	6,88 (0,17)
Challenge	5,38 (0,22)	7,06 (0,26)	7,36 (0,34)	7,49 80,11)	6,06 (0,28)	6,93 (0,18)
Self-fulfillment	6,98 (0,21)	6,72 (0,27)	7,01 (0,30)	7,55 (0,09)	7,02 (0,25)	6,87 (0,17)

3 Data analysis and emergence of the “smartness"

Table 1 shows the mean values of the 10 numerical indicators produced by the questionnaire (see Appendix A) that represent the outcomes of the mapping procedure described in [16,17]. As usual for this kind of investigations possible correlations among the indicators were expected and we planned to investigate them once a reasonable sets of data were collected from few universities, six in this case study.

Fig. 1a shows a snapshot of the cross-correlations among indicators. Some of them - *Safety* and *Mobility* - show important correlation with quite a large number of other indicators and, thus, were removed to obtain a first reduction of the space of representation, without risking the loos of relevant amount of information. After their removal we are left with couple of indicators strongly correlated ($R > 0,7$): *Challenges* and *Social Interaction, Satisfaction* and *Self-fulfillment, Environment* and *Food*. Since it is almost impossible to select a subspace of fully independent indicators, we applied a Principal Component Analysis (PCA) [18,19] to identify the

additional indicators that could be dropped. It turned out that the higher loading on the first two principal components, Y1 and Y2, can be obtained by dropping *Social Interaction, Self-fulfillment* and *Food*.

Fig. 1. (a) Snapshot on the correlations among the full set of indicators; (b) Residual correlations among the subset of 5 indicators.

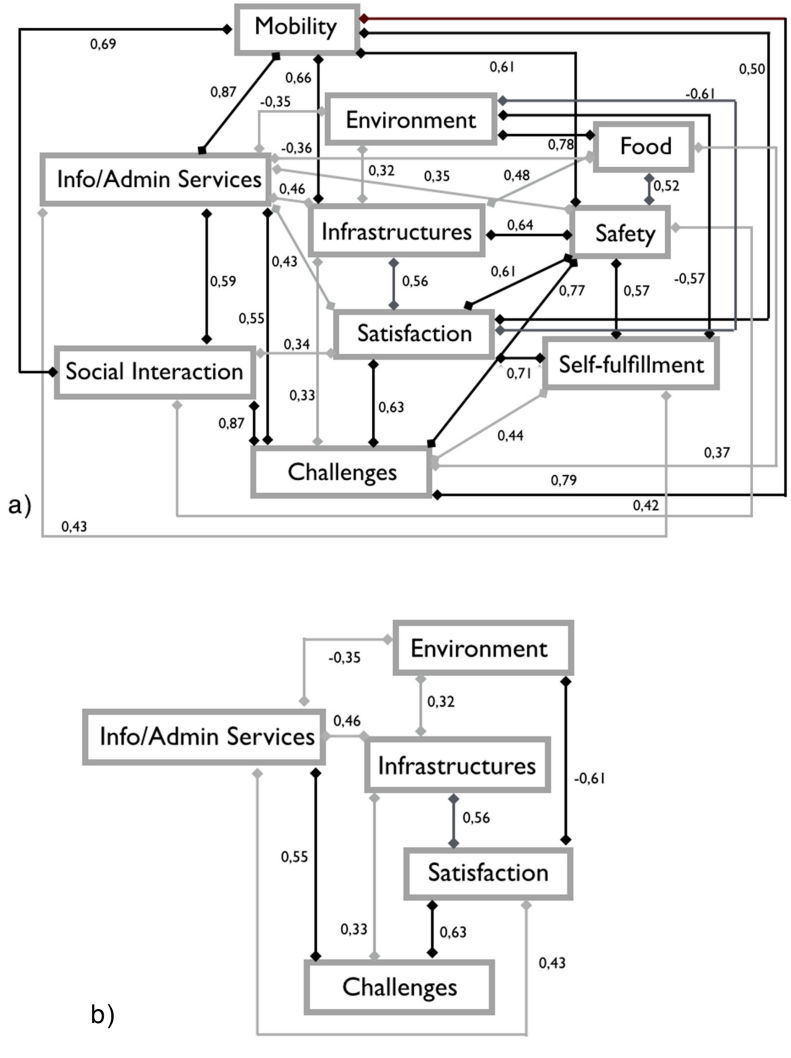
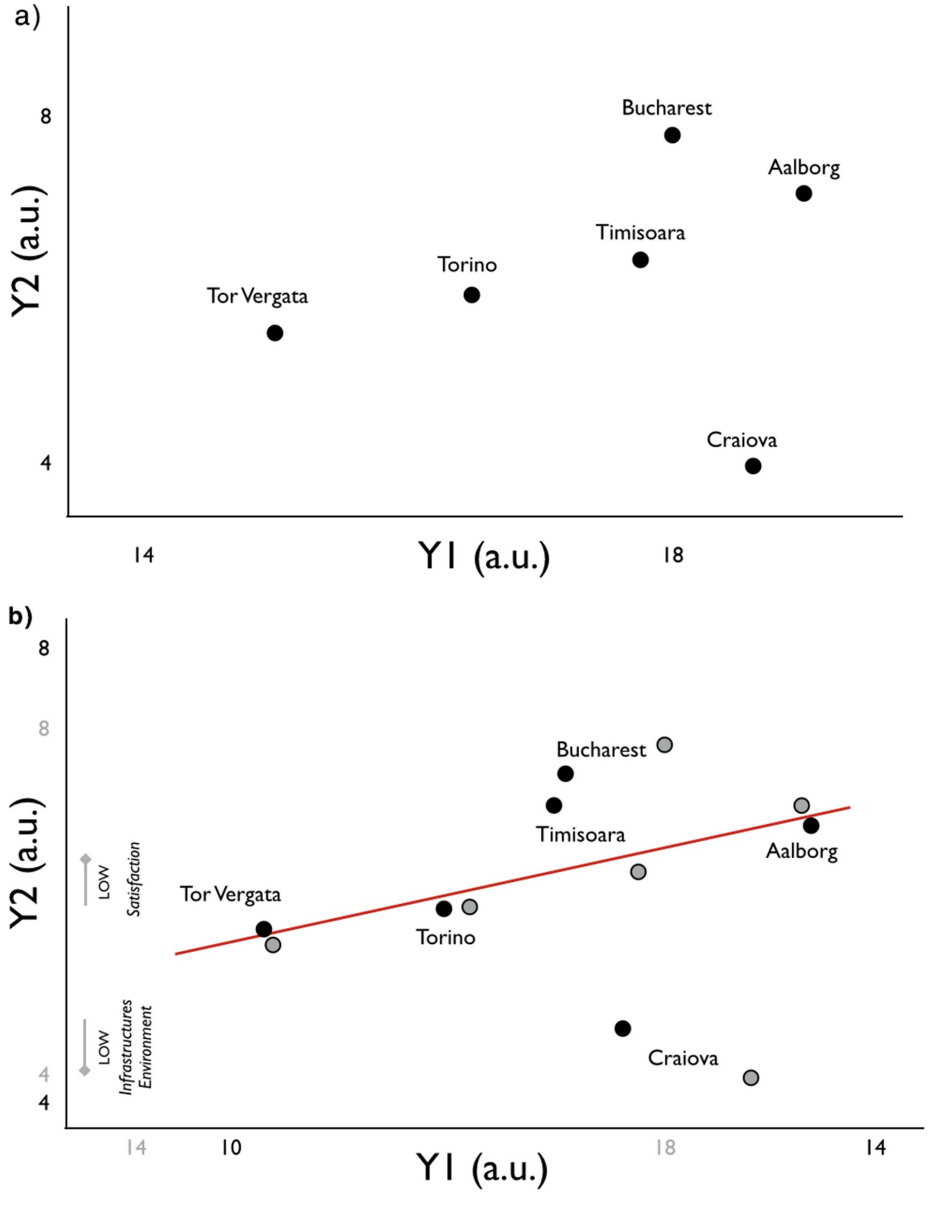


Fig. 2. Positioning of the universities on the plane identified by the two principal components, Y1 and Y2, derived from a PCA applied to the following two cases: (a) full set of 10 indicators reported in Fig. 1a; (b) reduced set of 8 indicators shown in Fig. 1b. The grey circles in Fig. 2b show the relative positions that universities have in fig. 2a, although the Y1 scale of fig 2a is more expanded (see grey figures on the axis) than that of fig 2b. The red line, as explained in the text, represent the axis of "smartness"



The final 5-dimensional reduced space of representation is shown in Fig. 1b. The first two principal components derived by applying the PCA to this subspace of representation carry around 84,5% of the initial information and have been used as basis to generate Fig. 2b.

Figs. 2a and 2b show the comparison between the case where we considered the principal components of an orthogonal space derived from all the initial 10 indicators/ dimensions, and the case in which we considered the principal components of a reduced orthogonal subspace obtained considering only the 5 indicators reported in Fig. 1b. Overall, the two representations are very similar, and indeed no very relevant variations in the relative positioning of the universities are produced. We observe only a compression of the Y1 scale.

The main research question that arises at this point is: *How can these indicators be combined to determine the "smartness" of a learning ecosystem ?*

To answer this question it is necessary to analyze the contribution of each of the five parameters to the two principal components, Y1 and Y2, of Fig. 2b. We remind, in fact, that Y1 and Y2 are linear combinations of the original dimensions.

The indicators *Info-Admin Services*, *Challenge* and *Satisfaction* are strong contributors to higher Y1 values like, although to a less extent, the indicator *Infrastructure*. In other words Y1 put together *basic physical* indicators like *Infrastructure and Info-Admin Services* with the those related to the highest human needs (see Maslow's Pyramid). The indicator *Infrastructure,* however, contributes also to increase the positive value of Y2 together with the indicator *Environment,* while *Satisfaction* provides a negative contributions to the second principal component.

Therefore the universities that performs at best on all indicators tend to place at the top right of the plane of representation. Accordingly we can draw the linear regression (in red) from Fig. 2b, which represents the *axis of smartness* that increases with both Y1 and Y2. The distance of the universities from the red line, (see Fig. 2b) is mainly determined by a substantial deviation of one or more of the indicators with respect to the average values of all other indicators: for example, in the perception of the students, University of Craiova underperforms in *Infrastructures* and *Environment* while University Politehnica of Bucharest slightly underperform in *Satisfaction*.

It is worthwhile to stress that the landscape derived from our analysis may not fully coincide with the outcomes of top-down approaches to the university benchmarking. In our bottom-up approach in fact, the "quality" of the scientific and technological research is not directly evaluated. It is not an explicit dimension of the model and, moreover, we cannot expect bachelor students to judge it.

Nevertheless the quality of the research should reverberate itself on the impression that a students may have about the capability of the learning ecosystem to develop their potentiality and to challenge their competences. In fact, if the research by itself or the transfer of its outcomes to the productive system are not able to generate challenges for students they will not contribute to increase the value assigned by the student to the *Challenge* indicator.
It is not a goal of this work to compare the outcomes of bottom-up and top-down benchmarking approaches, however we may state that whenever discrepancies among top-down and bottom-up approaches are detected it may be necessary to put in place adequate countermeasures as *research* would risks to be perceived as a "private hinting reserve", difficult to access, unable to stimulate the propensity toward innovation that a large majority of students may have, with the overall result to decrease the potentialities of the whole system. The same applies when the productive system under-utilizes the skills acquired by graduated students during their studies. This would result in the decrease of the level of the self-development achieved and perceived by the individuals that, because of this, will possibly never achieve a state of flow. Generalizing, we can state that there could be a potential problem to be mitigated when the indicators used to benchmark top-down the processes and/or their products do not coincide with the *customers*' perception (in our case study the students).

4 Future Developments

Apart from the goals to extend the number of universities involved in our trials and to disseminate the culture of the bottom-up benchmarking approach, an additional future objective is the extension of our method to the exploration of the mediation role of technologies in supporting the development of an increasing level of smartness of the ecosystems. Another objective consists in the involvements of additional categories of stakeholders operating in the learning ecosystem.
Moreover, since the questionnaire has been designed to be easily adapted to measure the smartness of any learning ecosystem, whether physical or virtual, an additional goal would be to measure schools' smartness. Preliminary experiments in this direction have already started with a quite relevant number of schools, 15, in the Rome area.
The current work describes only a comparative analysis of the data collected by six universities. A detailed analysis of the answers provided to the open questions and of the results obtained for each university is underway and will be published in forthcoming papers.

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Appendix A

Questionnaire
(questions on personal information - e.g. sex, age, etc. - have not been included)

1) *Basic needs:* on a scale 1-10, if you live in student or rented house, please indicate how satisfied you are about your living arrangement.

2) *Basic needs:* with respect to the previous question, please comment also on the problems you may have encountered (open answer)

3) *Basic needs:* How do you usually move ?
Car
Moto
Public transportation
University shuttles
Bicycle
On foot
Other solution (please specify)

4) *Basic needs:* with respect to the previous question, could you please explain the reason of your choice ?

5) *Basic needs:* on a scale 1-10, please indicate how easy is to move within your campus/ university area and within the University buildings.

6) *Basic needs:* with respect to the previous question, please comment on any mobility or orientation problems you may have experienced (open answer)

7) Basic needs: when you have to stay a full day long at your University where do you take your lunch ?
At home
At the University/Campus canteen
In a bar/pub/restaurant
I bring my lunch-box
Other solution (please specify)

8) *Basic needs*: with respect to the previous question, could you please explain the reason of your choice? (open answer)

9) *Basic needs:* On a scale 1-10, please indicate the level of appropriateness of the basic facilities, like bar, canteens, restaurants and access to drinking water.

10) *Basic needs:* with respect to the previous question, please comment also on the problems you may have encountered (open answer).

11) *Environment:* on a scale 1-10, please indicate your perception on the “green level” of the Campus (availability and care of green areas, air quality, separate waste collection, etc..)

12) *Environment:* with respect to the previous question, is there any specific problem you wish to point out? (open answer)

13) *Safety:* on a scale 1-10, please indicate how safe you feel on campus (not only on a physical level).

14) *Safety:* with respect to the previous question, is there any problem you wish to point out? (open answer)

15) *Infrastructures:* on a scale 1-10, please indicate how University infrastructures (classrooms, libraries, laboratories, student areas, WI-FI) are adequate for the activities you are carrying out on campus?

16) *Infrastructures:* with respect to the previous question, are there any problems to point out or infrastructure improvements to suggest? (open answer)

17) *Infrastructures:* which infrastructures or services may improve your experience in the campus/university and make it more adequate to your needs ?

18) *Internet:* Which device do you use to connect to the Internet from within the Campus/ University ?
Smart Phone
Tablet
Laptop
Desk computer
Other solution (please specify)

19) *Internet:* How do you connect to the Internet ?
Campus/University WI-FI
Private provider
Other solution (please specify)

20) *Internet:* How long are you connected to the Internet on Campus/at the University ?
I do not connect
Less than half an hour
More than half an hour less than two hours
More than two hours less than five hours
I am always on

21) *Internet:* as far as Internet connection do you have any problems to point out or suggestions? (open answer)

22) *Administrative and information services:* on a scale 1-10, please indicate how, in your opinion, does your University provide easy access to information (considering also the support given by the website).

23) *Administrative and information services:* on a scale 1-10, please indicate how, in your opinion, does your University facilitate the accomplishment of administrative procedures (considering also the support given by the website).

24) *Administrative and information services:* with respect to the previous question, do you have any problems to point out or service improvements to suggest? (open answer)

25) *Social interaction:* on a scale 1-10, please indicate how in your opinion, does your University support social interaction (student/worker organizations, web environment, cultural and sports activities, interaction with the surrounding territory, etc.)

26) *Social interaction:* with respect to the previous question, do you have any problems to point out or improvements to suggest? (open answer)

27) *Challenges and opportunities:* on a scale 1-10, please indicate how much do you feel that the University is able to challenge you and/or offer appealing opportunities (exchanges and scholarships, participation in projects with concrete impact, internships, etc..).

28) *Challenges and opportunities:* with respect to the previous question, do you have any suggestions on possible initiatives? (open answer)

29) *Satisfaction:* on a scale 1-10, please indicate how satisfied you are with the quality of the curricula you have undertaken (if student) or the work you are carrying out (if member of the faculty).

30) *Satisfaction:* how can your satisfaction be improved? (open answer)

31) *Self-actualization:* on a scale 1-10, please indicate how, in your opinion, skills and competences you are currently developing may meet those requested by the working domain in which you operate or wish to operate in the future

32) *Self-actualization:* on a scale 1-10, please indicate to which extend your University has been/is able to develop your potentialities.

33) *Self-actualization:* how can your self-actualization could be improved? (open answer)