

Knowledge Integration for Interdisciplinary Research and the Study of Methods



José María Díaz-Nafría¹, Enrique Díez-Gutiérrez², Wolfgang Hofkirchner³, Rainer E. Zimmermann⁴
Simone Belli⁵, Gustavo Martínez-Mekler⁶, Markus Müller⁷, Luis Tobar⁸, Fernando Martín-Mayoral⁹
Modestos Stavrakis¹⁰, Teresa Guarda¹¹, Edgardo Ugalde¹²

¹ Madrid Open University, Madrid, Spain

{josemaria.diaz.n@udima.es}

² Universidad de León, León, Spain

³ Institute for a Global Sustainable Information Society, Vienna, Austria

⁴ Institute for Design Science, Munich, Germany

⁵ Universidad Complutense de Madrid, Madrid, Spain

⁶ Universidad Autónoma de México, Cuernavaca, México

⁷ Universidad Autónoma del Estado de Morelos, Cuernavaca, México

⁸ Universidad Politécnica Salesiana, Cuenca, Ecuador

⁹ Facultad Latino Americana de Ciencias Sociales, Quito, Ecuador

¹⁰ University of the Aegean, Syros, Greece

¹¹ Universidad Estatal Península de Santa Elena, La Libertad, Ecuador

¹² Universidad Autónoma de San Luis Potosí, San Luis Potosí, México

ABSTRACT: *We in this work, intend to start an exercise for promoting interdisciplinary research capabilities and skills to develop the skill to meet challenges where the complexity is moving towards the domains. We have carried out exercises on education, research and innovation activities based on theoretical and methodological tools for the integration of knowledge. We have explained in the part the aim of the work in detail, and the next part describes the objectives and approach as regards theoretical and methodological underpinnings, as well as its technical and social dimensions.*

Keywords: Interdisciplinarity, Transdisciplinarity, Knowledge Integration, Open Science, Open Education, Open Data Labs, Systems Science, Information Studies, Social Innovation

Received: 19 April 2020, Revised 20 May 2020, Accepted 2 June 2020

DOI: 10.6025/jitr/2020/11/4/133-144

Copyright: with Authors

1. The Need for Integrative Research

“Modern science is characterized by its ever increasing specialization, necessitated by the enormous amount of data, the complexity of techniques and theoretical structures within every field. Thus science is split into innumerable disciplines

continually generating new subdisciplines. In consequence, the physicist, the biologist, the psychologist and the social scientist are, so to speak, encapsulated in their private universes, and it is difficult to get word from one cocoon to the other...” [1].

These words of the prominent Austrian scientist, who pioneered system science, provides a good outlook of the problem that PRIMER initiative aims to address. The fact that scientists move with difficulty across the borders of disciplines hinders the tackling of problems of high social concern which need a broader perspective, as well as the learning across disciplines. European and international institutions, being aware of this problem, target since long the promotion of interdisciplinarity (ID) and integrative approaches in research and education as a fundamental means to promote new knowledge, facing major societal and environmental challenges, enabling innovation, transferring knowledge and attaining broad societal alliances [9–12]. Hence, ID is included in most of the national and international agendas concerning education and research. Relying on these policies, a number of successful educational and research programs have been established. They have indeed shown to yield broad cooperation, to attract significant investments and to solve intriguing problems of technical, societal and environmental nature, as referred to in numerous studies.

Nevertheless, there are notorious impediments, as it has been recurrently assessed [2–6, 13, 15–18], for a more systematic establishment of ID through education and research policies and within the institutions. Among these barriers is worth mentioning the lack of common criteria and methodology, strategic vision in the creation of new studies, proper recognition, and cooperative paths to converge into knowledge alliances. As a result, a number of ID programs instead of granting a better integration of sciences have often yielded in the long run to the explosion of new disciplines that close their borders after being established. PRIMER initiative, supported by a consortium of European and Latin American academic and scientific institutions, aims at avoiding these pitfalls in the proper and necessary integration of knowledge through the combination of Systems Science; Science of Information and Social Innovation [20].

2. PRIMER Initiative. Objectives and Approach

PRIMER initiative’s global objective is to strengthen the capacities of interdisciplinary research while these are oriented to the confrontation of specific social and scientific challenges involving the affected social groups. To this purpose, it aims at the development of interdisciplinary studies at the crossroad of education and research, based on the integration of three approaches: systems science, social innovation, and information science, as represented in Fig. 1, branded as ISI approach:

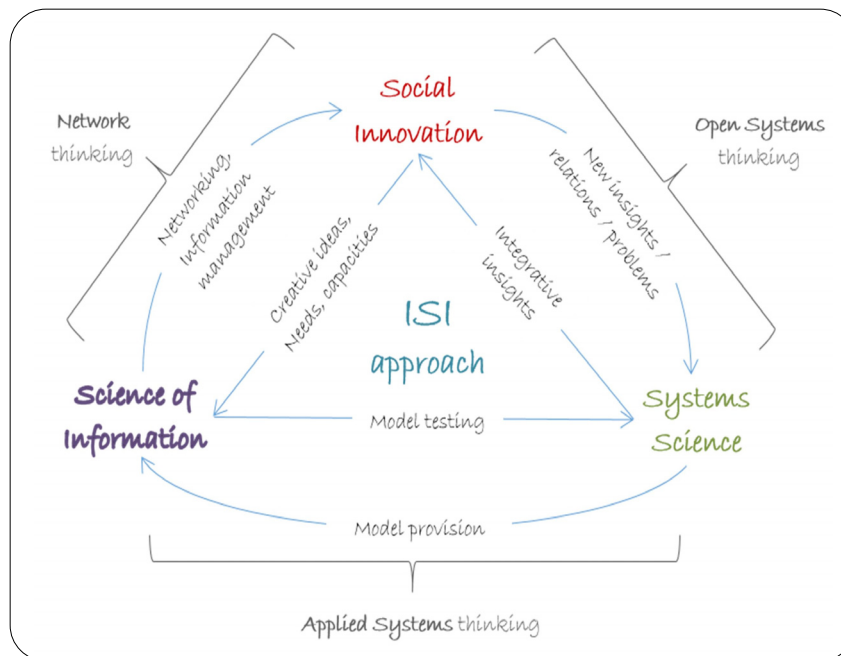


Figure 1. PRIMER ISI approach concept (methodological linkage among main perspectives)

1. *Systems Science* (SS), understood in a broad sense which includes, among others, complexity science, cybernetics, and design science. It faces reality in its relational, functional and evolutionary aspects.
2. *Social Innovation* (SI) which focuses its methodology on an open and creative incorporation of knowledge and agents to the solution of problems and social needs.
3. *Information Studies* (IS), understood in a strong interdisciplinary sense, as the study of information in all its manifestations, be it of physical, biological, cognitive, social or technical nature, and focus in the analysis, manipulation, and management of informational phenomena. We consider within this axis: general and specific information theories, network theory, organization and management of information and knowledge, information systems design, and data science.

Figure 1. illustrates the functional link between the 3 pillars of the ISI approach. It shows the functional relations between the 3 axes, whose binary combinations can be expressed in terms of three thinking modes: *open systems* (SS+SI), *Network thinking* (IS+SI) and *applied systems thinking* (SS+IS). From the interplay between the axis stem three methodological components:

1. *Formal System* as a means to express the problems dealt within SI into systemic approaches,
2. *Model and Simulation* as a means to articulate the cooperation between the systemic and information approaches,
3. *Digital and cooperative methods and skills* as means to articulate the cooperation of distributed agents involved in social innovation into an effective cooperation.

2.1 Practical Dimension: Open Labs

Besides the core theoretical framework referred to above, another fundamental aspect of the PRIMER methodological approach is the link to both, *research and innovation*, understanding that challenging open problems requires a participatory and direct contact with research. This turns the learning subjects in knowledge actors facing the process of both, acquisition and creation of knowledge in a holistic, participatory, critical, and responsible way (to the extent that the addressed research projects highlight the social relevance as well as the engagement with the community).

The specific deployment of this practical side is structured through research and innovation LABS devoted to specific issues of social relevance and complex nature. The labs are conceived as hubs where a number of focused interdisciplinary projects are being developed using the ISI approach. As an example, the biciLAB, supported by several partners, carries out integrative projects oriented to the development of sustainable mobility and urban life quality using the information collected from bike-sharing systems [7].

In order to promote creativity, there is a commitment to use art, usually through collective creations which are shown in public in connection to open debates. This element is indeed motivated from the three angles of the ISI approach: for the *systems science*, in terms of the systematic aspects of art in the relationship between the parts and the whole as well as in terms of creation of the 'artificial' (historically also through the relevance of aesthetic reflection in the systemic philosophy and the contemporaneous linkage to some artistic movements such as conceptual art). For the open *social innovation*, through its fostering of creativity and experimentation in expressive techniques. For *Science of Information* the aesthetic moment is understood as the process of generating and reproducing beautiful forms.

2.2 Technical Dimension

A third fundamental aspect is the use of **information technology** (IT) in its capacity to structure new processes of learning, innovation, design, and analysis of reality. This relevance is present not only in the science of information but also in the other axis of the ISI approach: from the systemic point of view, information is an essential component of system dynamics and its adaptation to the environment, thus IT represents a fundamental modification of social systems dynamics. For open innovation, IT offers innovative possibilities to bring about the meeting of social needs and techno social capabilities, which in turn provide solutions to the faced problems.

In this terrain, the use of **interdisciplinary glossaries** is remarkable [4,6]. They are intended to ease the disciplinary understanding as well as the conceptual building stemmed from the intersection of different disciplines. Interdisciplinary glossaries are built up collectively and are articulated in a system of electronic publications embracing from contributions

carried out in learning processes to the elaboration of scientific or technical publications of impact. They offer in addition the possibility to use it as a proxy of the knowledge integration achieved for its assessment in terms of 2 dimensions: (i) the diversity of the integrated discipline, in terms of a normalized Shannon Diversity Index; (ii) the effective integration of the knowledge in terms of the connectedness of the semantic and agent networks [4–6].

To facilitate the effective convergence of tools that makes the development of hybrid ecologies of learning and interdisciplinary research easier, PRIMER pays special attention to the development of an **e-infrastructure** that integrates components of **e-education**, **e-science** and **e-participation** with extra attention to multilingualism and inclusion. This is intended to jump over the characteristic spatial and temporal limitations of education and practice in face to face environments, thus enabling fertile knowledge alliances.

2.3 Education Programs Tested and Planned

With this basic orientation, PRIMER initiative has promoted and carried out since 2012 diverse education and research programs of different lengths and systematicity. From a set of courses aimed at testing the approach, to training programs and postgraduate programs. The results presented hereby correspond to the test period of a year, constituted by training and summer courses, while the design of postgraduate programs is presented at the end as one of the outcomes of the testing phase.

3. Results of the Testing Period

Following PRIMER objectives, a number of activities, scientific gatherings, and courses were organized during a testing period of one year (from May 2013 to February 2014) as shown in Table 1. Within this framework, the participant institutions have carried out research and have awarded academic credits through official and Open Badge accreditation. These activities, described in detail in a summary report [19] and still available in PRIMER portal [20], have enabled the polishing of PRIMER approach, the deployment of resources useful for subsequent development. Besides, they have served to the initiation of research projects, as glossaLAB, which is currently alive [5], and educational experiences for the nurturing of interdisciplinary studies.

3.1 Impact Analysis for One Year Testing Period

As we can see in Table 1, the activities organized within PRIMER initiative in the example period gathered the participation of 26 researchers from various origins and disciplines and the face to face attendance of 350 participants. However, the hybrid design of these activities shows a significantly larger impact. Figure 2. displays the number of visits per day registered in the primer platform since it is operative (September 2013). If we add the visits to the pages within the portal of the workshop on Open System Thinking, it amounts to 2038 visits. Assuming a similar ratio between visits and unique visitors, Figure 2. corresponds to some 800 different visitors.

Nevertheless, portal visits only represent a part of the online impact since other contents were shared through other means. The 80 videos compiled within PRIMER framework amounted to 1682 views, while the 14 presentations, shared online through www.slideshare.net, accumulated 5470 visits. Table 2 summarizes the most relevant impact figures. These values, together with qualitative results from an individual assessment of participants, highlight the interest arisen from the initiative

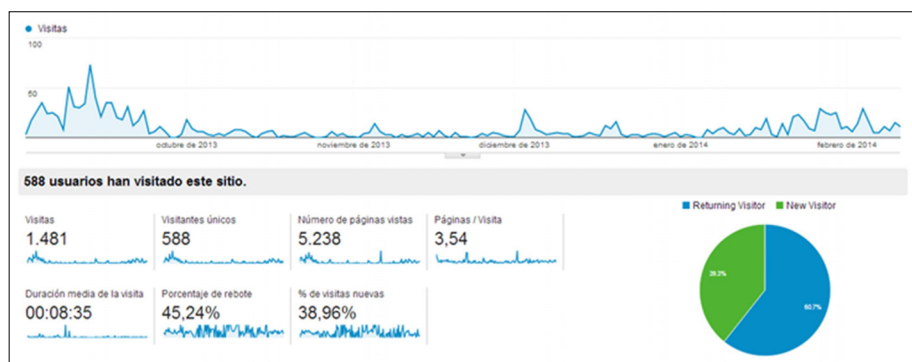


Figure 2. Web-analytics of visits to primer.unileon.es between Sep.2013 and Feb.2014

Activity Type	Name	Dates	Scholars/ attendees	Hybrid-Learning	Open Badge Certif	ECTS	Publications in National & local media	Publications in Associated media
Advanced Training course for scholars	The University in the face of a complex world	15/5	5/18 ¹	Yes	No	0.5	1	4
Workshop and Extension Course	Open system thinking. At the Crossroads of a complex world	15-31/5	14/75	Yes	Yes	1	4	8
Webinar	Saliendo del circulo vicioso del ser autonomo	30/5	4/ND	Online	Yes	-	1	3
Seminar	General understanding of information	Spring and autmn	2/20	Yes	Yes	2	0	3
Seminar	Utopias and the information society	Spring and autmn	2/24	Yes	Yes	2	0	3
Workshop and summer course	Social Networks: from communicating to solidary networks	13-15/9	15/76	Yes	Yes	2.2	8	6
Sound-painting workshop	Painting solidarity with music and lyric	13-14/9	2/10 ²	Yes	Yes	-	2	5
Webinar	Social dynamics in the information society (part 1)	31/10	2/53 ³	Online	Yes	-	0	4
Webinar	En la sociedad de la information, todos contamos portigual?	5/12	4/64	Online	Yes	-	0	4
Workshop and course in English	Understanding complexity: systems, emergence and evolution the City	27-30/01/2014	9/20	Yes	Yes	1.5	6	8
Webinar	Social dynamics in the information society (part 1)	28/01/2014	3/24	Yes	Yes	-	0	2
Total	11 events	Apr-Jan	26/350	Yes	Yes	9.2	20	50

Table 1. Summary of PRIMER activities in the testing period

¹ No. of teaching scholar vs attending scholars.

² To the performance in Teatro Albeitar attended some 60 spectators

³ In Webinars, it is considered as attendees either if followed while broadcasted or afterwards.

as to foster a kind of capacities and skills that are absent in the academic offer. These results strengthened the motivation to develop a more systematic program based on the PRIMER approach.

Gathered Scientists	26
Face-to-Face Attendees	350
Visits to PRIMER site (and OST Workshop portal)	2038
Unique visitors to PRIMER pages (estimation)	800
Videos views (to 80 compiled videos)	1682
Visits to the 14 presentations shared in www.slideshare.net	5470
Sources: ULE registration files, Google-, Youtube- and Slideshare- analytic	

Table 2. Relevant figures concerning impact assessment

4. Design of a Postgraduate Program

Based on the aforementioned PRIMER approach (sec.2) and the results observed in the testing period (sec.3), an educational program of flexible learning pathways, linked to open science research, was devised by an international consortium of European and Latin American academic and scientific institutions, which is currently candidate to an international funding program. This program (of international postgraduate and research training) was discussed with Ecuadorian authorities in the field of education, which endorsed the program, and was awarded with a prize on educational innovation. Figure 3. shows the open data labs previewed for the deployment of the program in four Ecuadorian and three Mexican universities in collaboration with European academic and scientific institutions: biciLAB (sustainable mobility, s. [7]), coopLAB (sustainable management of fishing resources and cooperatives, s. [8, 14]) glossaLAB and cogLAB (knowledge integration and cognition), inclAB (inclusiveness and interculturality) and complexityLAB (modelling and simulation of complex problems).

4.1 PRIMER Postgraduate Program

The educational program devised is based on seven core courses linked to research carried out in the open data labs. For the deploying phase, these courses are planned to be held in a rotational basis in International Summer Academies taking place in 6 venues (4 in Ecuador, 2 in Mexico, 1 in Spain). In the long term, an international center supported by the consortium shall coordinate the international program in compliance with the legal frameworks of each country.



Figure 3. PRIMER education program linked to open data labs

It will also provide coherence and cooperation among the open data labs and the associated institutions, communities and social groups involved in the research frameworks. The summer academies, conceived as blended extended program onstitute the most important activity of the project since most scheduled activities converge into their effective development. Nevertheless, there are other relevant activities contributing to PRIMER’s education and research program, as training workshops, open online courses etc., planned to deploy the program based on the set of seven core courses. The program as a whole is conceived to provide flexible learning pathways of different sizes within the ISI approach to integrative science.

According to the knowledge triangle shown in Fig. 1 and the ‘PRIMER’ approach of progressively building upon robust underpinnings, the program is based on: (1st) providing **foundations** of *Systems, Information and Innovation*, (2nd) the development of **core capacities** provided by: *System Science, Information Studies and Social Innovation*, and (3rd) offering **methodological abilities**, aimed at stretching out the core ones: *modeling and Simulation, Digital and Collaborative Skills and Formal Systems and Tools*.

The previewed learning pathways are equivalent to a student effort below and above what is estimated for a core course (10 ECTS). This flexibility is underpinned, on the one hand, by the modular design within courses and among the 7 courses of the program (Table 3); on the other, by the open-badge certification standard in combination with regular accreditation procedures of the organizing universities and the EQF. This enables flexible accreditation to recognize properly the learning paths effectively carried out by the learners. In addition, specific research topics (linked to the aforementioned open data labs) will be programmed for each course and summer edition, adapted to the interests, capabilities, strengths and contextual problems that each institution wishes to address. The completion of any program course requires the development of research tasks coached by the teaching and research staff according to and adapted to the corresponding learning objectives.

Course	Effort in hours:	On-site	On-line	Personal Work	Total (h)	Total (ECTS)
C1	Foundations of systems, information and Innovation (GF)	28	47	175	250	10
C2	Systems Science and Complexity Science (SS)	28	47	175	250	10
C3	Social and Open Innovation (SI)	28	47	175	250	10
C4	Information Studies (IS)	28	47	175	250	10
C5	Formal Systems and Tools (FS)	28	47	175	250	10
C6	Modelling and Simulation (MS)	28	47	175	250	10
C7	Digital and collaborative skills (DC)	28	47	175	250	10
	Master Thesis (MT)	6	14	480	500	20
	Total:	202	343	1707	2250	90

Table 3. Courses of the educational program on integrative science

Figure 4. shows the systematic relation among the core courses of the program, whose equivalent efforts and ECTS are given in Table 3. As it is shown in the latter, the sizes are conceived to offer a master accreditation according to European standards. The seven core courses to be carried out in the ISAs are represented within the green dotted hexagon of Fig.4, while the master thesis, which has to show effective integration of different scientific disciplines, is represented by the bounded hexagons at the outer hexagon belt.

Example of PRIMER course: General Foundations. This course offers general orientation for the education program as a whole, summarizing the repertoire of theories, methodologies, and strategies that are covered in detail in the other courses of the program (Table 3).

This course, whose structure is alike the other courses, will be held once at each program venue and also offered as training course for scholars and open online course in order to maximize the possibilities of learners and researchers’ engagement and to facilitate the self-organization of learning upon the open resources and infrastructures to be developed. In virtue of its relation with all the matters of the program this course paves the way for general orientation regarding methodologies and theories to be applied while facing the interdisciplinary development of research projects and frameworks. Nevertheless, this course will be particularly devoted in each edition to the research framework, for which local partners are responsible.

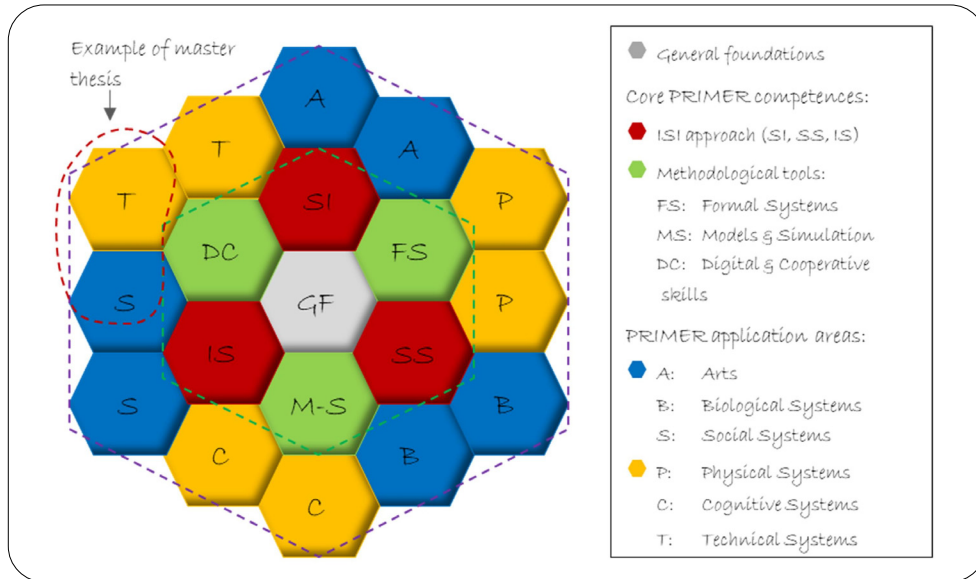


Figure 4. Digital open-badge honeycomb certification of the educational programme on integrative science

Figure 5, shows summarizes the structure of this course, whose specific design comprises summary description, target skills and learning outputs, program, literature and resources.

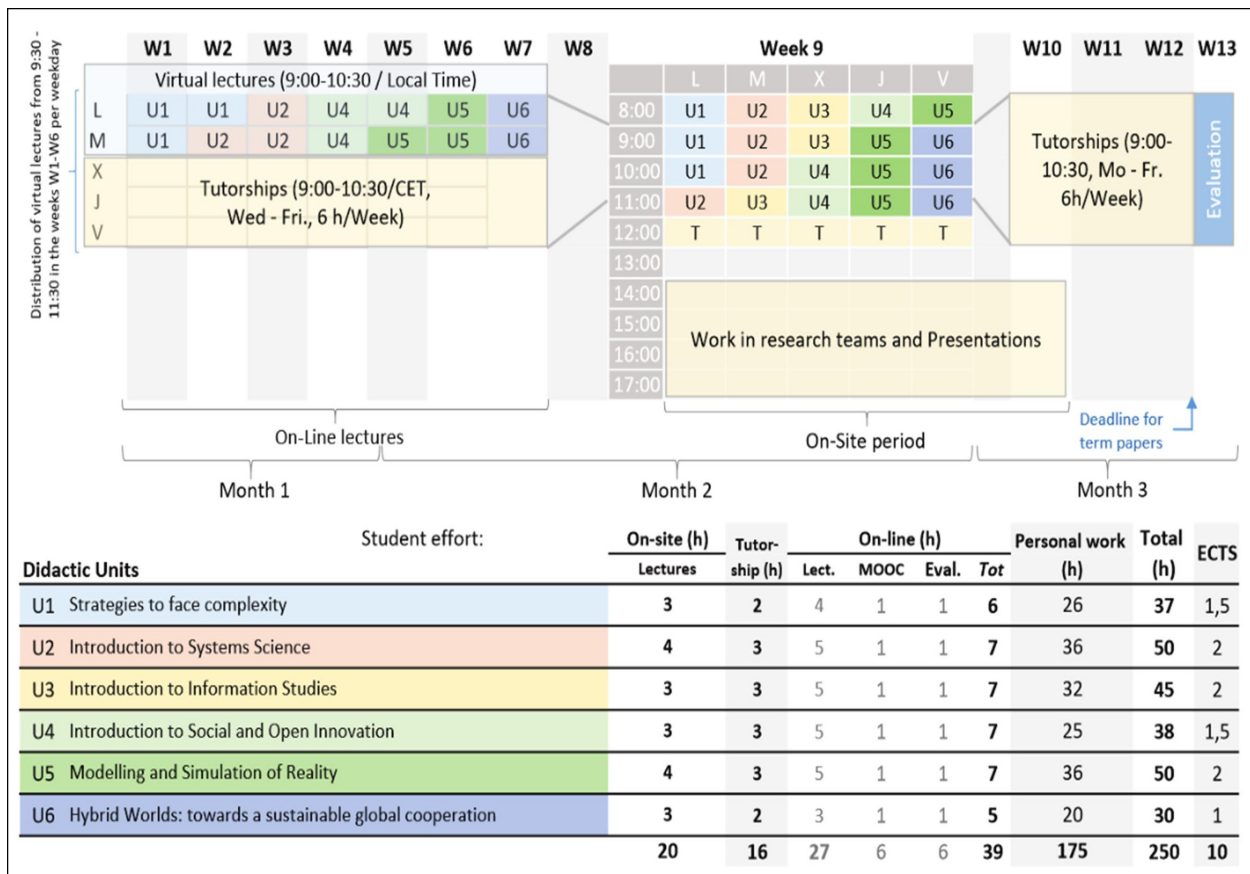


Figure 5. Timetable and modular structure of the example course on General Foundations

4.2 Embedded Research: Open Data Labs

Besides the theoretical and methodological core content of the courses, which will remain stable throughout the project, each venue will be particularly devoted to a problem-oriented research framework. These frameworks shall be supported by dedicated research and innovation labs, set up during the deployment phase aiming at gaining sustainable autonomy (s. Figure 3). Simultaneously, the summer academies will contribute not only to the research developed within the local lab, but also to the research attached to other labs in which the participants are involved. The focus of these labs will be related to problems of social relevance, sufficiently complex to require the participation of multiple and distant disciplines.

For setting up each of the Open Labs and the horizontal lines, the universities and research centers attached at each location will be responsible of and will coordinate the efforts from the non-local partners who will also contribute to support ongoing research according to their own capacities and strengths. During the preliminary stages of each summer academy, before the on-site phase, a number of projects will be selected upon participants' proposals to be carried out by operative working teams composed by not more than 10 people (among facilitators, training researchers and other learners). Program team will strive (since the preparatory stages before the start of the summer academies) to develop the selected projects in an integrative manner and to facilitate an active and effective development during the on-site period which should catalyze team throughput. E-Collaboration tools will facilitate the continuation of the projects during the online periods and the time between summer academies through learners and researchers willing to continue research and consolidate participation.

Support of research projects. The partners from each venue will offer a support from their own resources for the development of the research projects awarded within the context of the program belonging to the respective research labs (this will contemplate equipment, HD, SW, bibliography, and services required for the development of the research projects). The coordinator will seek to balance resource partner's provisions and needs. Nonetheless, in order to facilitate the sustainability and the strengthening of the initiated research, each project team must elaborate a formal proposal to a program of public/external funding, which together with the elaboration of a submitted research paper will constitute requirements for learning accreditation.

Research and Innovation Projects' Pool. For the development of research projects, required for the participation in any PRIMER course, the program offers in the first place research frameworks attached to each venue as explained above. These frameworks offer a set of resources and focused problems that will serve to the definition of specific projects. Participants, before the beginning of the ISAs, will make project proposals within the given research frameworks that will be selected against quality criteria, though they can also opt to propose the integration in already opened projects. All running projects will be opened by teams integrating scholars and learners and will be added to a pool of open projects. At the same time, proposed projects will integrate another pool of suggested projects. These both pools will be a constitutive part of the research offer which newcomers can use to determine their own research plans. Either the integration in an open project or the opening of new ones will be decided by a panel of experts of each research framework against quality criteria, available capacities and the opportunities to integrate results.

Venue	Research & Innovation Labs
Cuernavaca (Mexico)	Complexity-LAB: devoted to the study of different complex phenomena, as the ones arisen from other labs, based on dataintensive analysis and simulation
Quito (Ecuador)	Inc-LAB: understanding social divides and facilitating inclusiveness and intercultural cooperation
Santa Elena (Ecuador)	coop-LAB: An inclusive framework for developing sustainable management of fisher cooperatives and marine resources
Urcuquí (Ecuador)	cog-LAB: understanding and facilitating knowledge networks and knowledge integration
Cuenca (Ecuador)	cycling-LAB: A participatory and data-based framework to integrate smart-citizenship into smart and sustainable cities

Table 4. Research and innovation Open Data Labs planned

The ongoing projects will be reflected in the pool of open research projects to which newcomers can join. To that purpose, the description of the project in the pool will show the tasks and roles that still need to be covered or can be reinforced.

Research and Innovation LABs. The five specific research frameworks, hosted in Research and Innovation LABs at each Latin American venue and supported by the corresponding partners in cooperation with the rest of consortium members, are planned to be adapted to the interests, capacities, strengths, opportunities and contextual problems that each institution wish to address. The preliminary distribution R+I Labs per venue is given in Table 4. With the exception of the Complexity LAB, devoted to the modeling and simulation of complex and high computational demanding problems, arisen from any of the other labs, follow a similar pattern that can be well illustrated by the biciLAB Open Data Lab.

Example of Open Data Lab: biciLAB. The framework to be hosted in Cuenca (but also applied to the urban areas of Quito and Santa Elena) is based upon resources and activities carried out by ULE's Green Office since 2009 who offers to the university community about 150 bicycles, equipped with tracking systems, for free. This project is nowadays planned to be enlarged by the international joint project supported by several European institutions and municipalities [7].

The impersonalized data collection (currently limited to non real time position data) is then used for different purposes of scientific and social interests, as students' thesis or enhancement of municipal mobility policies (<http://ulebici.unileon.es/>). Upon this experience and resources, PRIMER team plans to improve tracking systems and to carry out additional activities in order to develop applications in the field of health, energy efficiency, inclusive urban spaces, bike- lanes and parking optimization, information resources for bikers, social and political engagement (including active participation of the affected community), sustainable management, etc. Thus involving: technical development, modeling, and simulation of urban systems and body structures, applied mathematics and operation research, management, environmental sciences, political sciences, social and community engagement, etc.

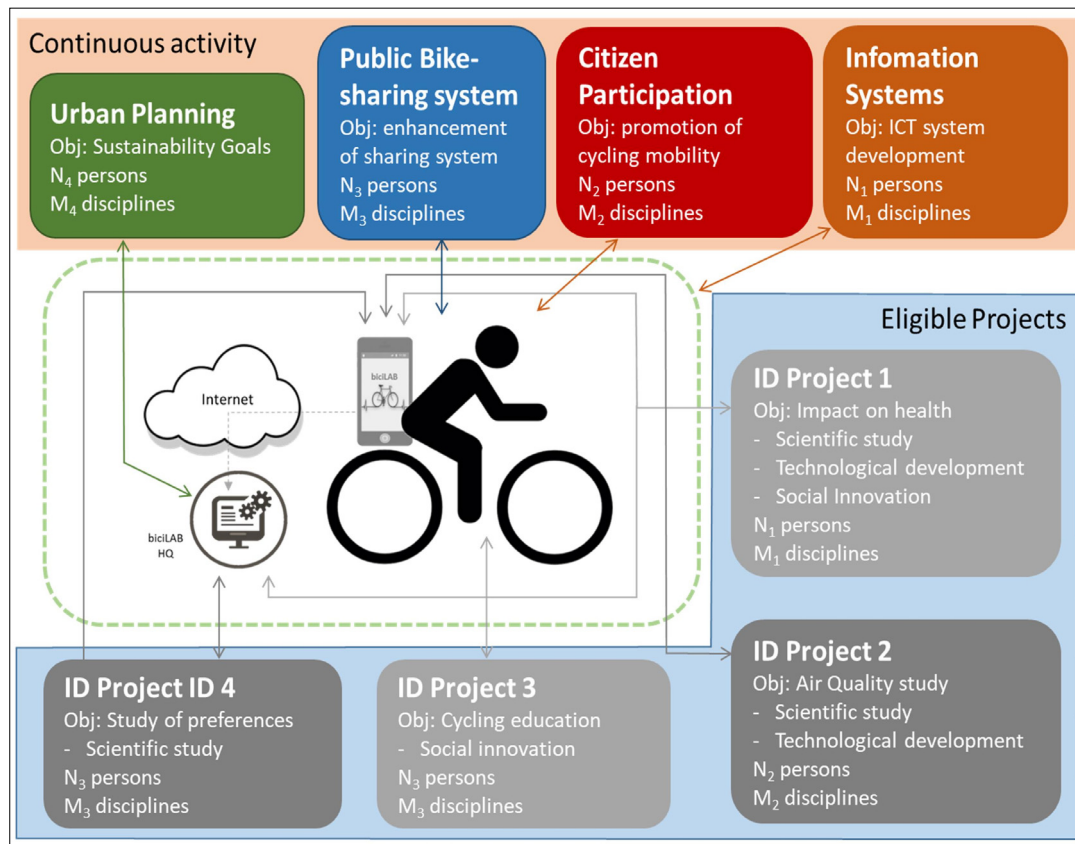


Figure 6. Basic components of the cycling-LAB within the green dotted line and schematic representation of the structural and eligible projects

Figure 6 represents the concept of the open data lab which in essence can be applied to the other labs. It is composed by a basic infrastructure within the green dotted line, *structural projects* (continuous activity) conceive to set up the research and innovation framework linked to projects of institutional interest in mid and long term basis, and *eligible projects*, which are selected by a scientific committee among proposal submitted to an open call. Both will be subject of the projects to be developed within the PRIMER education program.

5. Conclusions

As we justified at the beginning, there are sufficient reasons to urge the development of capacities and skills for interdisciplinary research. The integration of knowledge is a requisite to cope with the global challenges which our societies are now facing as it has been acknowledged by international institutions, which strive to impulse interdisciplinary at different levels. However, the organization of the academy, the dominant organization of labor and the techno economic systems do not offer an adequate scenario for the flourishing of sound interdisciplinary. As shown in sec. 2, PRIMER initiative offers an innovative approach to foster interdisciplinary research capacities and skills through the integration of trans disciplinary fields (systems science and information studies). The results obtained in a one year testing period of the PRIMER approach, referred to in section 3, show its capacity to achieve intended impacts. Both the global scarcity of integrative approaches to underpin interdisciplinary capacities and the need of these abilities to face global challenges underpin the interest and relevance of a systematic education and research postgraduate program like the one presented in section 4.

References

- [1] Bertalanffy, L. (1968). *General Systems Theory. Foundations, Development, Applications*. George Braziller, New York.
- [2] Chettiparamb, A. (2007). *Interdisciplinarity: a literature review*. The Interdisciplinary Teaching and Learning Group–University of Southampton, Southampton, UK.
- [3] DEA-FBE: *Thinking Across Disciplines - Interdisciplinarity in Research and Education*. Danish Business Research Academy (DEA) & Danish Forum for Business Education (FBE), Copenhagen (2008).
- [4] Díaz-Nafría, J. M., Burgin, M., Rodríguez-Bravo, B. (2019). *Evaluation of Knowledge Integration through Knowledge Structures and Conceptual Networks*. In G. Dodig-Crnkovic, M. Burgin (eds.), *Philosophy and Methodology of Information*, World Scientific Publishing, Singapore.
- [5] Díaz-Nafría, J. M., Guarda, T., Burgin, M., Hofkirchner, W. (2019). *glossaLAB: Co- Creating Interdisciplinary Knowledge*. *Communications in Computer and Information Science*, 1051 [in press].
- [6] Díaz-Nafría, J. M., Guarda, T., Coronel, I. (2018). *A Network Theoretical Approach to Assess Knowledge Integration in Information Studies*. *Smart Innovation, Systems and Technologies*, 94, 360-371. <https://doi.org/10.1007/978-3-319-78605-6-31>
- [7] Díaz-Nafría, J. M., Guarda, T. (2018). *Participatory Sensing in Sustainable Mobility: biciLAB as a model of knowledge integration*. *Smart Innovation, Systems and Technologies*, 94: 97-104. <https://doi.org/10.1007/978-3-319-78605-6-8>
- [8] Díaz-Nafría, J. M., Guarda, T. (2018). *Is the structure of our digital world suited for a fair intercultural life?* *Culture - Communication - Cooperation*, 22, 243-276.
- [9] European Commission: *New societal challenges for the European Union – New challenges for social sciences and humanities. Thinking across boundaries – Modernising European Research*. Publication Office of the EU, Luxembourg (2009).
- [10] European Commission: *Communication from the Commission: Horizon 2020 – The Framework Programme for Research and Innovation*. COM/2011/0808 final, European Commission, Brussels (2011).
- [11] EURAB: *Interdisciplinarity in Research. Final Report*. European Commission - European Research Advisory Board (EURAB), Brussels (2004).
- [12] EURAB: *The new Renaissance: will it happen? Innovating Europe out of the crisis. Third and Final Report of the European Research Area Board*. European Commission- European Research Area Board, Brussels (2012).
- [13] Frodeman, R., Klein, J. T., Mitcham, C. (2010). *The Oxford Handbook of Interdisciplinarity*. Oxford University Press, Oxford, UK.

- [14] Guarda, T., Díaz-Nafría, J. M., Augusto, M. F., Vitor, J. A. (2018). Territorial Intelligence in the Impulse of Economic Development Initiatives for Artisanal Fishing Cooperatives. *Smart, Innovation, Systems and Technologies*, 94, 105-115. <https://doi.org/10.1007/978-3-319-78605-6-9>
- [15] Hainaut, L. (1986). *d': Interdisciplinarity in General Education*. UNESCO, Paris.
- [16] Klein, J. T. (1990). *Interdisciplinarity: History, Theory, and Practice*. Wayne State University Press, Detroit, US.
- [17] National Academy of Sciences: Facilitating Interdisciplinary Research. National Academy of Sciences (NAS), National Academy of Engineering (NAE) and Institute of Medicine (IM), The National Academies Press, Washington (2005). <https://www.nap.edu/catalog/11153/facilitating-interdisciplinaryresearch>. Accessed 1 September 2019
- [18] OECD: Interdisciplinarity. Problems of teaching and research in universities. Organisation for Economic Cooperation and Development, Paris (1970).
- [19] PRIMER Consortium: Pre-PRIMER 2016 Report. *In: PRIMER Website [Internet]*. PRIMER Consortium, León, Spain (2016) . <http://primer.unileon.es/updates/primer2016report>. Accessed 30 September 2019
- [20] PRIMER Consortium: PRIMER: PRomoting Interdisciplinary Methodologies in Education and Research [Internet]. PRIMER Consortium, León, España (2019). <http://primer.unileon.es>. Accessed 1 September 2019