Pattern languages as a design tool to tackle "wicked problems" in sustainability science

Humanity is facing global and local sustainability challenges that call for the involvement of a wide range of expertise drawn from academia, civil society, the private sector, as well as funding and development agencies. The challenge will be to leverage this diversity to nurture decision making. To make such discussions successful we propose a pattern language approach. It can be used as a practical step-by-step process to guide interdisciplinary collaboration between researchers and to facilitate transdisciplinary interactions between the academic and nonacademic worlds. The patterns are documented and freely accessible online in the Sustainable Science Pattern *database.*

Lilian Ricaud, Maxime Thibon, Laurent Marseault, Jean-Luc Chotte

Pattern languages as a design tool to tackle "wicked problems" in sustainability science | *GAIA* 30/4 (2021): 237–242
Keywords: knowledge system, pattern languages, sustainability science, Sustainable Development Goals, value creating systems, wicked problem

International collaboration drawing on the global expertise of a wide range of actors (academia, civil society, the private sector, funding and development agencies, etc.) is often seen as a prerequisite for overcoming global and local sustainability challenges and tackling "wicked problems", defined as problems that are difficult or impossible to solve because of incomplete, contradictory and changing requirements that are often difficult to recognize (see Rittel and Webber 1973). A practical step-by-step process to steer such interdisciplinary collaboration is needed. Pattern languages could be adapted to boost both interdisciplinary cooperation between researchers and transdisciplinary interactions between the academic and nonacademic worlds, and could thus pave the way to productive and meaningful discussions.

Pattern languages and *Sustainable Development Goals*

The *2030 Agenda for Sustainable Development (2030 Agenda)* (UN 2015) provides a shared blueprint for peace and prosperity to achieve human well-being and eradicate poverty for all. This political agenda with its 17 associated *Sustainable Development Goals (SDGs)* reflects the global assessment reports (from organizations such as Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], Intergovernmental Panel on Climate Change [IPCC], and High Level Panel of Experts on Food Security and Nutrition [HLPE]). The current COVID-19 pandemic has heightened its relevance, having underlined weaknesses in the understanding of and policy response to the complex relationships between biodiversity, the anthropization of environments and human health. The global and local sustainability challenges currently faced by humanity are indeed wicked problems, sustainability science, cited as a problem-solving approach to research into such problems, is meant to address the interdependencies and complexities of sustainability challenges. Participatory approaches are often suggested as an appropriate means of addressing such challenges. However, the often diverse postures and visions of the multi-stakeholders involved could hamper the sought-after resolution of the problems.

Committed to the achievement of the *SDGs,* the French National Research Institute for Sustainable Development (IRD) takes an original approach to research, expertise, training and knowledge sharing for the benefit of countries and regions, making science and innovation key drivers in their development. In the global context of sustainability science, IRD has launched a process for its implementation in the context of North-South-South collaborations.

As part of this process, this paper explores the potential of pattern languages in addressing the unity-versus-diversity dilemma when dealing with wicked problems. To tackle this objective, a pattern language approach was implemented over a series of three interdisciplinary, multi-stakeholder collaborative workshops focused on *SDGs* interactions.

>

Dr. Jean-Luc Chotte | Institut de Recherche pour le Développement (French National Research Institute for Sustainable Development) | 44, boulevard de Dunkerque | CS 90009 | 13572 Marseille Cedex 20 | France | +33 4 99612101 | jean-luc.chotte@ird.fr

Lilian Ricaud | Collectif Animacoop | Toulouse | France | contact@lilianricaud.com

Maxime Thibon | United Nations Convention to Combat Desertification | Bonn | Germany | mthibon@unccd.int

Laurent Marseault | Outils-Réseaux | Claret | France | laurent@marseault.info

https://doi.org/10.14512/gaia.30.4.6
Received January 17, 2021; revised version accepted July 12, 2021 (double-blind peer review).

Pattern language approach in the context of sustainability science

Finidori (2014 b) identified six design challenges in systemic transformation approaches: 1. gaining insight into intricate wicked problems and the hidden phenomena of the system; 2. catalyzing and leveraging distributed agency; 3. expanding views of reality and the whole system; 4. creating conditions for coordination; 5. generating coherence from disparate efforts; and 6. fostering shared discovery and mutual recognition. In a series of papers (Finidori 2014 a, b, 2016, Finidori and Tuddenham 2017), she proposed that pattern languages could be a practical and powerful method for systemic change.

Patterns are generic solutions to frequently occurring problems. Introduced by architect Christopher Alexander (Alexander 1979), a design pattern is a formal way of documenting a solution to a design problem in a particular field of expertise. It has since been adapted for various disciplines, including computer science, social movements, education, and group facilitation (Bergin et al. 2012, Schuler 2008, Bressen et al. 2015). In computer science in particular, it sparked a revolution in thinking and led to a new way of writing computer code (Cunningham and Mehaffy 2013). According to Alexander (1979), the solution expressed in a pattern should be general enough to be applied to very different systems, but still specific enough to give constructive guidance. Because of their explicitness, the patterns allow for discussion, debate, and gradual improvement of the material. The use of pattern language for systemic change has been increasingly explored (Ricaud 2015). Finidori (2016) suggests that the concept of pattern has unfulfilled potential as a cognitive technology for meaning making, mediation, systemic configuration and exchange of knowledge, both within and across domains of human activity. However, whereas her arguments are highly theoretical, our aim here was to test whether pattern languages could really serve as a practical tool to address complex design problems.

Pattern languages as a tool for complex design

To design the whole process, the first stages were devoted to brainstorming sessions between IRD researchers from different scientific fields (from humanities to health and natural sciences) with three objectives: 1. to ensure a comprehensive and common understanding of sustainability science in the IRD context; 2. to agree on future steps for the process and first activities to be implemented; and 3. to test first patterns, ensuring interactions and constructive dialogue between several scientific disciplines, from humanities to biophysics and health science. Eventually, three *SDG* nexus were identified as relevant and legitimate topics for IRD:

- *Responsible consumption and production (SDG 12) – Life on land (SDG 15) – Clean water and sanitation (SDG 6);*
- *Good health and well-being (SDG 3) – Climate action (SDG 13) – Life on land (SDG 15);*
- *Sustainable cities and communities (SDG 11) – Climate action (SDG 13).*

The three workshops were designed to identify ways of unraveling the complex and diverse views of the various stakeholders associated within these three nexus, and to propose recommendations for implementing and promoting of sustainability science. For each workshop, about 30 selected participants representing a wide diversity of stakeholders, from different social, economic, and environmental domains and countries were invited to attend. The process also benefited from over 200 individual contributions through online consultations (table 1). However, while brainstorming the design of the workshop series and the pathways to achieving concrete results in a limited amount of time, it emerged that several components (e. g., cultural context, background, expertise) should be taken into account. Although the core design team consisted of only four people, there was already some complexity in making collective sense, reaching a common understanding of the problem at hand and making decisions about what the next steps should be. We therefore decided to use a customized "pattern mining process" (see next paragraph) to design the organization and the progress of each workshop.

Process to define the patterns

In the whole workshop process, key tangible or intangible elements deemed important for our design context were identified and singled out as patterns candidates by the core design group. For each candidate, a short and explicit name was chosen and a file created. To get the pattern list started, the core design group made use of first "candidates" that originated or derived from the first brainstorming: for example, "innovative ice-breaking", "online processes and survey", "flexible workshop structure", and "live collaborative writing".

Additional information about pattern candidates and new pattern candidates was then added as knowledge was acquired. This knowledge came variously from on the ground experience (the design of workshops and face-to-face workshop), feedback and suggestions from participants, and academic and nonacademic literature (table 2, p. 240). One crucial aspect of the method compared to other methods is its strong emphasis on the network of connections between patterns (i. e., which pattern is supported by other patterns and which pattern supports other patterns).

Patterns are documented in a formal structure that makes it easy to get a quick overview of individual design elements or dig deeper. In the online database *Sustainability Science Pattern* (see below), this formal structure is itself described in terms of a "pattern structure", while the design details and arguments for choices are detailed in the "pattern mining process".[1]

1 http://pattern-sustainability-science.org/?Pattern

TABLE 1: Multi-stakeholder workshops and online consultation focused on *Sustainable Development Goals (SDGs)* interactions: *SDG* nexus, participants, tangible and intangible deliverables.

SDG NEXUS	WORKSHOP 1	WORKSHOP 2	WORKSHOP 3	ONLINE CONSULTATION
	Responsible consumption and production (SDG 12) – Life on land (SDG 15) – Clean water and sanitation (SDG 6)	***Good health and well being (SDG3) – Climate action (SDG 13) – Life on land (SDG 15)***	***Sustainabile cities and communities (SDG 11) – Climate action (SDG 13)***	
goals	■ strengthen multi-stakeholder (users, scientific decision-makers) and multi-level (local, national and international) dialogue ■ identification of expectations and needs of stakeholders to achieve *SDGs* ■ options to implement/promote sustainability science			■ increase participation and engagement of stakeholders ■ allow participation of remote participants who couldn't attend face-to-face workshops ■ maintain a dynamic between face-to-face workshops ■ transmit/collect information to/from stakeholders to maximize to use of face-to-face time for others goals
number of participants	40	25	30	200

participants	■ researchers (North and South)
	■ Africa Centre of Excellence (ACE)
	■ *Multilateral Environmental Agreements (MEA)*
	  ■ civil society organizations
	  ■ *MEA* national focal point
	  ■ private foundation
		■ researchers (North and South)
		■ *Regional Environmental Agreements*
		■ civil society organizations; representative
		■ development bank
			■ researchers (North and South)
			■ civil society organizations; representative
			■ development banks
			■ national technical services
			■ UN bodies	

location	Rabat, Morocco	Montpellier, France	Abidjan, Ivory Coast	*http://pattern-sustainability-science.org/?PagePrincipale*
tangible deliverables	■ proposition of 3 topics on transdisciplinary research ■ options to deploy sustainability science in the Global South ■ options to promote *SDG 12* into the agenda of MEAs ■ propositions for youth engagement	■ identification of priority inter-disciplinary research themes ■ options for multi-actor spaces for transdisciplinary approaches ■ inventory of training and capacity building activities ■ advocacy activities towards decision-makers communities ■ development of communities of health/environment/climate practices	■ option for sustainable cities in a West African context ■ options for metadata portals ■ proposition of interdisciplinary research topics ■ option for African multi-stakeholder platform on cities	■ online who's who ■ list of participative methods ■ list of digital tools ■ list of worshop synthesis ■ list of survey's data
intangible deliverables	■ collective meaning-making ■ experimentation and acculturation to collective intelligence methods ■ re-use of the collaborative approach in others multicultural groups			■ sustained engagement, remote participation and inputs from participants who never came to face-to-face workshops ■ internal and external communication

V

TABLE 2: Process for pattern identification illustrated by means of an intangible pattern – PROCESS OF CONTINUOUS REFLECTION – and of a tangible pattern – MINDMAPS, taken from the online database *Sustainability Science Pattern*[2].

STEPS	EXAMPLE OF INTANGIBLE PATTERN	EXAMPLE OF TANGIBLE PATTERN
0. source material and initial pattern language	Oberlack et al. (2019, p. 108 ff.): 10 propositions for theories of change (ToCs) in sustainability science	face-to-face workshop
1. Identify key tangible or intangible elements that seem important for your design context (candidate pattern), and give them a short and explicit name.	"Proposition 3: ToCs must be embedded in a *continuous reflection process* to remain adaptive and embrace surprises. [...] To remain a useful tool over time, formalized ToCs require ongoing critical reflection and adjustments to ensure that they meaningfully reflect new conditions, new information, and can update strategies (Oberlack et al. 2019, p. 108).	Use of *mindmapping* tool to map complex issues discussed and present them to participants so they can discuss them collectively.
2. Create file for the candidate pattern.		
3. Tweak the name to make it explicit (PATTERN NAME).	PROCESS OF CONTINUOUS REFLECTION	MINDMAPS
4. Write a one-line summary describing pattern value.	Use a PROCESS OF CONTINUOUS REFLECTION to remain adaptive and embrace surprises.	Use MINDMAPS to visualize links between various data and navigate in complex web of concepts.
5. Add pattern description including some elements of context, proposed solution and arguments for why it is useful. Provide bibliographic references if possible.	"Once elaborated and agreed upon, ToCs provide a mental model representing a project approach at a given time. However, tension can arise between the explicit knowledge formalized in ToCs and the evolving tacit knowledge generated in the day-to-day practices of project members. Therefore, to remain a useful tool over time, formalized systemic approaches require ongoing critical reflection and adjustments to ensure that they meaningfully reflect new conditions, new information, and can update strategies."[a]	"MINDMAPS allow a non linear vizualisation of information that is particularly suitable to map complex ideas ad can be used to map conflicting views (DIALOGUE MAPPING). Cunningham and Mehaffy (2005) conducted a user study in which 80% of the students thought ‚mindmapping helped them understand concepts and ideas in science'."[b]
6. Check if pattern is linked or belongs to other patterns.		Supportive digital technology used for DIALOGUE MAPPING.
7. Check if pattern is granular enough. Complex patterns can be broken down into smaller sub-patterns. Create new patterns as needed.	Use COLLABORATIVELY DEFINED INDICATORS, and regularly perform EVALUATION METHODS such as RETROSPECTIVE.	Use VIDEOPROJECTOR to display live mindmap in front of large audience.
8. Go back and forth to adjust content between linked patterns.		
9. Test pattern in real situation to get feedback on pattern value.		
10. Explore bibliography to refine the description of the pattern.	Oberlack et al. (2019)	Cunningham and Mehaffy (2005)

a *http://pattern-sustainability-science.org/?ContinousReflectionProcess*
b *http://pattern-sustainability-science.org/?MindmapS*

Stock-take of our process

The knowledge gained from each workshop was used to design the next few, using a reflexive approach. This open-ended iterative process was used to allow for the emergence of unexpected outputs and led us to new insights about how to conduct multi-stakeholder procedures for working on wicked problems. Knowledge about the best practices identified was formalized as a database of patterns called *Sustainability Science Pattern*.[2] Over 100 patterns that we thought salient were described. For user-friendly purposes, these patterns were grouped into different categories:

- ***scientific approach*** (28 patterns): this category corresponds to what we believe are key design elements for sustainability science (e.g., SYSTEMIC THINKING, MULTI-STAKEHOLDER PROCESS, ORGANIZATIONAL LEARNING PROCESS, PROCESS OF CONTINUOUS REFLECTION);
- ***strategy*** (18 patterns): this category specifically explores design elements we used in our particular context (e.g., CO-DESIGN, REGULAR GOAL ASSESSMENT, LEARNING BY DOING, ITERATIVE PROCESS);
- ***workshop structure and design*** (16 patterns): this category describes the way we designed a series of connected workshops both as a way to work on *SDGs* and as an experimental field in which to test and improve our patterns (e.g., WORKSHOP CYCLE, ONLINE INTERACTION BEFORE WORKSHOP, FLEXIBLE WORKSHOP STRUCTURE, OUTPUTS AS INPUTS);
- ***facilitation recipes*** (12 patterns): this category describes sophisticated methods that can be used to conduct productive/efficient workshops in the context of large groups of multi-stakeholders (e.g., WORKING AGREEMENTS, ICEBREAKERS, DIALOGUE MAPPING, RETROSPECTIVE);
- ***facilitation ingredients*** (20 patterns): this category specifically describes key elements that the designer should bear in mind while facilitating workshops and meetings (e.g., TIME CONSTRAINTS, ENABLING ARCHITECTURES, REVERSE FRAMING, FERTILE DISAGREEMENTS);
- ***supportive digital technologies*** (11 patterns): this category describes digital tools that can be used to enhance the workshop experience (e.g., LIVE COLLABORATIVE WRITING, MINDMAPS, WIKI OPEN PLATFORM, ONLINE POLLS);
- ***enabling operational conditions*** (7 patterns): this category identifies constraints specific to the academic world and outlines how to deal with them (e.g., SUPPORTIVE HIERARCHY, REAL LIFE POLITICAL CONSTRAINTS, BUDGET, TRAINING);
- ***compostability*** (13 patterns): finally, this section provides good practices to make knowledge "compostable", that is, documentable in such a way that it can be easily shared, transferred and reused in other contexts (e.g., PATTERNS, APPROPRIATE GRANULARITY, INTEROPERABILITY, FREE LICENCE).

Each of these patterns highlights one element that should be considered when conducting sustainability science initiatives. Some of these patterns provide an exhaustive description of what we identified as good practices. Some are still at a rough stage and simply provide an outline that warrants further exploration. This pattern collection is still a work in progress, requiring further developments.

Due to the large number of patterns, it might be worth exploring the use of cards as a way to handle a subset of patterns at a given time. The use of cards, individually or collectively, can act as a primer for thinking and discussion (Gray et al. 2010). Collaborative identification and characterization of key elements (patterns) and their relationships by multi-stakeholders provide a structure for collective sense-making and shared responsibility. Furthermore, in addition to the language we co-created, the co-creative process itself might be of interest to practitioners. This process can be used at various scales to create shared responsibility among stakeholders and collective sense-making of the problems at hand.

The use of pattern languages enabled us to overcome classic linear workshop (roundtable, presentations, working groups, conclusions) and knowledge management formats by proposing new ways of interacting with the data. It also gave participants the opportunity to take ownership of the workshop and propose a solution for each request or specific context, leading to a new understanding of complex situations.

In this regard pattern languages provide a powerful way to 1. document, share, use or discuss best practices and other key design elements; and 2. improve the capacity of any participant to approach wicked problems and sustainability issues. In addition, the iterative process used to "mine" the patterns and the flexible structure of the pattern makes this an intrinsically adaptable method that can be used in many contexts.

Conclusion

Despite its potential, there has been little exploration by researchers of the use of pattern languages in sustainability initiatives, and the literature on the topic is sparse (Kuenkel 2017, Tippett 1994).

Our cycle of workshops offered a dual opportunity to build and to use this set of patterns in different cultural contexts. In general, the participants appreciated the tools used to build collective intelligence and obtain concrete first outputs, some of which were quickly implemented after the workshops or the cycle. Depending on the context, additional time was needed for the approval of the tools, which in turn allowed for the refining of some patterns. As a result, and following our constant interactions with some participants, we observed that some of these patterns are already being used for specific purposes, such as responses to calls for tender for projects or the creation of networks aiming at quantitative understanding of sustainable development pathways.

>

2 *http://pattern-sustainability-science.org/?Pattern*

Following on from our work, we proposed a practical step-by-step process to act as a guide for anyone wishing to implement actionable sustainability science. Practitioners seeking to address complex issues might choose between the following two approaches: 1. to use the list of identified patterns to trigger stakeholder discussions (preferably using cards), or 2. to start with a blank page and co-create their own pattern language using multi-stakeholder workshops. In practice, a combination of the two might be the best option, choosing one approach or the other according to the context and the number of participants.

Most of our patterns pertain to the organization of multi-stakeholder workshops (workshop structure/design, facilitation recipes, facilitation ingredients, supportive digital technologies). However, our collection also includes many patterns that are not specific to the workshops themselves (scientific approach, strategy, enabling operational conditions, compostability), suggesting that pattern languages could be used in other fields of sustainability sciences.

The work we present here is far from complete. We hope it will be reused, adapted and improved by others, and trigger interest in pattern language methods within the sustainability science community and beyond.

The transdisciplinary workshop cycle was funded by a IRD specific budget (MP2I). The views expressed herein are those of the author(s) and do not necessarily reflect the views of the United Nations.
The authors sincerely thank the two anonymous reviewers for their efforts and helpful comments.

References

Alexander, C. 1979. *The timeless way of building.* Oxford, UK: Oxford University Press.

Bergin, J., et al. 2012. *Pedagogical patterns: Advice for educators.* North Charleston, SC: CreateSpace Independent Publishing Platform.

Bressen, T., D. Pollard, S. Woehrlin, D. Lindenberger. 2015. *Group works: A pattern language for bringing life to meetings and other gatherings.* https://groupworksdeck.org (accessed January 12, 2020).

Cunningham, W., M. W. Mehaffy. 2013. Wiki as pattern language. In: *PLoP 13: Proceedings of the 20th Conference on Pattern Languages of Programs.* Monticello, IL, October 23–26. https://dl.acm.org/doi/10.5555/2725669.2725707 (accessed November 8, 2021).

Finidori, H. 2014 a. An ecology of transformative action awaiting to be discovered. *Spanda Journal* V/1: 5–14.

Finidori, H. 2014 b. A pattern language for systemic transformation (plAsT) – (re)generative of commons. Paper prepared for a workshop prior to the conference *Pursuit of Pattern Languages for Societal Change.* Danube University July 2015.

Finidori, H. 2016. Patterns that connect: Exploring the potential of patterns and pattern languages in systemic interventions towards realizing sustainable futures. Advanced Author Paper presented at the *60th Annual Meeting of the International Society for the Systems Sciences "Realizing Sustainable Futures."* University of Colorado, July 23–30.

Finidori, H., P. Tuddenham. 2017. Pattern literacy in support of systems literacy: An approach from a pattern language perspective. In: *PLoP 17: Proceedings of the 24th Conference on Pattern Languages of Programs.* Vancouver, CA, October 23–25. https://dl.acm.org/doi/10.5555/3290281.3290287 (accessed November 8, 2021).

Gray, D., S. Brown, J. Macanufo. 2010. *Gamestorming: A playbook for innovators, rulebreakers, and changemakers.* Sebastopol, CA: O'Reilly Media.

Kuenkel, P. 2017. *A pattern approach to stewarding sustainability transformation: How the 17 SDGs can become a starting point for transformative change.* Collective Leadership Studies 5. Potsdam: Collective Leadership Institute.

Oberlack, C. et al. 2019. Theories of change in sustainability science: Understanding how change happens. *GAIA* 28/2: 106–111. https://doi.org/info:doi/10.14512/gaia.28.2.8.

Ricaud, L. 2015. Permaculture patterning: A design framework for systemic transformation. *Spanda Journal* VI/1: 195–203.

Rittel, H. W. J., M. M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4/2: 155–169. https://doi.org/10.1007/BF01405730.

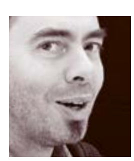
Schuler, D. 2008. *Liberating voices: A pattern language for communication revolution.* Cambridge, MA: MIT Press.

Tippett, J. 1994. *A pattern language of sustainability: Ecological design and permaculture.* BA diss. Lancaster University, Lancaster, UK. www.holocene.net/dissertation.htm (accessed November 15, 2021).

UN (United Nations). 2015. *Transforming our world: The 2030 Agenda for sustainable development.* New York: UN.

Lilian Ricaud
Studies in plant biology. 2000 BSc in plant biotechnology, University of Toulouse, France. Formerly working on plant sciences at French Research Institute for Agriculture, Food and the Environment, and Cambridge University. Since 2005, open collaboration specialist studying collaborative practices. Areas of expertise: strategies for co-creative events involving large multi-stakeholders, pedagogical tools on facilitation practices, stigmergic collaboration and pattern languages.

Maxime Thibon
Studies in environmental sciences and law. 2000 Master's degree, University of Montpellier, France. Environmental specialist, formerly involved in in research and development institutions such as the Sahara and Sahel Observatory and the French Research Institute for Sustainable Development. Currently working at the United Nations Convention to Combat Desertification. Areas of expertise: sustainable management of natural resources, *SDGs* interactions, transdisciplinarity.



Laurent Marseault
Studies in social career 1992. 1992 to 2005 teacher in environmental education. Since 2005 professional facilitator. 2006 co-founder of Outils-Réseaux, a French nonprofit organization specialized in collaborative tools and practices, for example, *Animacoop,* a hybrid professional training for collaborative skills development. Areas of expertise: digital tools for collaboration and collaborative practices.

Jean-Luc Chotte
Studies in soil science. 1986 PhD, University of Nancy, France. Senior scientist at the French Research Institute for Sustainable Development (IRD). 2015 to 2019 United Nations Convention to Combat Desertification Science Policy Interface Committee Member. Since 2020 Chair of the French Scientific Committee for Desertification. Research interests: soil organic carbon, land degradation and restoration, science policy interface, Agriculture, Forestry and Other Land Use (AFOLU), transdisciplinarity.