

Permaengineering

A theoretical framework towards a strong sustainability paradigm in design. An HCI study

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Agenda

Engineering
in the
Anthropocene

Engineering and
interactions for
strong
sustainability

Proposal of
Permaengineering

Methodology
and
experiments

Results

Contributions &
perspectives

Introduction

State of the art

Proposal

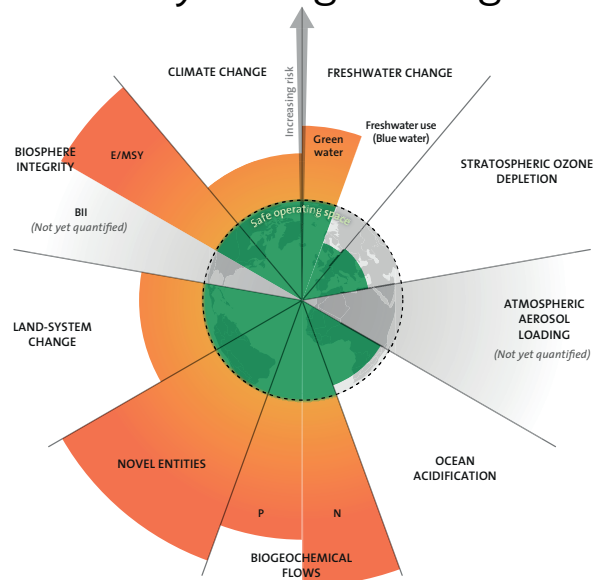
Experiments

Results

Conclusion²

Problem

Responsibility of engineering activities



[Rockström et al., 2009a], [Persson et al., 2022],
[Rockström et al., 2009b], [Steffen et al., 2015b],
[Wang-Erlandsson et al., 2022]

LitR

Link between engineering and culture

Engineering practice evolves with artefacts

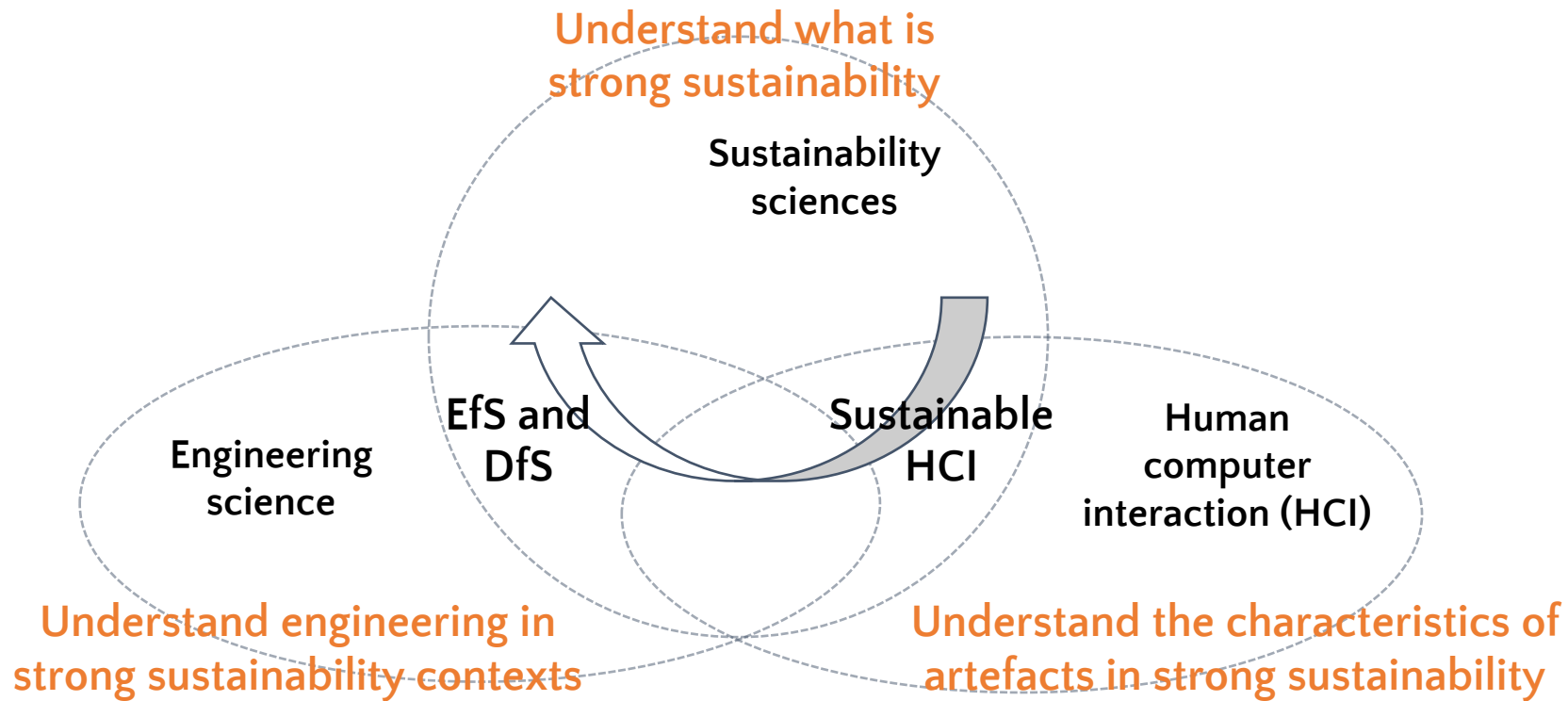
[Vérin, 1993], [Picon, 2004], [Dias de Figueiredo, 2014],
[Gero and Kannengiesser, 2004]

What kind of change do we need in engineering
for strong sustainability contexts?

State of the art

LitR

What kind of change do we need in engineering for strong sustainability contexts?



State of the art

What kind of change do we need in engineering
for strong sustainability contexts?

Understand what is
strong sustainability

Sustainability
sciences

LitR

EfS and
DfS

Sustainable
HCI

Human
computer
interaction (HCI)

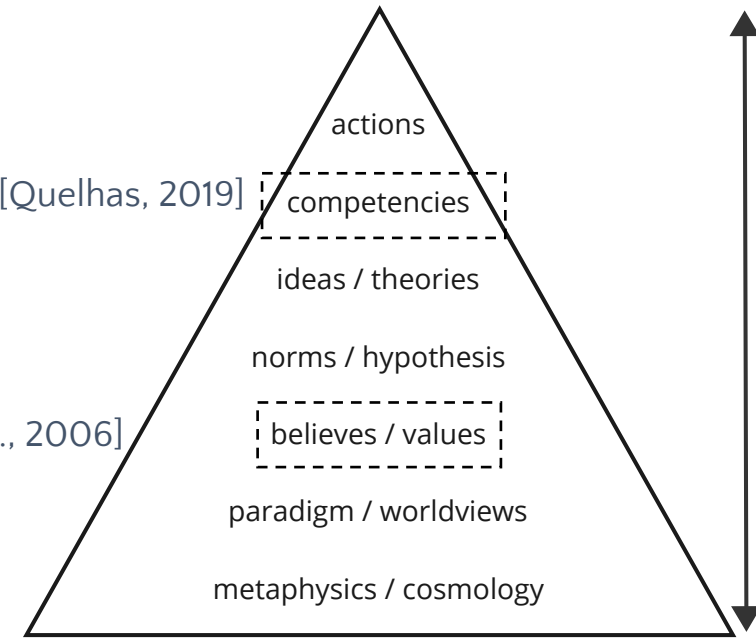
Engineering
science

Weak / Strong sustainability

[Dietz and Neumayer, 2007]

[Tardif, 2003], [Quelhas, 2019]

[Friedman et al., 2006]



Nested knowledge model

[Sterling, 2010], [Biberhofer et al., 2019]

State of the art

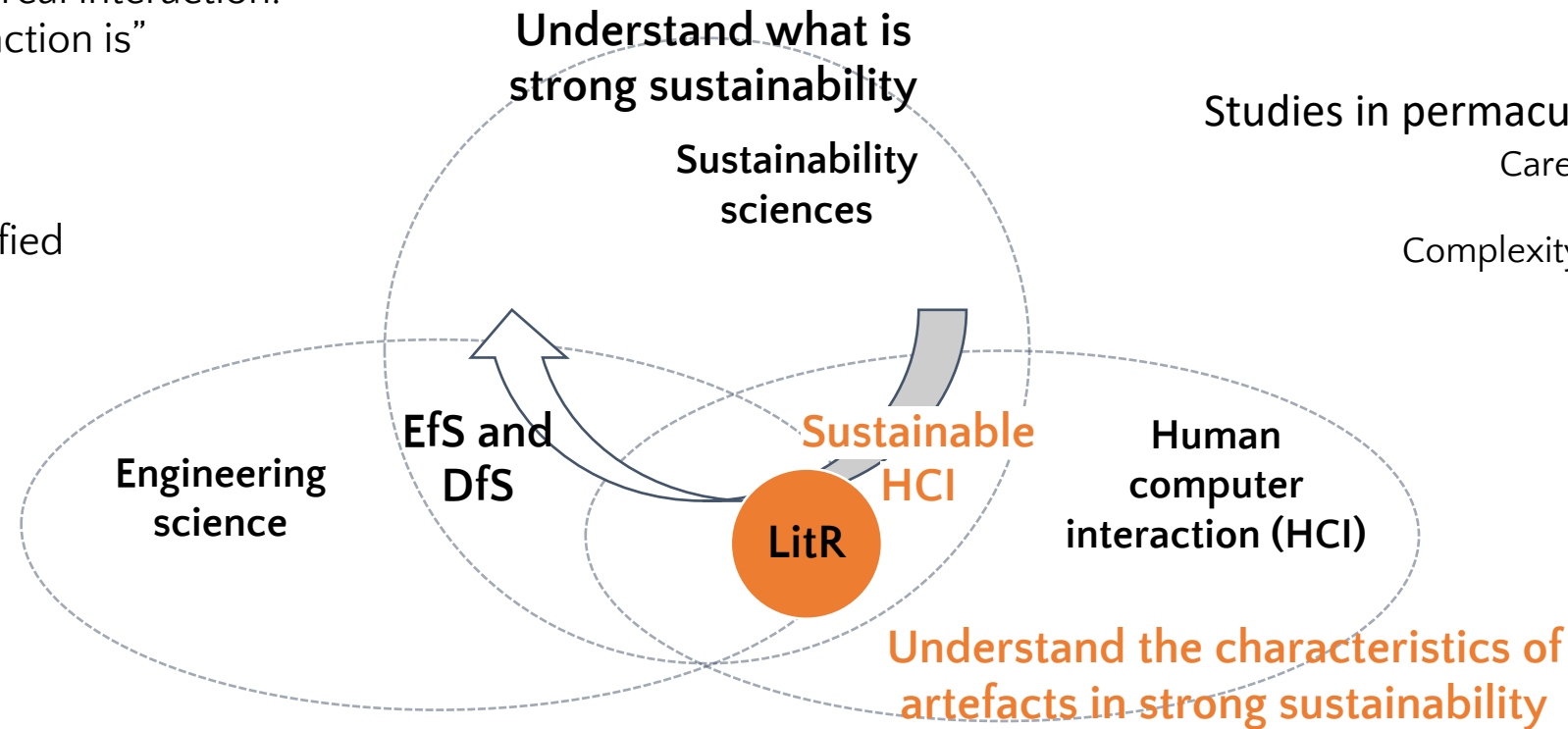
What kind of change do we need in engineering
for strong sustainability contexts?

Collaboration: attention to real interaction.
“the app is not where the action is”

Low-level of complexity

Artefacts that can be modified

Artefacts enabling learning



Studies in permaculture communities

Care ethics [Liu et al., 2018]

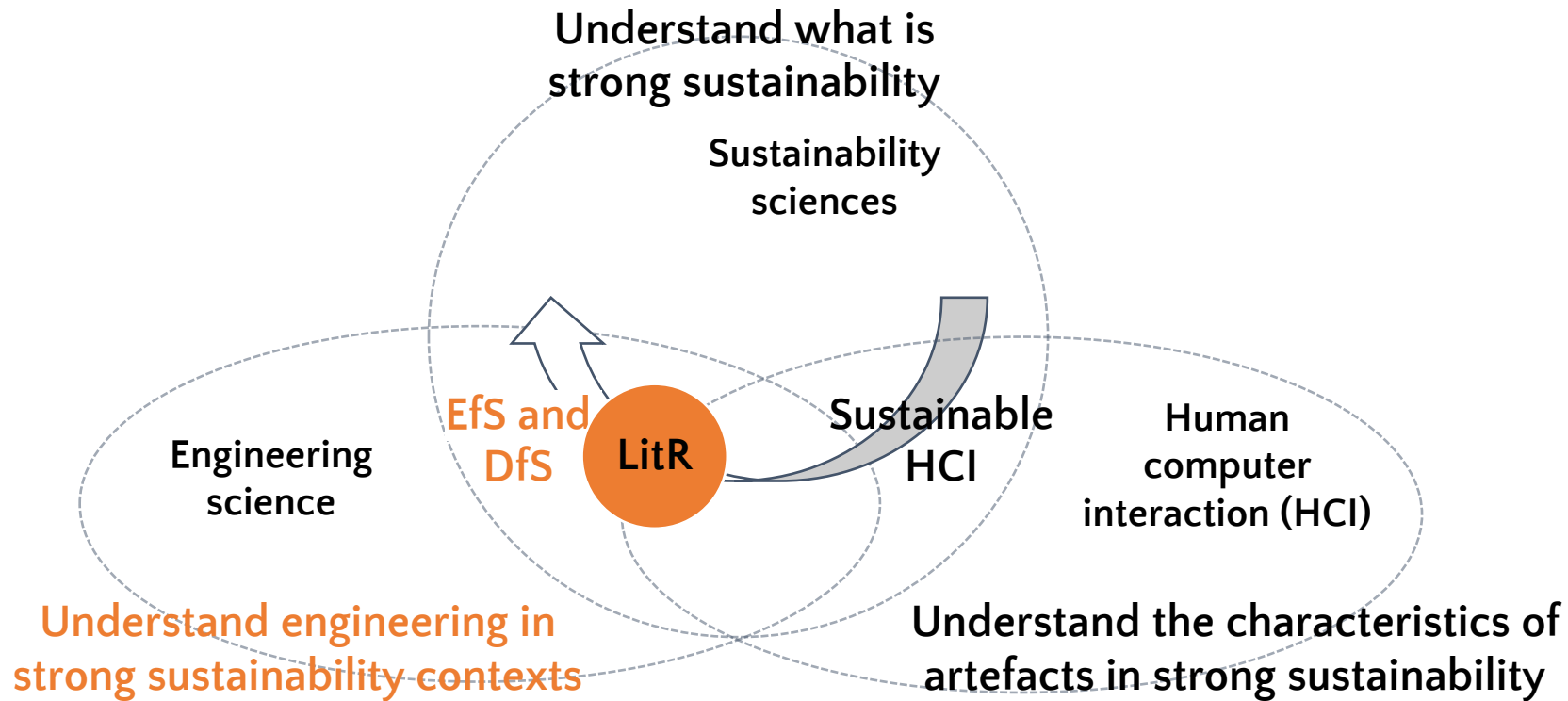
[Hansen, 2020],

Complexity [Norton et al., 2019a],

[Norton et al., 2019b],

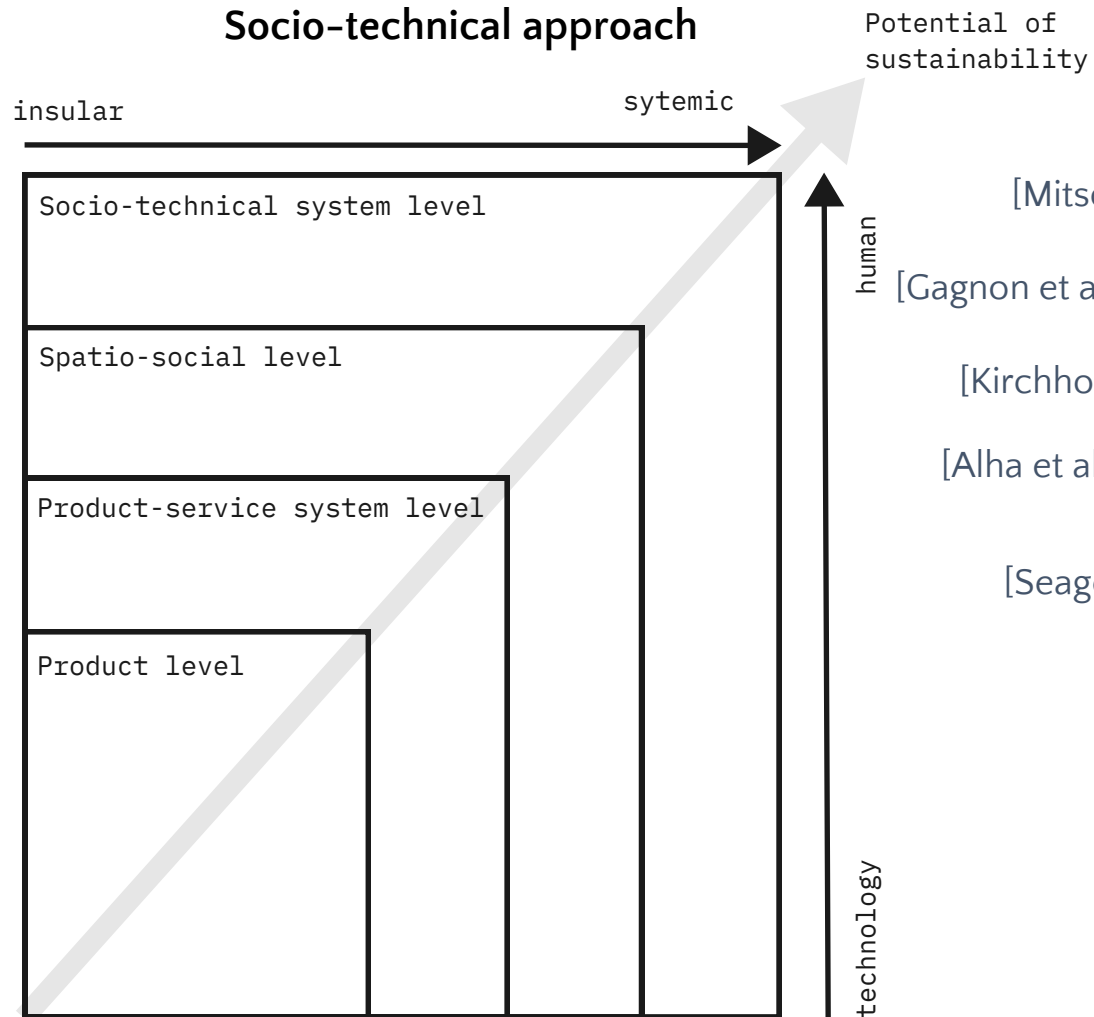
State of the art

What kind of change do we need in engineering
for strong sustainability contexts?



State of the art

Socio-technical approach



[Ceschin and Gaziulusoy, 2016]

Potential of sustainability

human

technology

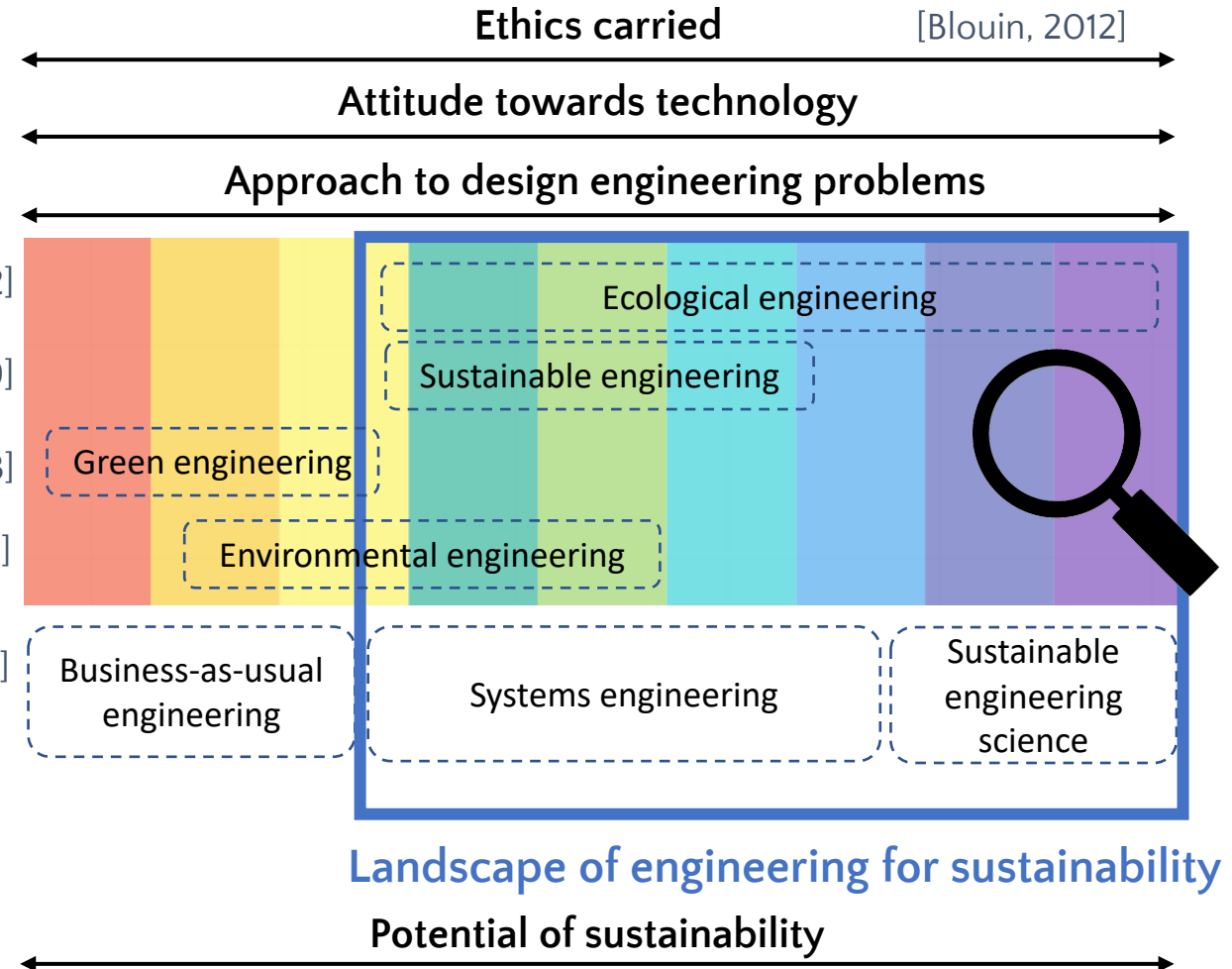
[Mitsch, 2012]

[Gagnon et al., 2009]

[Kirchhoff, 2003]

[Alha et al., 2000]

[Seager, 2012]

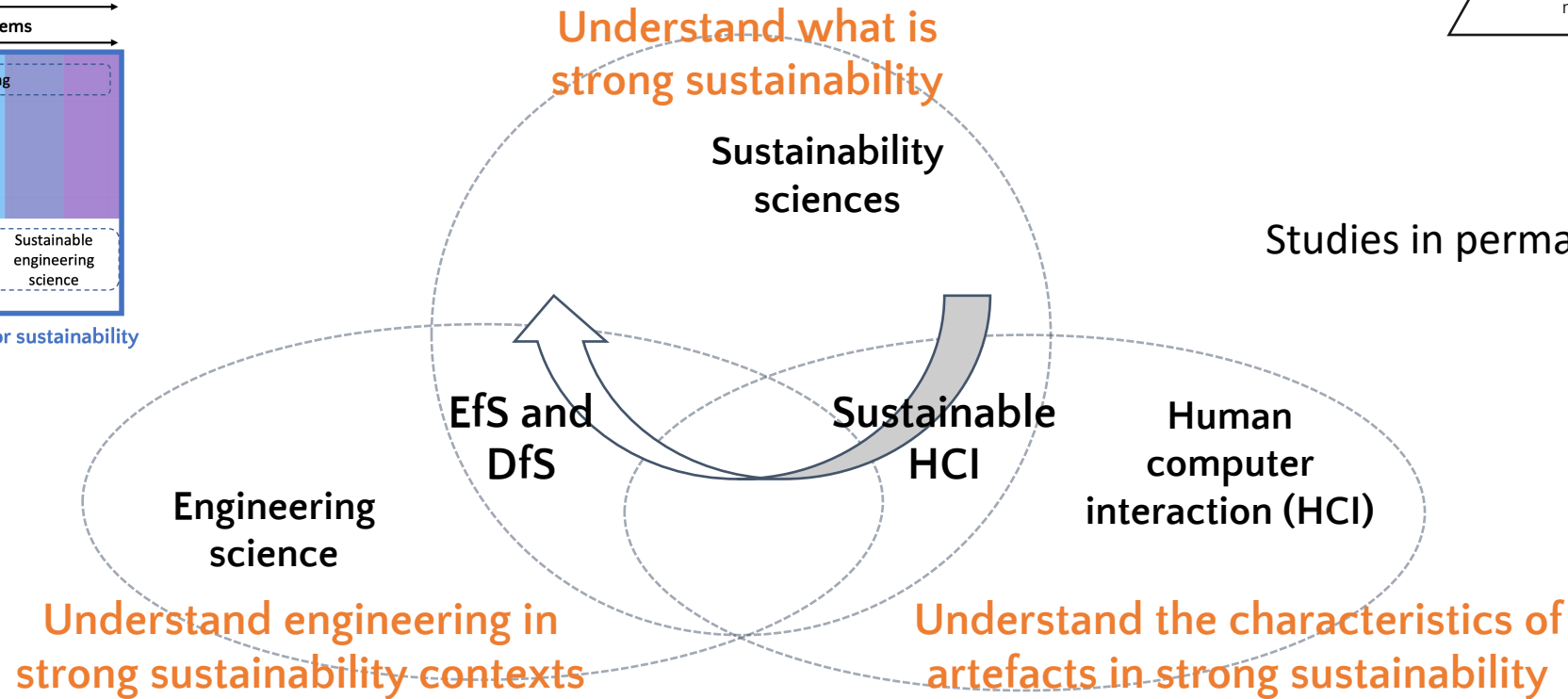
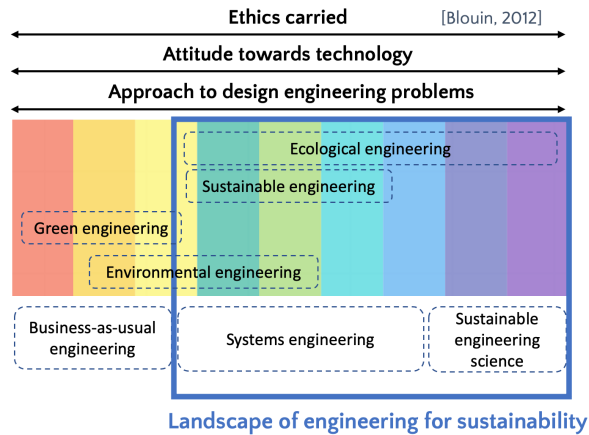
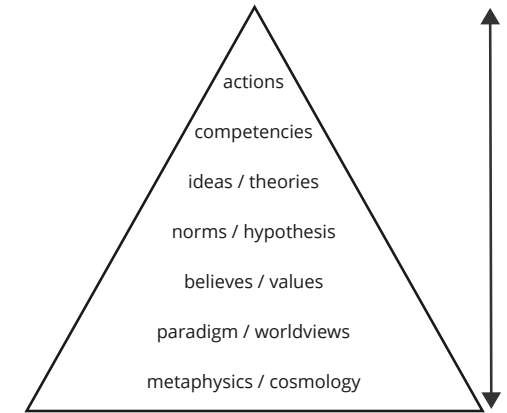


We need to further explore engineering in strong sustainability contexts.

State of the art

LitR

What kind of change do we need in engineering for strong sustainability contexts?



Findings from state of the art

Goal of **strong sustainability**

Clarification of ethics: **care ethics**

- Questioning the application domain

- Attention to relation (not blocking action)

Socio-technical approach: **collaboration**

- Low-level of complexity

- Supporting interaction among people

- Artefacts enabling learning

- Artefacts that can be modified

Ability to act: **engineering competencies for sustainability**

- An artefact which supports the development of the 8 competences

Research questions (RQ)

What kind of change do we need in engineering
for strong sustainability contexts?

Engineering level

Gap 1: Design engineering in strong sustainability contexts is not enough addressed

RQ 1: In a context of ecological transition, to what extent **engineering** can evolve towards other ways of being and being practiced?

Digital transition

Interactions level

Gap 2: Understanding HCI in engineering practices for strong sustainability

RQ 2: What are the **digital tools and methods** to support engineering practices in line with strong sustainability contexts?

Proposal

(1) Goal of **strong sustainability**

(2) Clarification of ethics: **care ethics**

Questioning the application domain

Attention to relation (not blocking action)

(3) Socio-technical approach: **collaboration**

Low-level of complexity

Supporting interaction among people

Artefacts enabling learning

Artefacts that can be modified

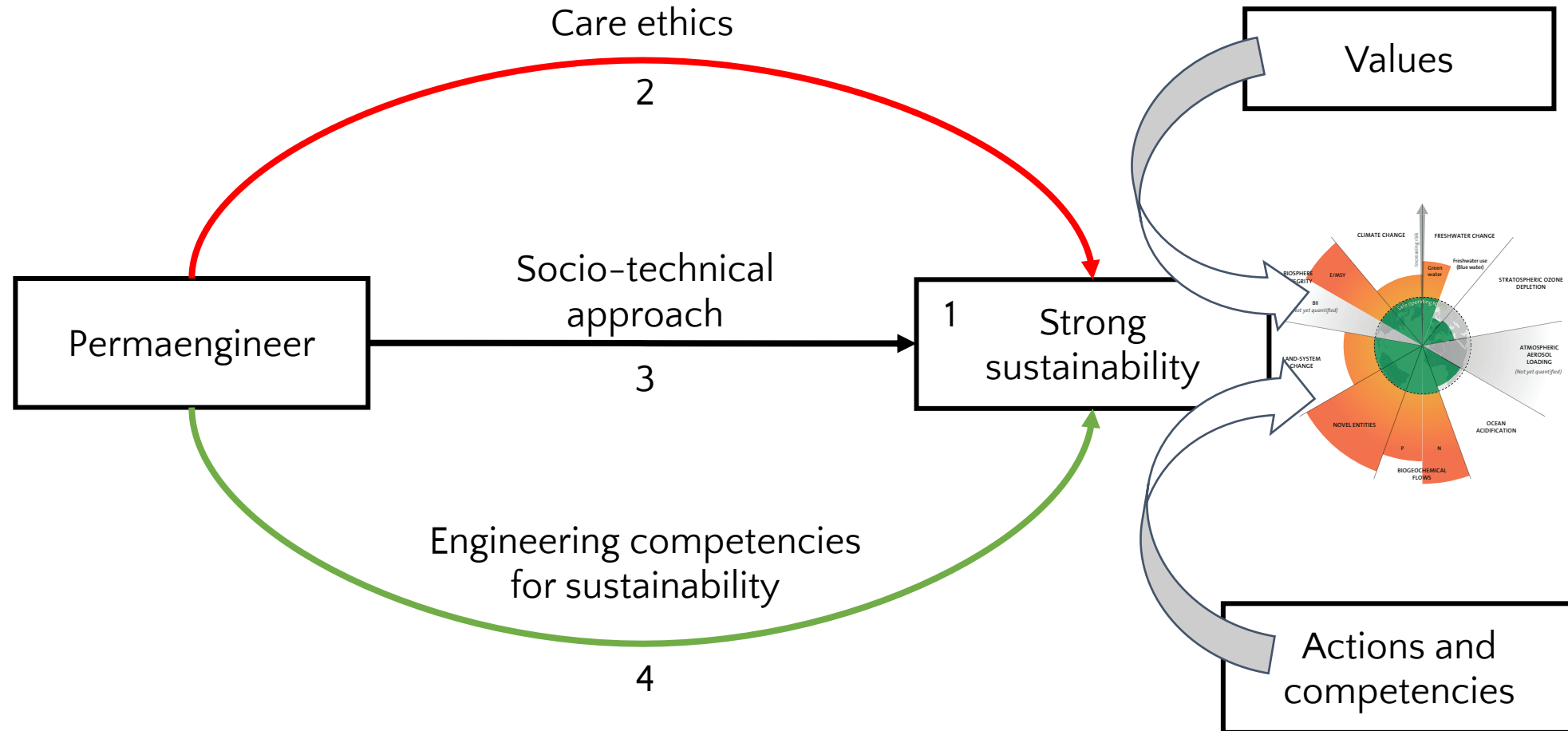
(4) Ability to act: **engineering competencies for sustainability**

An artefact which supports the development of the 8 competences

Proposal: In a (1) context of strong sustainability, (2) care ethics, (3) collaboration and (4) engineering competencies for sustainability enable to align values and actions

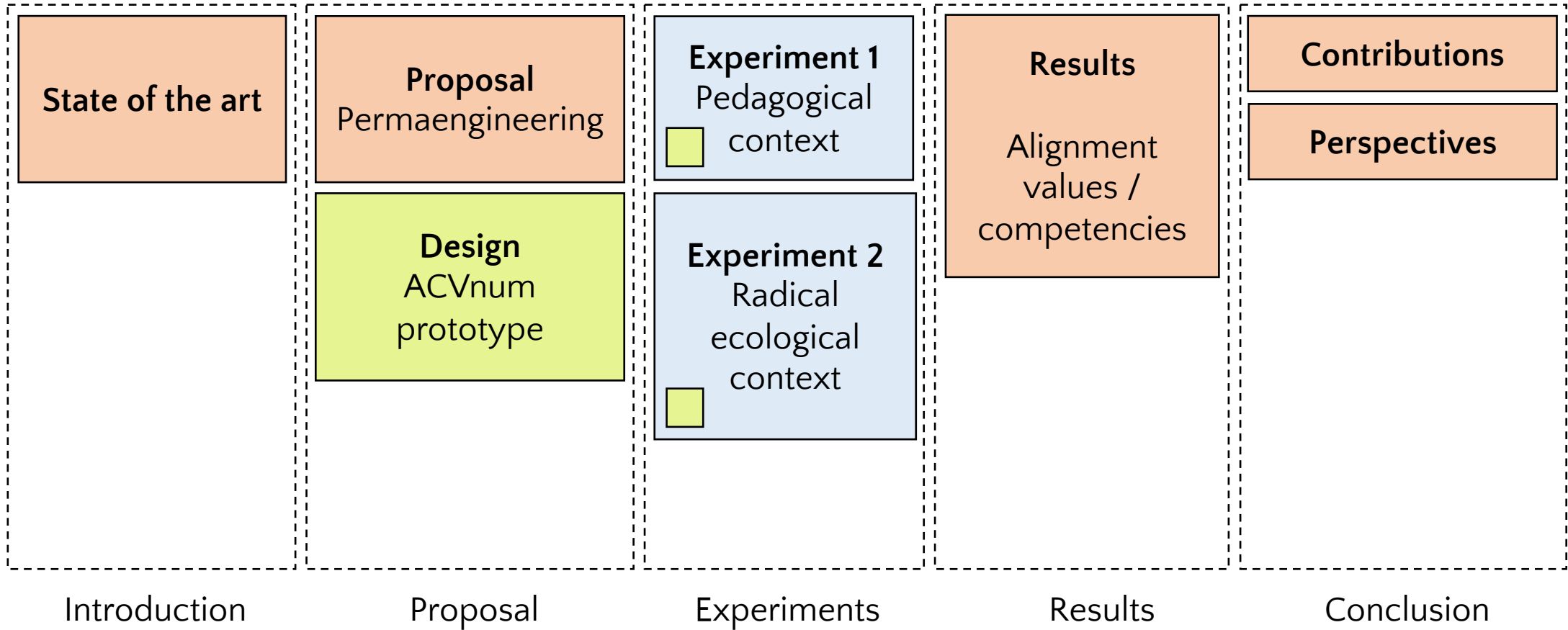
Proposal

To better understand the alignments
between competencies and values

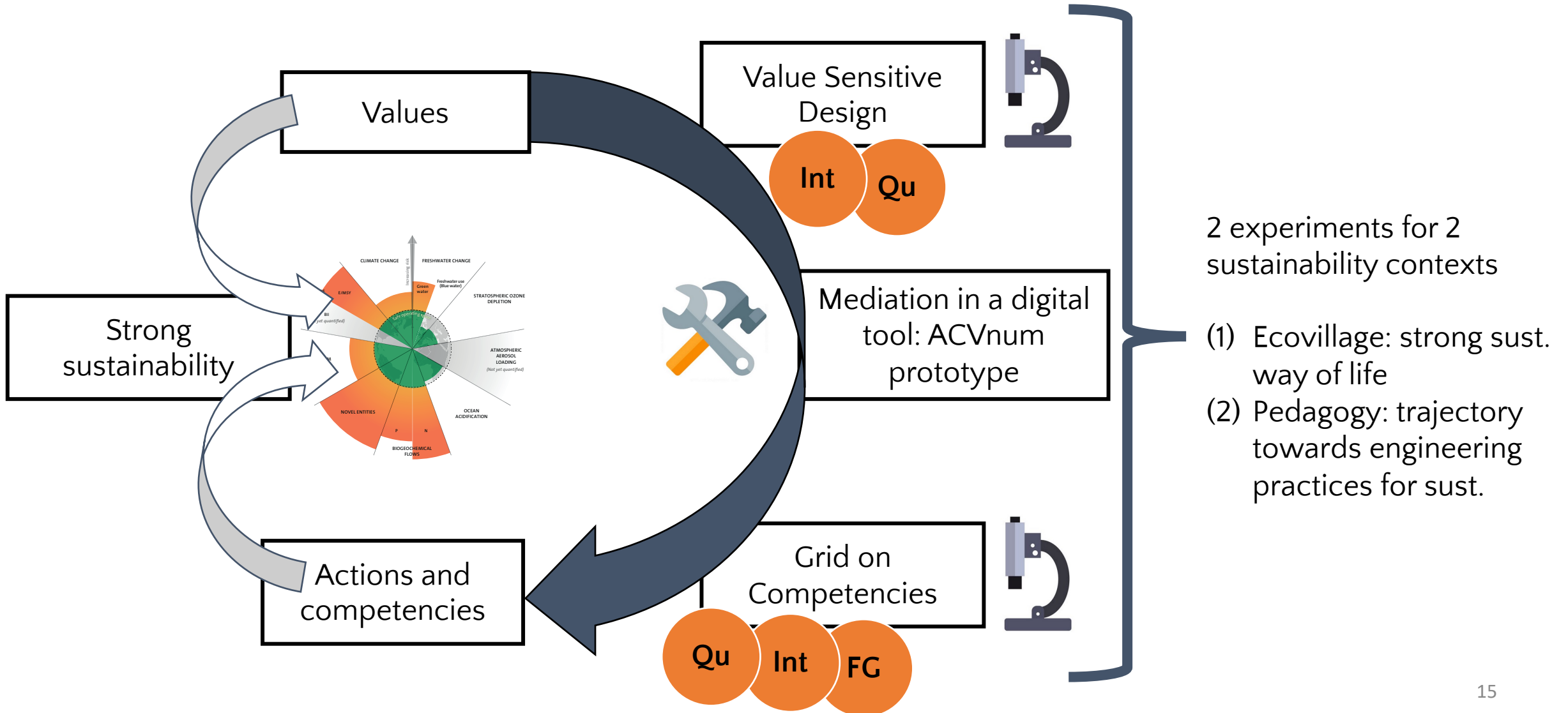


Value sensitive design

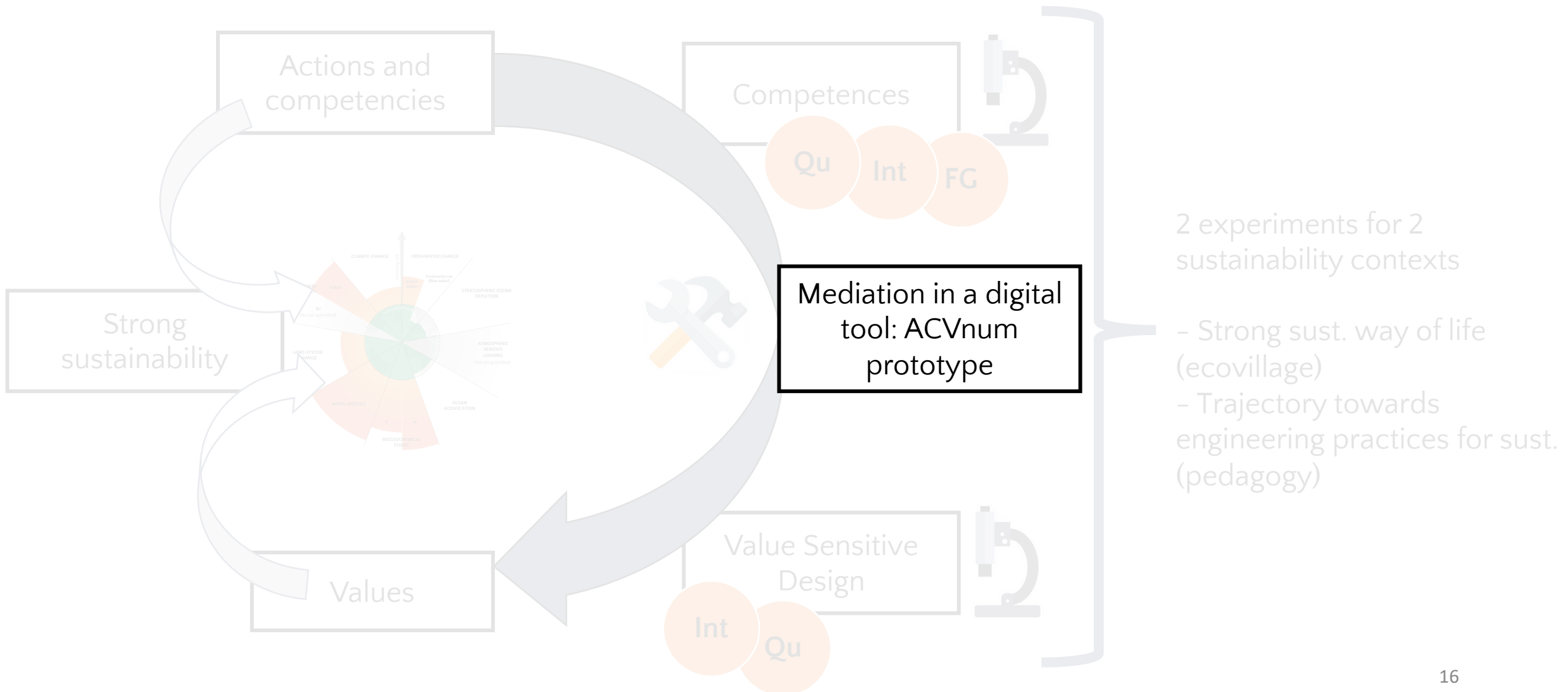
Empirical investigations
 Technical investigations
 Conceptual investigations



Understanding HCI in engineering practices for strong sustainability

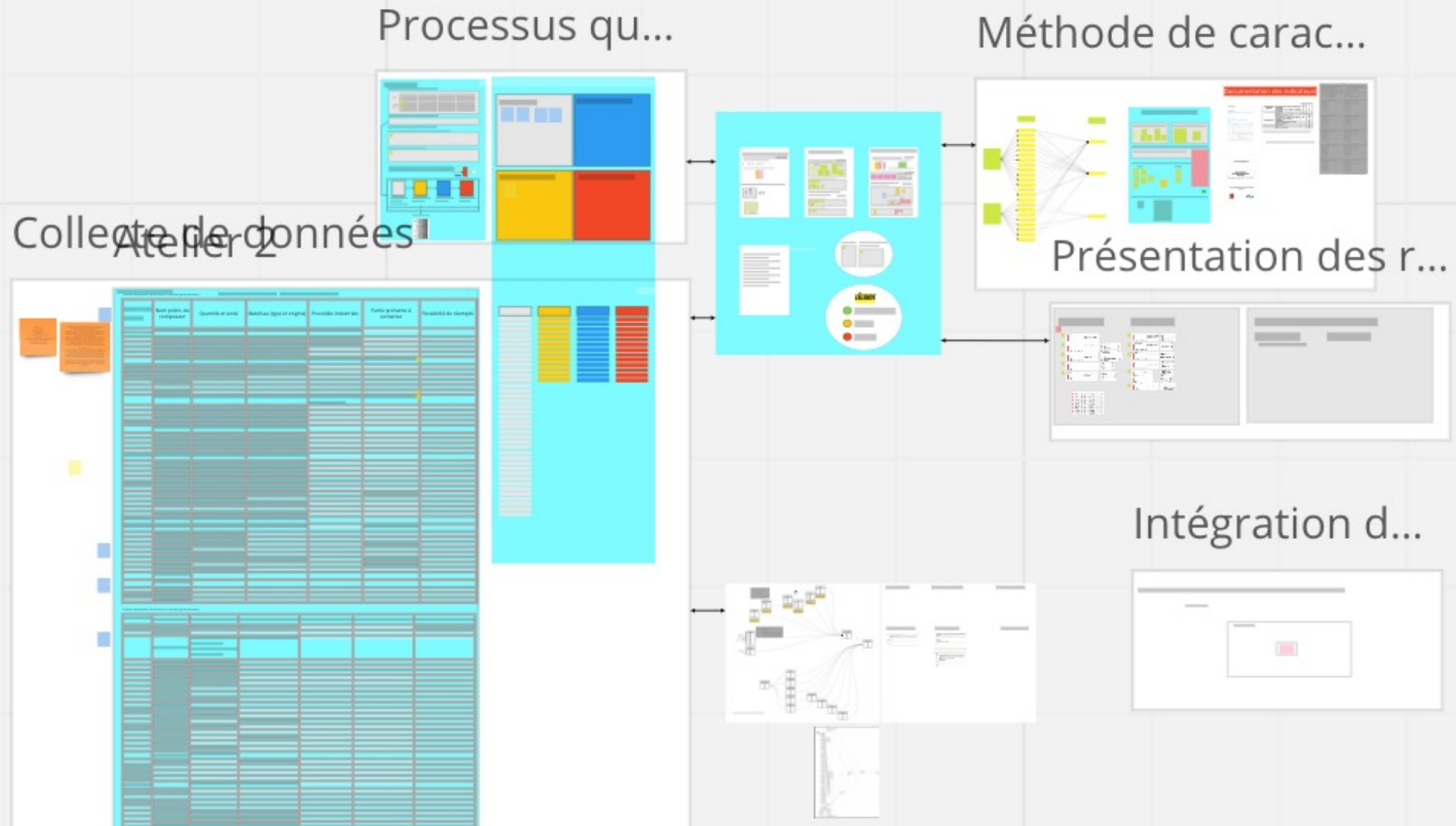


Understanding HCI in engineering practices for strong sustainability

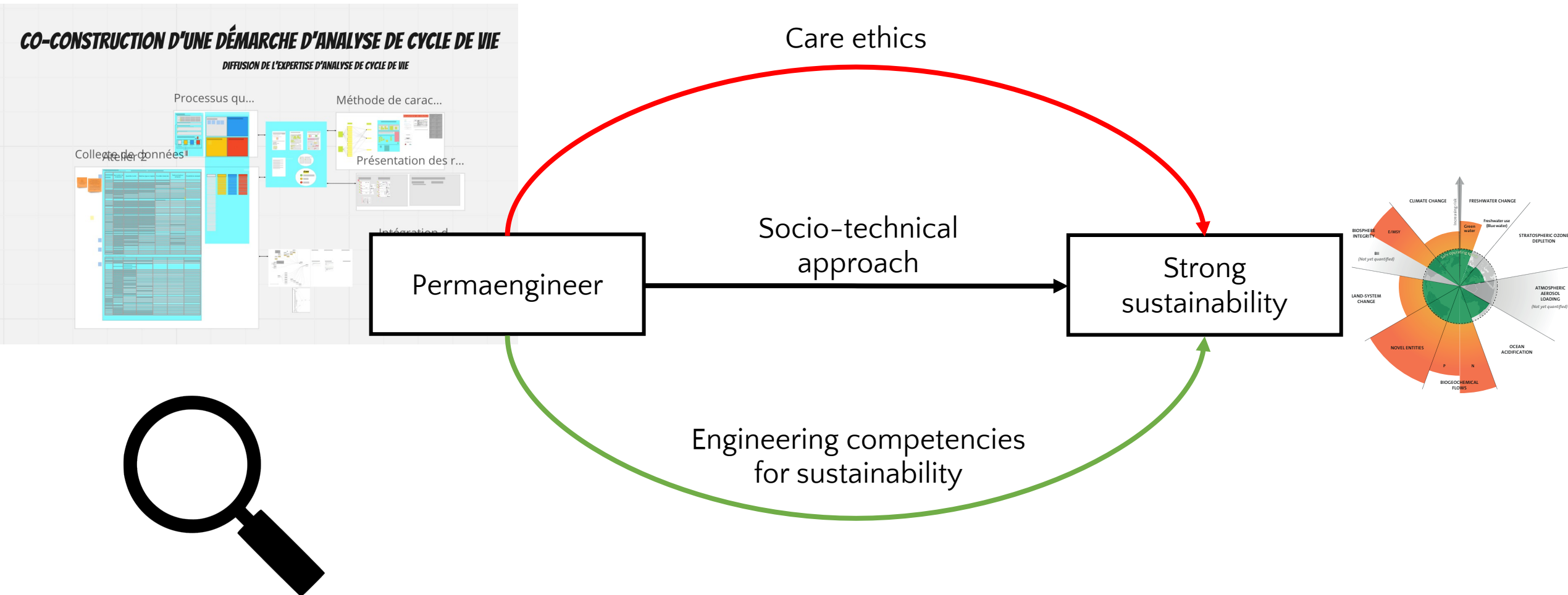


CO-CONSTRUCTION D'UNE DÉMARCHE D'ANALYSE DE CYCLE DE VIE

DIFFUSION DE L'EXPERTISE D'ANALYSE DE CYCLE DE VIE

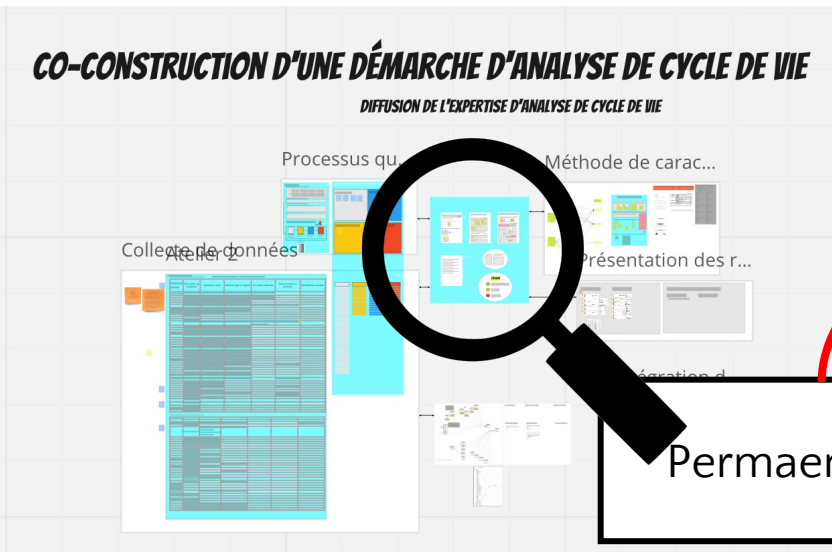


ACVnum prototype

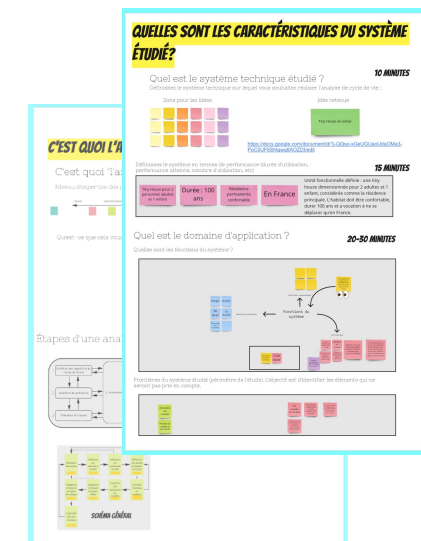
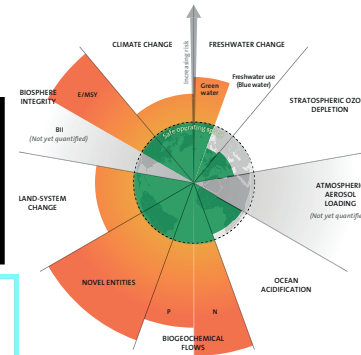


ACVnum prototype

Care ethics

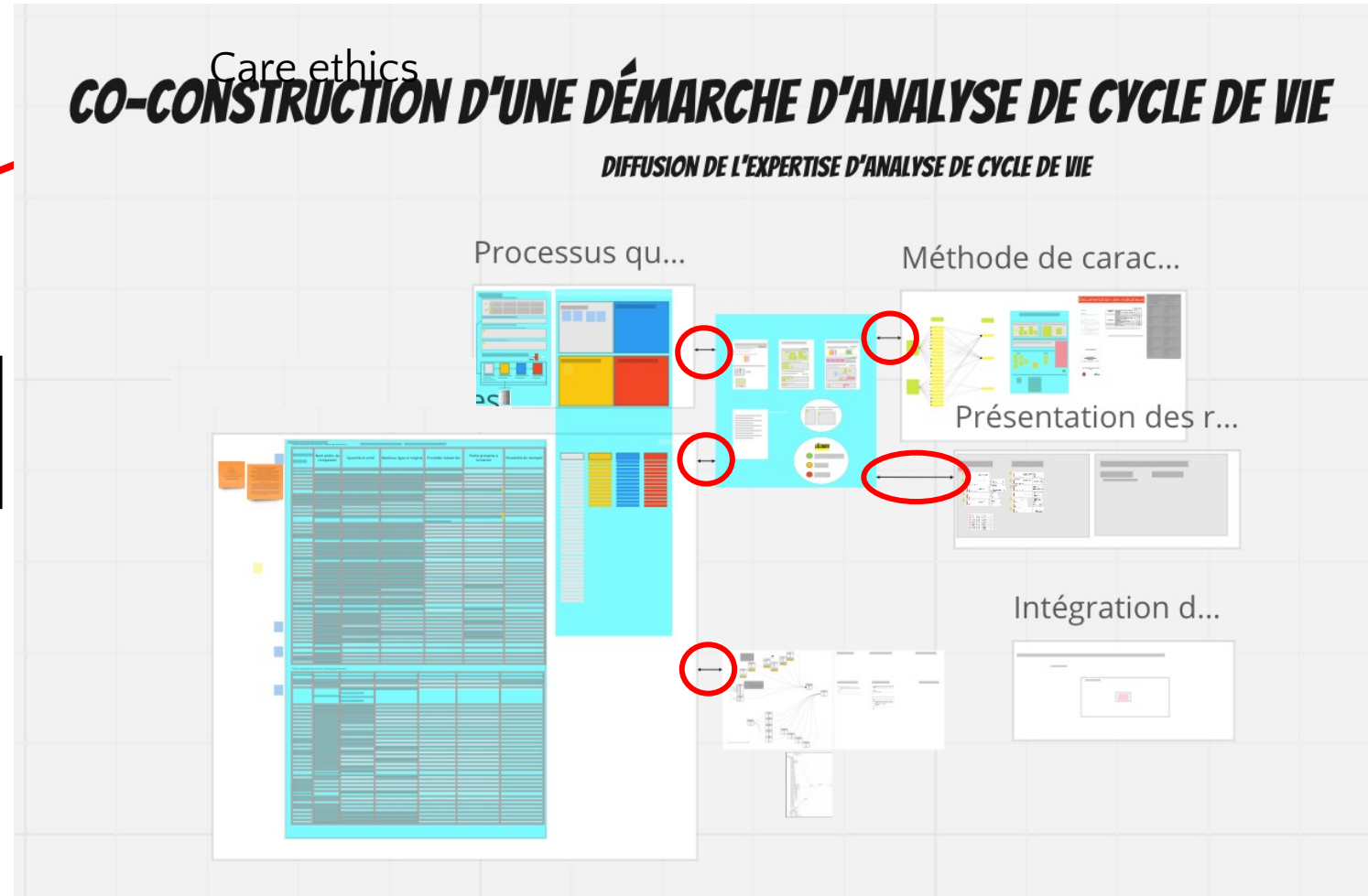
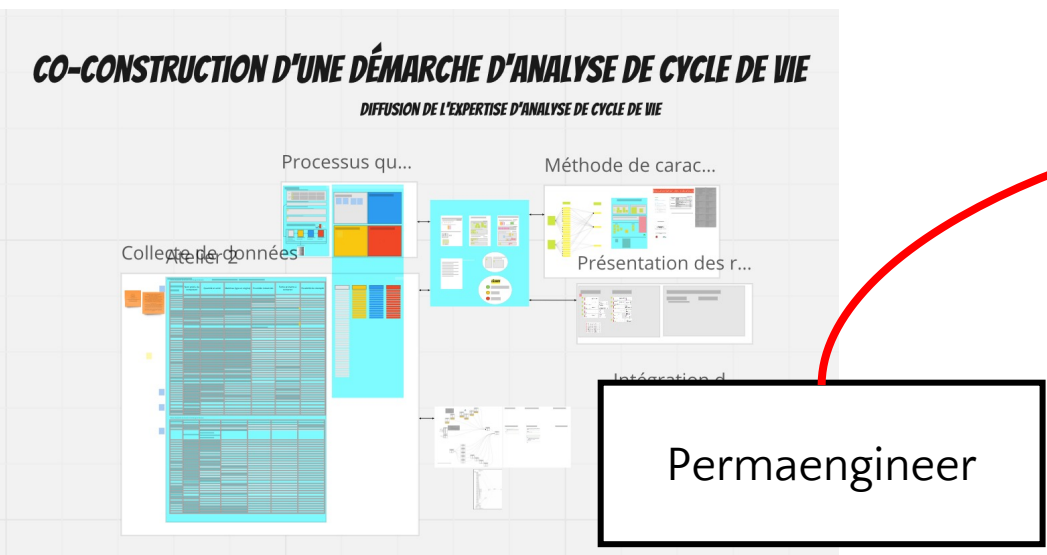


Strong sustainability



Questioning the application domain
Attention to relation (not blocking action)

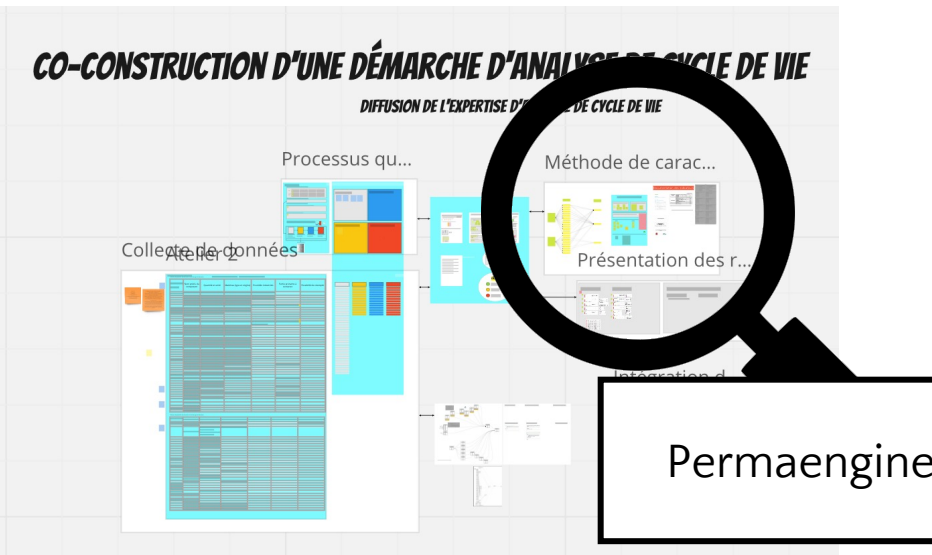
ACVnum prototype



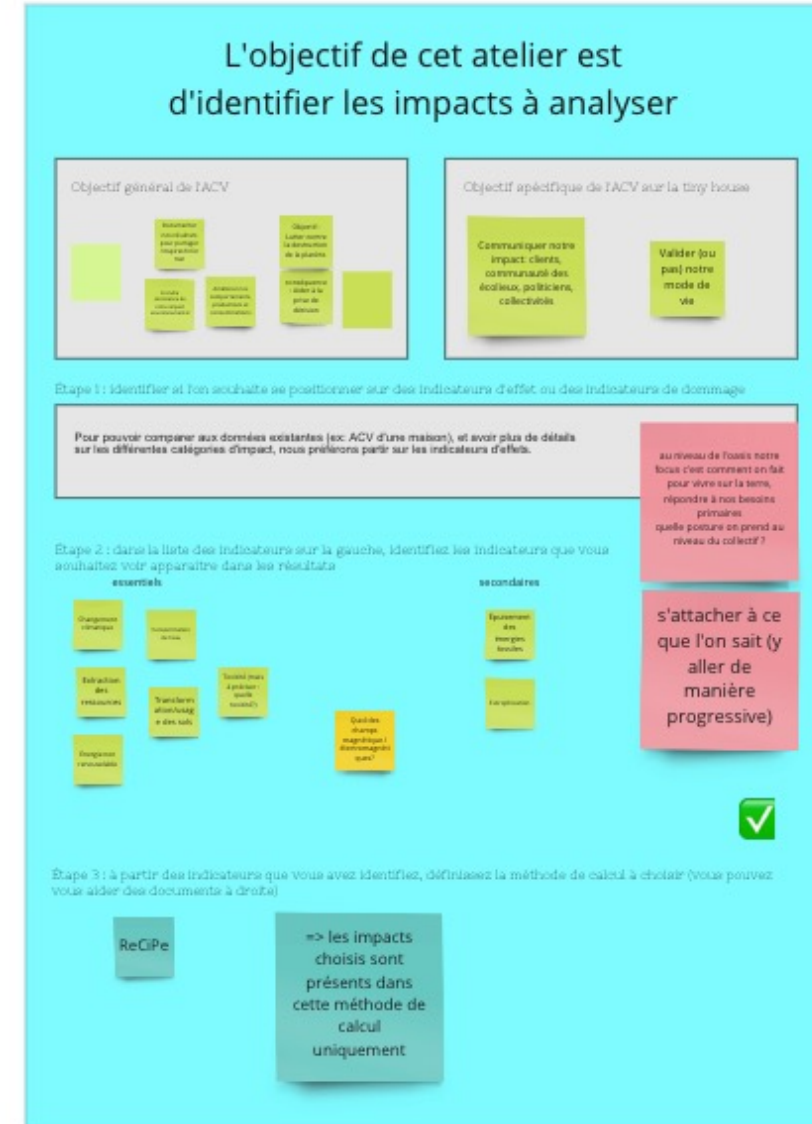
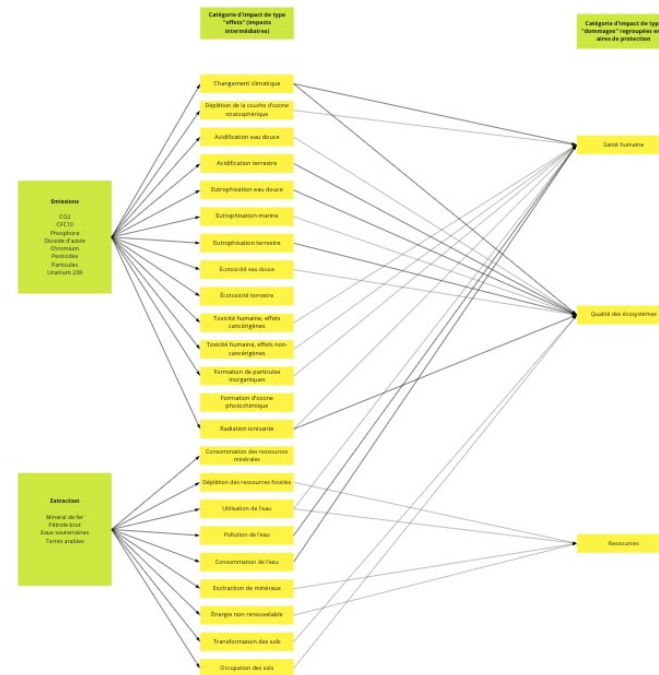
Questioning the application domain
Attention to relation (not blocking action)

[illegible]

ACVnum prototype



Définition des indicateurs et du modèle de caractérisation



Low-level of complexity
Supporting interaction among people
Artefact that can be modified
Artefact enabling learning

23

ACVnum prototype



Qu1

Question 1

Pas encore répondu

Noté sur 1,00

Marquer la question

Modifier la question

Quel est le niveau que vous vous donnez dans la compétence "capacité à travailler dans un groupe interdisciplinaire"?

ça veut dire quoi? Cela veut dire que vous êtes capable de comprendre des opinions et des besoins différents les uns des autres, que vous êtes capable de faire preuve d'empathie envers les autres membres de votre groupe.

- ☐ Niveau 0 : Je n'ai jamais développé cette compétence.
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- ☐ Niveau 2 : Je comprends et je peux parler de l'interdisciplinarité.
- ☐ Niveau 3 : Je connais l'interdisciplinarité car je l'ai pratiquée.
- ☐ Niveau 4 : Je sais gérer des groupes interdisciplinaires, je connais le concept, les outils techniques et méthodologiques.
- ☐ Je ne sais pas.

Question 2

Pas encore répondu

Noté sur 1,00

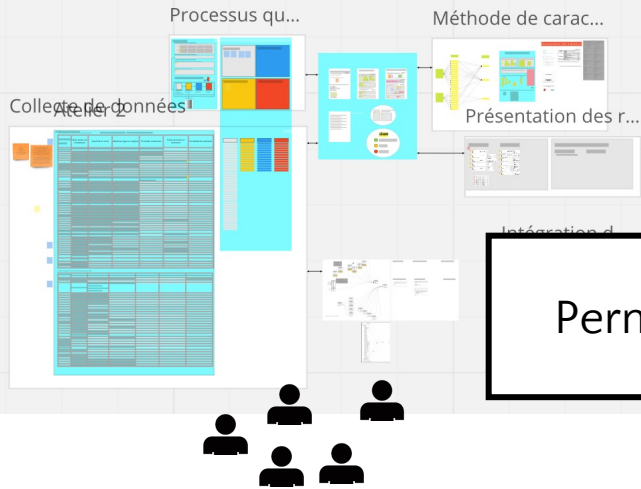
Marquer la question

Modifier la question

Pouvez-vous donner un exemple permettant de justifier votre choix? Si non, indiquez que c'est uniquement un ressenti.

CO-CONSTRUCTION D'UNE DÉMARCHE D'ANALYSE DE CYCLE DE VIE

DIFFUSION DE L'EXPERTISE D'ANALYSE DE CYCLE DE VIE



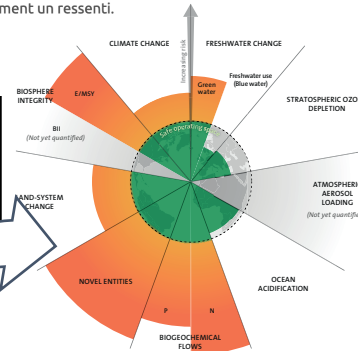
Permaengineer

Int1

Engineering competencies for sustainability

Strong sustainability

Actions and competencies



Regular LCA tools



- A system supporting the development of the 8 competences



Experiment in an ecovillage

In a (1) context of strong sustainability, (2) care ethics, (3) collaboration and (4) engineering competencies for sustainability enable to align values and actions

Heterogenous *focus group* (**actions** and **competencies**)

Individual interviews centred on **values** and **competencies** (7 months)

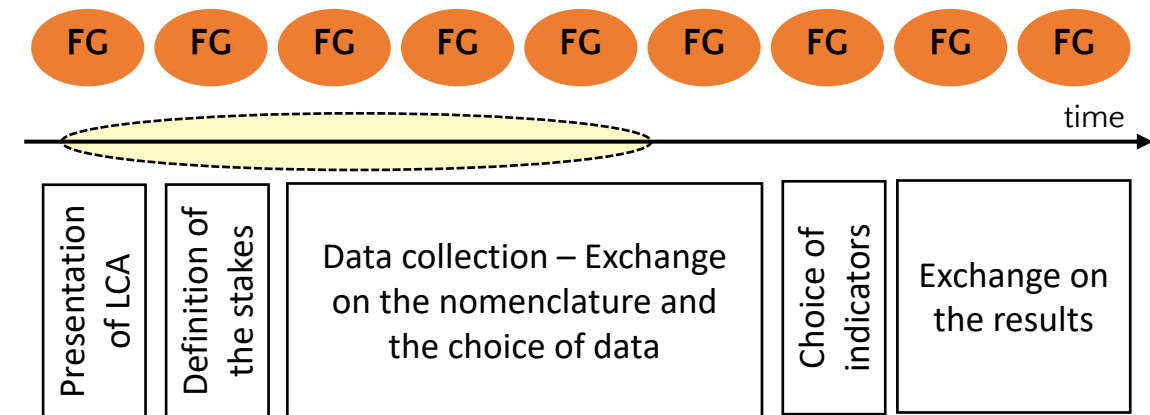
Group work sessions

Analysis with 3 main types of codes

- (1) Difficulties encountered by inhabitants
- (2) Elements easy to manage for inhabitants
- (3) Competencies developed along the process

Individual interviews

- 1) Motivational interviews [Pollak, 2011] & links with **values** [Friedman et al., 2006]
- 2) Interviews about the **competencies** developed [Quelhas, 2019], [de l'enseignement, 2011]

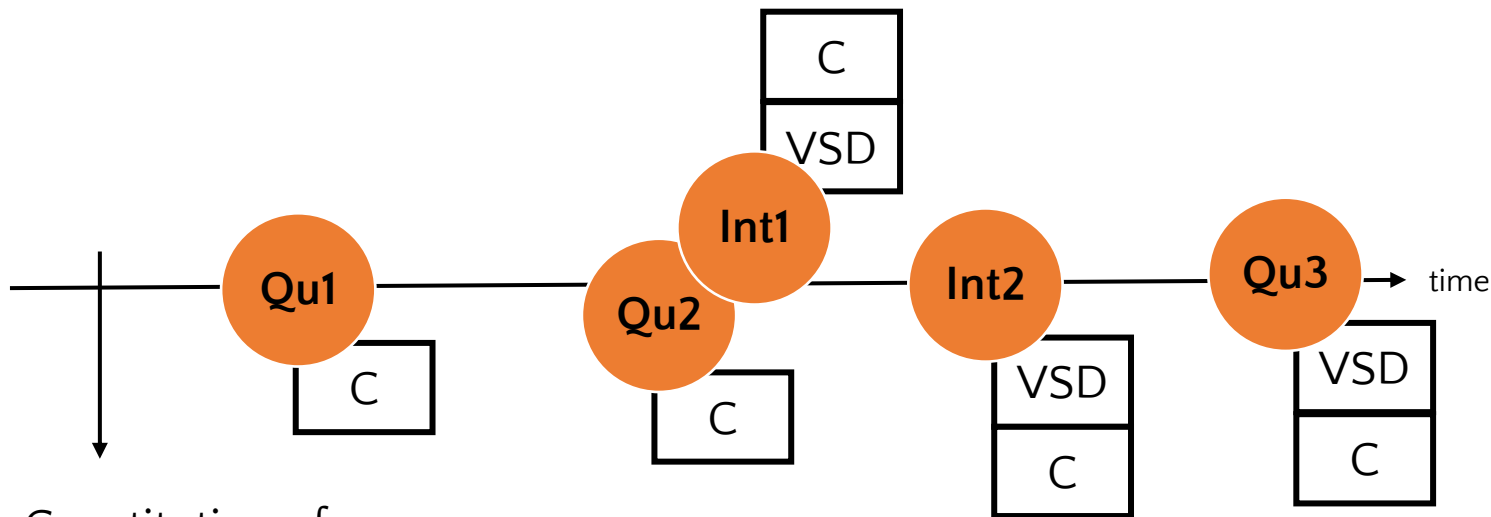


Experiment in a pedagogical context

In a (1) context of strong sustainability, (2) care ethics, (3) collaboration and (4) engineering competencies for sustainability enable to align values and actions

Goal: comparison of groups using ACVnum prototype and groups without the prototype

Groups: ACVnum groups (4) and control groups (4)



Constitution of groups
Choice of subject and “clients”

Question 1

Pas encore répondu

Noté sur 1,00

Marquer la question

Modifier la question

Quel est le niveau que vous vous donnez dans la compétence "capacité à travailler dans un groupe interdisciplinaire"?

ça veut dire quoi? Cela veut dire que vous êtes capable de comprendre des opinions et des besoins différents les uns des autres, que vous êtes capable de faire preuve d'empathie envers les autres membres de votre groupe.

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- ☐ Je ne sais pas.

Question 2

Pas encore répondu

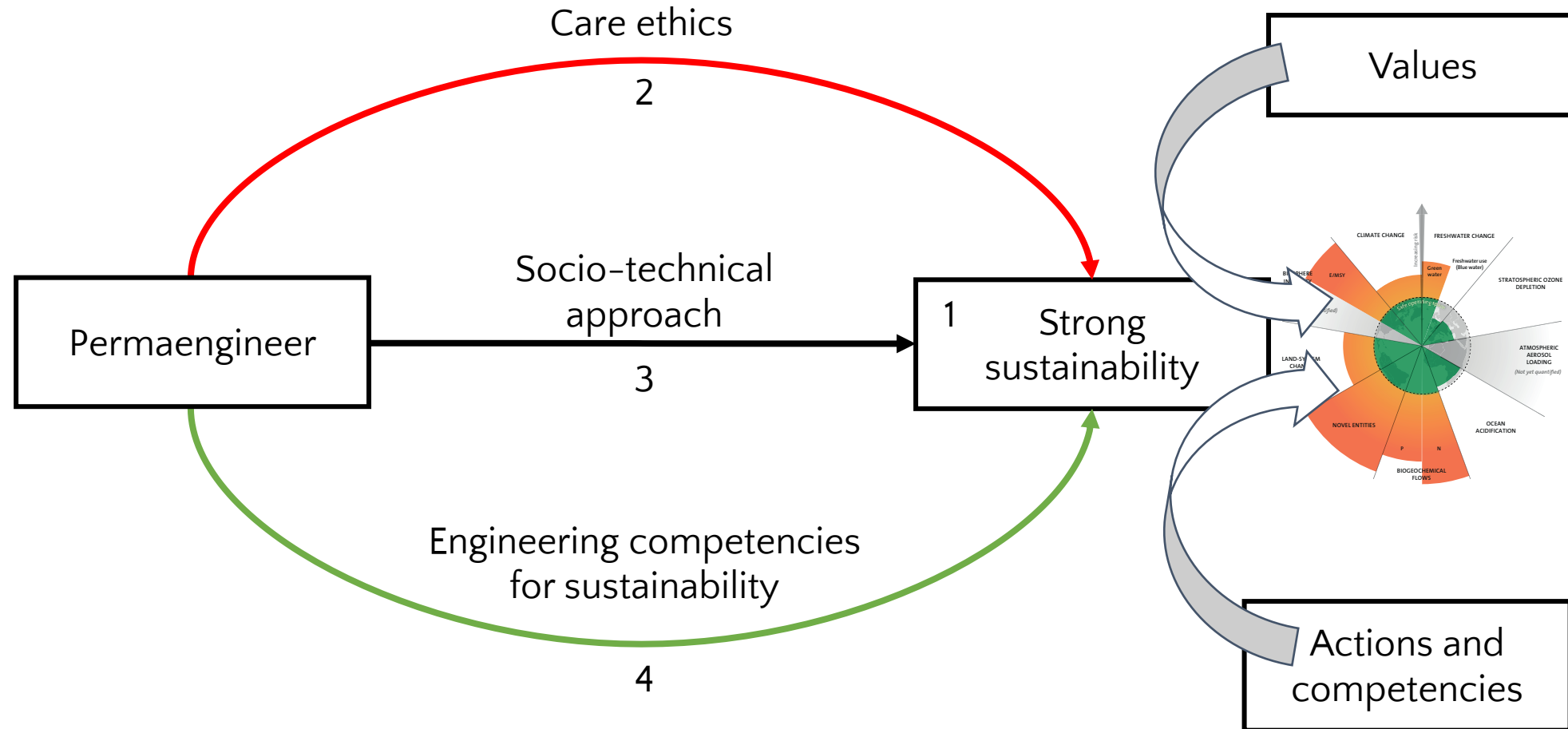
Noté sur 1,00

Marquer la question

Modifier la question

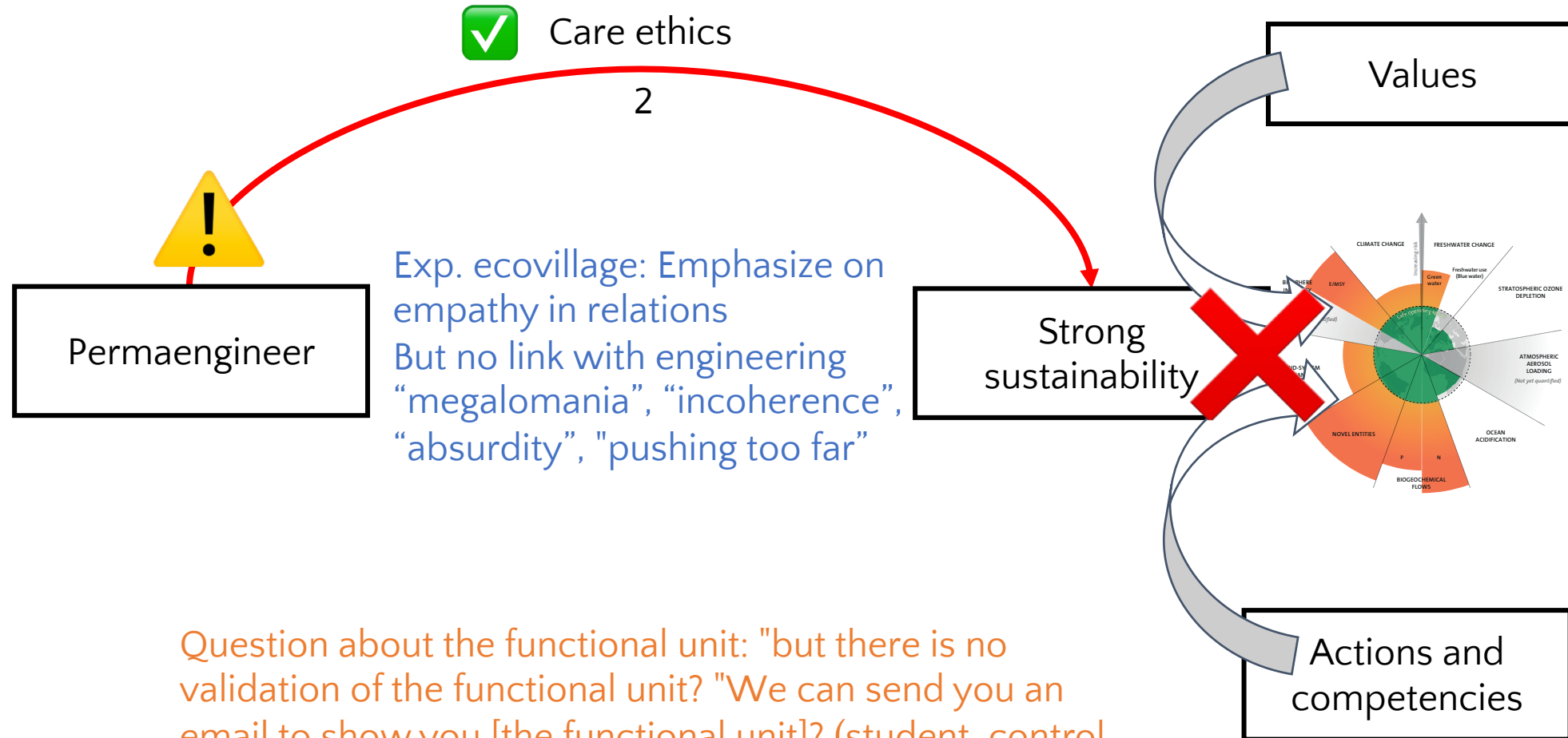
Pouvez-vous donner un exemple permettant de justifier votre choix? Si non, indiquez que c'est uniquement un ressenti.

Results



Care ethics

Exp. pedagogy: "I see the engineers more in a role of accompanying the transition process, with both a technical culture but also a knowledge of the issues of the territory in question, allowing them to dialogue and make the link between different actors" (student, ACVnum group)



Question about the functional unit: "but there is no validation of the functional unit? "We can send you an email to show you [the functional unit]? (student, control group)

Socio-technical approach

Exp. ecovillage

No collaboration with stakeholders external to the focus group

Whereas willingness to impact society at a local level

Implementation difficulties

Exp. pedagogy

Reluctance to collaborate (ACVnum groups > control groups)

1. The client was already an expert: « No because we had only 1 meeting with him. And he was already very engaged so he already knew all environmental actions possible to conduct »
2. Lack of interest from the client: « I don't think they had expectations from our work »

Permaengineer

Socio-technical approach

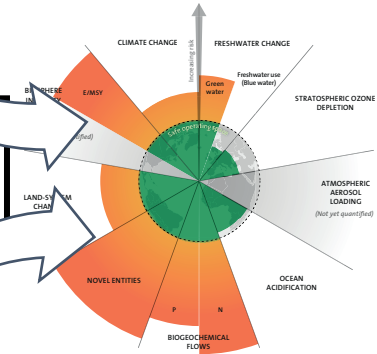
3



Strong sustainability

Values

Actions and competencies



Fear to have gaps between their work and clients expectations

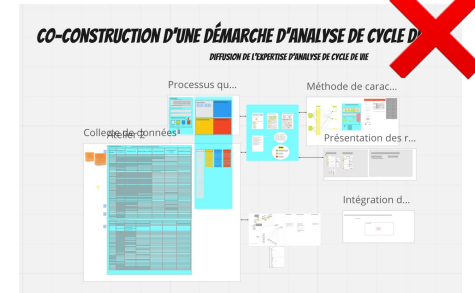
1. « I was afraid that we would end up being a bit silly with an LCA that would not meet their expectations »

Engineering competencies for sustainability

[Quelhas, 2019]



Interdisciplinary group
Self-knowledge
Normative competence
Systemic thinking
Ability to solve problems
Contextualisation and vision of the future
Critical thinking
Strategic competence



Exp. ecovillage

Already high level

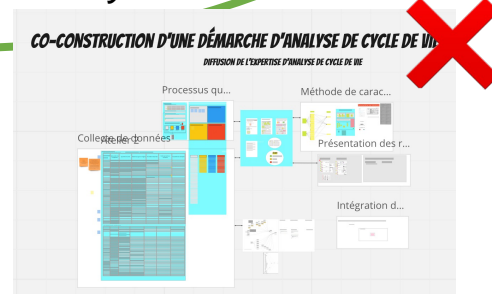
Formulation difficult to understand

Low impact of ACVnum prototype on inhabitants

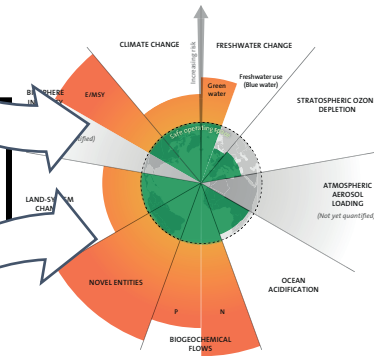
Permaengineer

Strong sustainability

Engineering competencies for sustainability



Values



Actions and competencies

Exp. pedagogy

No significative difference ($p > 0.05$)
between control groups and ACVnum
groups

Difficulty with normative competence

What kind of change do we need in engineering for strong sustainability contexts?

Engineering level

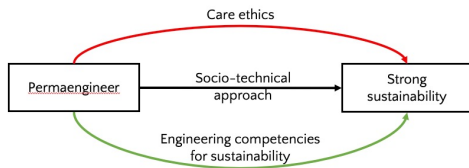
Gap 1: Design engineering in strong sustainability contexts is not enough addressed

RQ 1: In a context of ecological transition, to what extent **engineering** can evolve towards other ways of being and being practices?

Findings:

Better understanding the link between values and actions

Lack of normative competence is an hindrance to evolve towards strong sust.



Interactions level

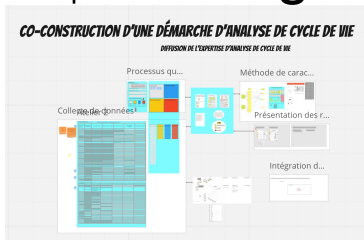
Gap 2: Lack of understanding of the role of HCI in strong sustainable

RQ 2: What are the **digital tools and methods** to support engineering practices in line with strong sustainability contexts?

Findings:

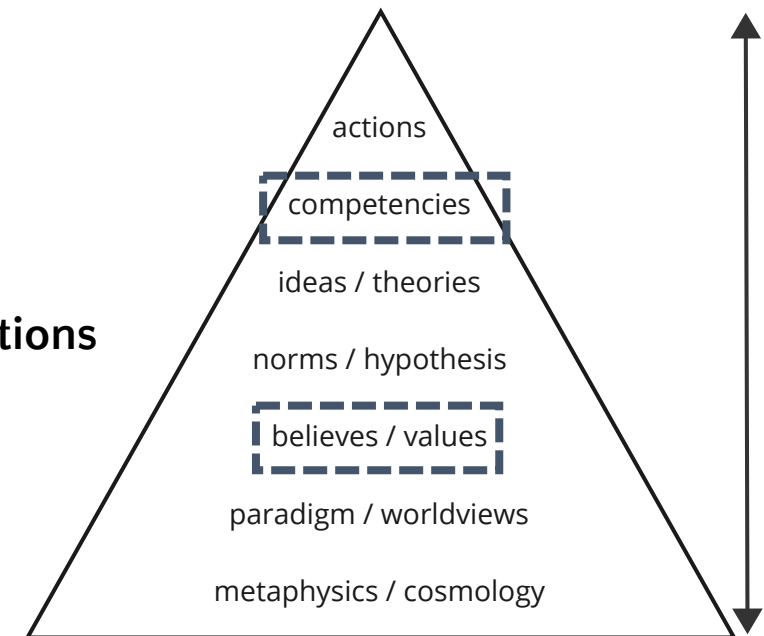
Artefacts can highlight the difficulty of collaboration

Difficult to change an already existing interactive tool into a strong sustainability one



Discussion and limits

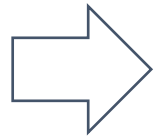
- **Evaluation and role of competencies**
 - Difficulty to assess the competencies [Wiek et al., 2011],
 - Scope of answers [Redman et al., 2021]
 - Methods to better collect and analysis data
- **Collaboration**
 - Interpretation of my results: why such a fear of collaboration?
 - LCA method and LCA software? ACVnum prototype?
 - Pedagogical situation?
 - Cultural difference between students and clients?
- **Still no good understanding of alignment process between values and actions**
 - Observations of gaps
 - Analysis of their origins



Perspectives

Perspective 1

Interdisciplinary group
Self-knowledge
Normative competence
Systemic thinking
Ability to solve problems
Contextualisation and
vision of the future
Critical thinking
Strategic competence

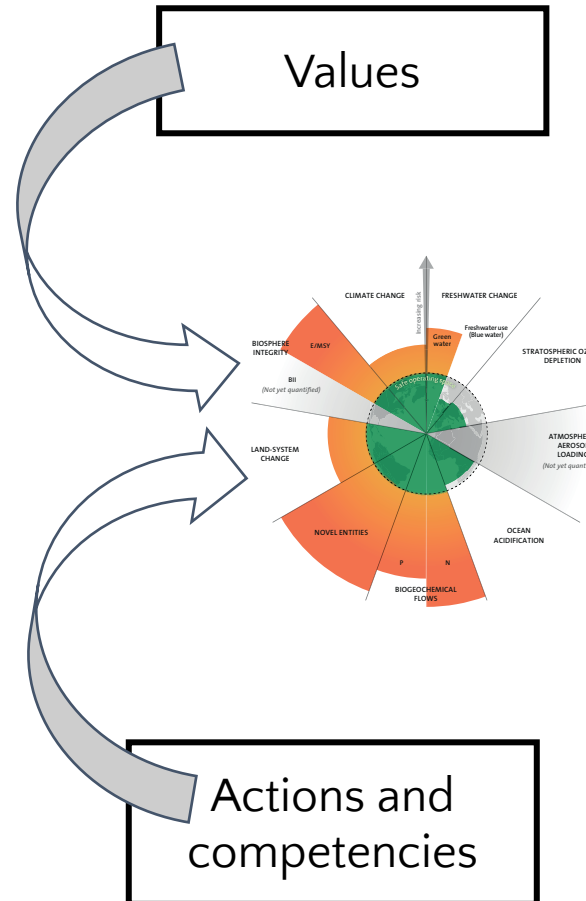


Assessment?
Links?
Global organisation?

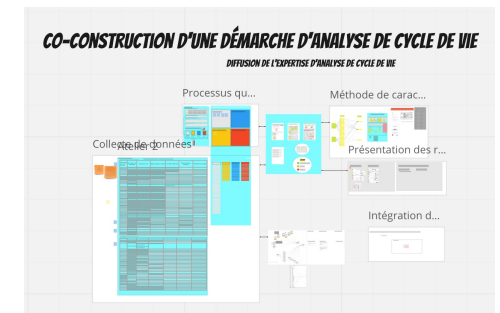
[Quelhas, 2019]

What is a permaengineer curricula?
Propose and test a curricula integrating
engineering competencies for
sustainability

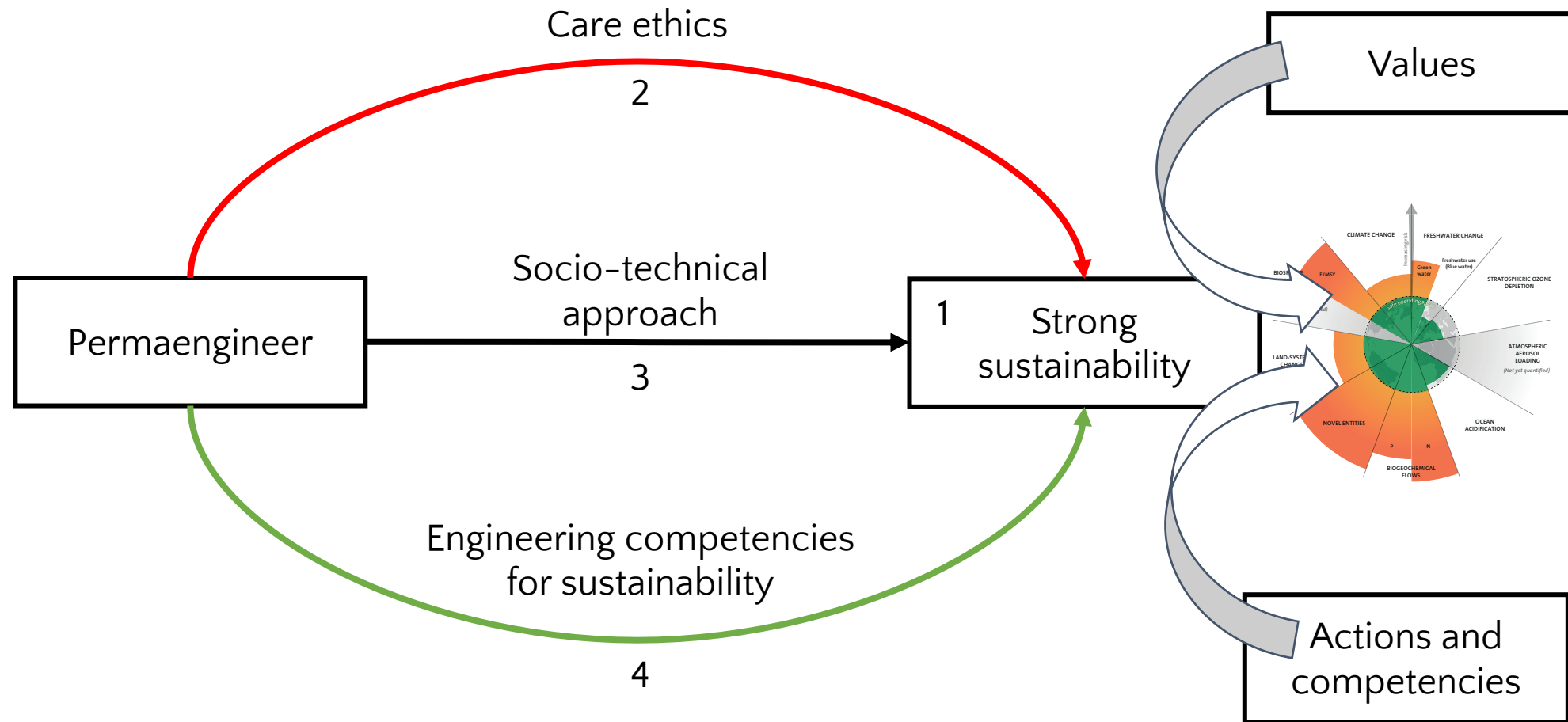
Perspective 2



Other mediation of
HCI for engineering in
strong sustainability
contexts



Permaengineering: a theoretical framework towards a strong sustainability paradigm in design. An HCI study



Thank you for your attention

Bibliography

- **[Vérin, 1993]** Vérin, H. (1993). La Gloire des ingénieurs. Albin Michel.
- **[Picon, 2004]** Picon, A. (2004). Engineers and engineering history : problems and perspectives. History and Technology, 20(4) :421–436. Publisher : Routledge _eprint : <https://doi.org/10.1080/0734151042000304367>
- **[Dias de Figueiredo, 2014]** Dias de Figueiredo, A. (2014). De la nature historique des pratiques d'ingénierie. Revue d'anthropologie des connaissances, 8, 2(2) :245–278. Place : Grenoble Publisher : S.A.C.
- **[Rockström et al., 2009a]** Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., and Schellnhuber, H. J. (2009a). A safe operating space for humanity. nature, 461(7263) :472–475. ISBN : 1476–4687 Publisher : Nature Publishing Group
- **[Persson et al., 2022]** Persson, L., Carney Almroth, B. M., Collins, C. D., Cornell, S., de Wit, C. A., Diamond, M. L., Fantke, P., Hassellöv, M., MacLeod, M., Ryberg, M. W., Sogaard Jorgensen, P., Villarrubia-Gomez, P., Wang, Z., and Hauschild, M. Z. (2022). Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. Environmental Science & Technology, 56(3) :1510–1521. Publisher : American Chemical Society.
- **[Rockström et al., 2009b]** Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin III, F. S., Lambin, E., Lenton, T. M., Scheffer, M., Folke, C., and Schellnhuber, H. J. (2009b). Planetary boundaries : exploring the safe operating space for humanity. Ecology and society, 14(2). ISBN : 1708–3087 Publisher : JSTOR.
- **[Steffen et al., 2015b]** Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., Vries, W. d., Wit, C. A. d., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., and Sörlin, S. (2015b). Planetary boundaries : Guiding human development on a changing planet. Science, 347(6223). Publisher : American Association for the Advancement of Science Section : Research Article.
- **[Wang-Erlandsson et al., 2022]** Wang-Erlandsson, L., Tobian, A., van der Ent, R. J., Fetzer, I., te Wierik, S., Porkka, M., Staal, A., Jaramillo, F., Dahlmann, H., and Singh, C. (2022). A planetary boundary for green water. Nature Reviews Earth & Environment, pages 1–13. ISBN : 2662–138X Publisher : Nature Publishing Group.
- **[Quelhas, 2019]** Quelhas, O. L. G., Lima, G. B. A., Ludolf, N. V.-E., Meiriño, M. J., Abreu, C., Anholon, R., Vieira Neto, J., and Rodrigues, L. S. G. (2019). Engineering education and the development of competencies for sustainability. International Journal of Sustainability in Higher Education, 20(4) :614–629. Publisher : Emerald Publishing Limited.

Bibliography

- **[Rauterberg, 2015]** Rauterberg, M. (2015). From Personal to Cultural Computing : how to assess a cultural experience.
- **[Biberhofer et al., 2019]** Biberhofer, P., Lintner, C., Bernhardt, J., and Rieckmann, M. (2019). Facilitating work performance of sustainability-driven entrepreneurs through higher education : The relevance of competencies, values, worldviews and opportunities. *The International Journal of Entrepreneurship and Innovation*, 20(1) :21–38. Publisher : SAGE Publications.
- **[Friedman et al., 2006]** Friedman, B., Kahn, P. H., and Borning, A. (2006). Value Sensitive Design and Information Systems.
- **[Dietz and Neumayer, 2007]** Dietz, S. and Neumayer, E. (2007). Weak and strong sustainability in the SEEA : Concepts and measurement. *Ecological Economics*, 61(4) :617–626
- **[Dewberry, 2011]** Dewberry, E. L. (2011). DEVELOPING AN ECOLOGY OF MIND IN DESIGN. *DS 68-5: Proceedings of the 18th International Conference on Engineering Design (ICED 11), Impacting Society through Engineering Design, Vol. 5: Design for X / Design to X, Lyngby/Copenhagen, Denmark, 15.-19.08.2011*, 165–175.
- **[Dourish, 2010]** Dourish, P. (2010, August). HCI and environmental sustainability: the politics of design and the design of politics. In *Proceedings of the 8th ACM conference on designing interactive systems* (pp. 1-10).
- **[DiSalvo et al. , 2010]** DiSalvo, C., Sengers, P., & Brynjarsdóttir, H. (2010, April). Mapping the landscape of sustainable HCI. In *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 1975-1984).
- **[Bremer, 2022]** Bremer, C., Knowles, B., & Friday, A. (2022, April). Have We Taken On Too Much?: A Critical Review of the Sustainable HCI Landscape. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (pp. 1-11).
- **[Brynjarsdóttir, 2012]** Brynjarsdottir, H., Håkansson, M., Pierce, J., Baumer, E., DiSalvo, C., and Sengers, P. (2012). Sustainably unpersuaded : how persuasion narrows our vision of sustainability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '12*, pages 947–956, New York, NY, USA. Association for Computing Machinery.
- **[Pargman and Raghavan, 2014]** Pargman, D., & Raghavan, B. (2014, October). Rethinking sustainability in computing: From buzzword to non-negotiable limits. In *Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational* (pp. 638-647).

Bibliography

- **[Hansen, 2020]** Hansen, A.-M. S. (2020). The App Is Not Where the Action Is : Discussing Features of an Internal Communication System for a Permaculture Village. In Proceedings of the 7th International Conference on ICT for Sustainability, ICT4S2020, pages 275–284, New York, NY, USA. Association for Computing Machinery.
- **[Norton et al., 2019a]** Norton, J., Penzenstadler, B., McDonald, S., Kang, E., Koirala, N., Konishi, R., Carmona, G. P., Shah, J., Troncoso, S., and Tomlinson, B. (2019a). The SAGE Community Coordinator : A Demonstration. In Proceedings of the Fifth Workshop on Computing within Limits, LIMITS '19, pages 1–10, New York, NY, USA. Association for Computing Machinery.
- **[Norton et al., 2019b]** Norton, J., Penzenstadler, B., and Tomlinson, B. (2019b). Implications of Grassroots Sustainable Agriculture Community Values on the Design of Information Systems. Proceedings of the ACM on Human-Computer Interaction, 3(CSCW) :34 :1–34 :22.
- **[Mollison 1988]** Mollison, B. (1988). Permaculture: a designer's manual. Permaculture: a designer's manual.
- **[Liu et al., 2018]** Liu, S.-Y. C., Bardzell, S., and Bardzell, J. (2018). Out of control : reframing sustainable HCI using permaculture. In Proceedings of the 2018 Workshop on Computing within Limits, pages 1–8.
- **[Fisher and Tronto, 1990]** Fisher, B. and Tronto, J. (1990). Toward a feminist theory of caring. In Circles of Care : Work and Identity in Women's Lives, pages 35–62. SUNY Press.
- **[Blouin, 2012]** Blouin, M. (2012). Définir l'ingénierie écologique: quels enjeux?. *Ingénierie écologique: action par et/ou pour le vivant*.
- **[Seager, 2012]** Seager, T., Selinger, E., & Wiek, A. (2012). Sustainable engineering science for resolving wicked problems. *Journal of agricultural and environmental ethics*, 25, 467–484.
- **[Gagnon, 2009]** Gagnon, B., Leduc, R., and Savard, L. (2009). Sustainable Development in Engineering : A Review of Principles and Definition of a Conceptual Framework. *Environmental Engineering Science*, 26(10) :1459–1472. Publisher : Mary Ann Liebert, Inc., publishers.
- **[Alha et al., 2000]** Alha, K., Holliger, C., Larsen, B. S., Purcell, P., and Rauch, W. (2000). Environmental engineering education-summary report of the 1st european seminar. *Water science and technology*, 41(2) :1–7.

Bibliography

- **[Borrion et al., 2019]** Borrion, A., Matsushita, J., Austen, K., Johnson, C., and Bell, S. (2019). Development of LCA Calculator to support community infrastructure co-design. *The International Journal of Life Cycle Assessment*, 24(7) :1209–1221.
- **[Pollak et al., 2011]** Pollak, K. I., Childers, J. W., & Arnold, R. M. (2011). Applying motivational interviewing techniques to palliative care communication. *Journal of palliative medicine*, 14(5), 587–592.
- **[Sakellariou, 2018]** Sakellariou, N. (2018). A historical perspective on the engineering ideologies of sustainability : the case of SLCA. *The International Journal of Life Cycle Assessment*, 23(3) :445–455.
- **[Wiek et al., 2011]** Wiek, A., Withycombe, L., and Redman, C. L. (2011). Key competencies in sustainability : a reference framework for academic program development. *Sustainability Science*, 6(2) :203–218.
- **[Redman et al., 2021]** Redman, A., Wiek, A., and Barth, M. (2021). Current practice of assessing students' sustainability competencies : A review of tools, *Sustainability Science*, 16(1) :117–135.