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# Aligning science education in formal contexts with the modus operandi of R&I

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# Research background

- Educational systems have been criticised as static, rigid, and incapable to keep the pace of technological and social changes (OECD, 2018; EC, 2015).
  - Knowledge organisation into disciplines with their own culture, cognitive and epistemological lenses is seen as a source of the young generation's loss of hope, disengagement from public life and lack of competencies to deal with challenges in life (Benasayag and Schmit, 2006) in the society of acceleration and uncertainty (Rosa, 2013).
  - ❖ Interdisciplinary educational models such as STEAM are argued to instill creativity, innovation, and synergy through collaboration, teamwork, application, and blurring of disciplinary boundaries (Haynes, 2017) and have a positive effect on adapting curricula to students' diversity (Liao et al., 2016).
  - ❓ There is a need to revise the institutional, methodological and conceptual organization in traditional disciplines in order to align science education at schools and universities with the inter-multi-transdisciplinary, multi-actor and open character of R&I.
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# Research aim

To construct a research evidence-based framework that aligns science education in formal educational contexts with the modus operandi of R&I and equips young people with future-scaffolding skills.





## 4 sub-studies and data triangulation

- **Literature review** (N=1469 n=378, Sept 2020-Jan 2021)
- **Cross-national interviews** (n=30; 20 collected in Feb-May 2021, 10 until May 2022)
- **Interdisciplinary study groups** (n=2, Jan-Feb 2021)
- **Cross-national surveys** (Students n=346, experts n=42, Feb-Apr 2022).

# Key terms

**Disciplinary or vertical knowledge organisation** denotes structuring of knowledge into single disciplines via curricula, research management, internal institutional design, teacher training, logic of national funding.

**Interdisciplinary knowledge organisation** encompasses all other forms of knowledge organisation that go beyond single discipline teaching, curriculum, education and research management etc.

**Boundary** is a metaphor of a borderline adapted from Akkerman & Bakker (2011) to model interdisciplinarity and its “paradoxical” nature: boundary both separates and connects.

**Barrier** is a metaphor that is used to denote a borderline which separates disciplines or professionals and is hard to overcome.



# Results

5 issues identified:

- Divergence between *de jure* and *de facto*,
- Demands from teachers,
- Disciplinary isolation and lack of interdisciplinary language,
- Graduates unprepared for life, and
- Social insensitivity.

Followed by Ways to address them and Recommendations for co-teaching and open-schooling.

ISSUES WHEN PROMOTING INTERDISCIPLINARITY	WAYS TO CROSS THE BOUNDARIES AND/OR DECONSTRUCT BARRIERS TO INTERDISCIPLINARITY
Divergence between <i>de jure</i> and <i>de facto</i> ▶	<ul style="list-style-type: none"><li>• Reengineering governance of educational institutions</li><li>• Changing criteria for evaluating research and study programmes quality at national level</li><li>• Acknowledging professional identity of teachers as co-constructors/co-facilitators of discipline-wise respectful learning spaces</li><li>• Changing criteria for teachers' recruitment and performance assessment</li><li>• Supporting creation of and acknowledging a context for co-teaching</li></ul>
Demands from teachers ▶	<ul style="list-style-type: none"><li>• Developing the core teaching team for STEM curricula</li><li>• Developing templates for Interdisciplinary teaching resources</li><li>• Accepting the notion that one cannot be expert in every science field and trusting co-teachers</li></ul>
Disciplinary isolation and lack of interdisciplinary language ▶	<ul style="list-style-type: none"><li>• Changing the attitude and becoming a "disciplinary nomad"</li><li>• Creating "third spaces" to learn taking and making different perspectives</li><li>• Integrating sense making with "strange making" skills</li></ul>
Graduates unprepared for life ▶	<ul style="list-style-type: none"><li>• Fostering the connection between formal and informal education</li><li>• Integrating scientific uncertainty and philosophy into curricula to develop interdisciplinary competences</li><li>• Fostering interdisciplinarity as a way to innovate and address complex problems</li><li>• Institutionalising interdisciplinarity to promote participative learning forms</li></ul>
Social insensitivity ▶	<ul style="list-style-type: none"><li>• Capitalising on the advantages of interdisciplinarity to offer curriculum differentiation for diversity (gender, cultural and socio-economic background, personal motivation) of students</li></ul>

# Divergence between *de jure* and *de facto*

**National regulations and institutional inconsistencies obstruct interdisciplinarity, institutional competitiveness and social impact**

- Although interdisciplinarity is promoted by strategic programmes, national criteria for institutional research and study programme assessment and funding still promote disciplinarity.
- Structural changes are made in RPOs to create diverse teams to address grand challenges, yet, the processes are not aligned with human resource management practices.

*Interdisciplinarity is a very relevant topic, but institutions (e.g. through formal school programs or through systems of reward, promotion, evaluation, funding) do not provide real guidance on how to manage interdisciplinarity. (Study group data)*

- Cultural aspects induced within institutional domains manifest themselves as perceptions that become implicit assumptions, rituals, habits of minds and can **emerge as emotional barriers**.

# Demands from teachers

*“lack of time, lack of will, lack of creativity”*

## Practising interdisciplinarity is challenging to teachers and researchers

- Interdisciplinarity threatens teachers' authority, self-confidence, and identity, creates discomfort or insecurity (emotional barriers):
  - It requires expertise in several disciplines,
  - It demands student-centred pedagogy and more dialogical forms of science communication with students (Bickmore, 2014:2).

*Besides the funding problem, besides, you know, the recruiting problem and the publication, the ranking of researchers, there's also an issue of identity of researchers (IT07 Philosophy and law RPO M).*
- Integrating technology within a subject area may be time consuming and complex to teachers (Chang et al., 2012).

Experts' views on the properties of disciplinary (1) vs. interdisciplinary (5) approaches

It challenges the ways in which work at schools is organized.
It demands additional efforts for teachers' preparation and development.
It requires too much administrative effort.
It helps students to perceive the interrelations between phenomena constituting the complexity of societal arrangements.
It creates social networking advantage to students.
It gives more opportunities to capture advantages of diversity of a students' group.
It opens up opportunities for diverse methods of teaching/learning (working).

Average	N
4.37	43
4.33	42
4.21	39
4.13	38
4.02	41
3.98	43
3.95	43

# Disciplinary isolation and lack of interdisciplinary language

## Disciplinary isolation and lack of interdisciplinary language to talk across different perspectives

- Closed cultures of conducting research and HRM practices, particularly in RPOs.
- Lack of common language or keeping the same metalanguage.
  - ...if you talk now in our faculty with a person who does particle physics, axiomatic theory, solid state physics, astrophysics, sometimes they don't even have a common language" (IT09 Physics RPO M)*
  - Disciplinary closed communities, in order to strengthen their **identities**, develop proper **symbolic languages, representations and communication practices**. When languages are competing, it can happen that there is little motivation to change (Study group).*
- Disciplinary knowledge organisation creates a 'silo' effect, which constructs **social, cultural and institutional barriers** as well as **cognitive and epistemological boundaries** to embrace interdisciplinarity in educational institutions.
- Barriers to innovation.

# Graduates unprepared for life

## Disciplinary knowledge organisation does not prepare graduates for work life and beyond

- Discipline-based approach is seen as erecting **systematic barriers** to developing transferrable skills needed by labour market and practical life, e.g. applying conceptual knowledge to practical problem-solving, self-confidence and efficacy, communication, existential skills, teamworking, life-long learning skills, futures thinking skills etc.

*Traditional lecture methods applied to large classrooms seem in this light more and more inadequate to our fast-changing societies, as they do not promote discussion and are adverse to problem-solving attitudes (Cowan 1999 : 33)".*

*Maybe that discipline is prepared, learned, but how to continue living in the world and how to communicate is not. Everyone gets this through practice" (LT06 Management Business F).*

Collaboration skills  
Appreciation of diversity in society  
Creativity skills  
Leadership skills  
Sustainability skills

4.17	42
4.13	39
4.02	41
3.93	41
3.93	41

Personal identity  
Self-regulation  
Career orientation  
Scientific identity  
Academic achievement

3.38	42
3.37	38
3.26	39
2.61	41
2.56	41

Experts' views on the skills produced by disciplinary (1) vs. interdisciplinary (5) approaches

# Social insensitivity

## Disciplinary education is less socially sensitive

- Rote learning, standardised tests, academic achievements driven culture fails to respond to the growing diversity.
- Intersectionality of students' race, ethnicity, gender, disability and other social categories decrease chances of socially excluded or underrepresented groups to pursue education in science.
- Western science curriculum is little relevant to the local culture and environment as well as indigenous ways of knowing (Kerr et al., 2018).

*I could think about a bit of like sort of ... gender kind of barriers because we're talking about still a very kind of male dominated, kind of academic and political world. And I think about gender because we're not particularly advanced kind of society in terms of multi ethnicity and so on"*  
(IT06 Engineering, Business Administration, RPO and Policy-Making F).

# Ways to address the issues

- Re-engineering governance and changing institutional processes, adding qualitative criteria to quantitative ones.
- Emphasis on collaboration at institutional level may contribute to maintaining **teacher teams** with the mindset of **co-ownership of interdisciplinary courses**.
- Developing **supporting materials** to teachers, including assessment of interdisciplinary learning.

Measurement of achievement should focus on deep learning as manifested by *“higher order cognitive skills, and more importantly, skills that support transferable learning, and abilities such as collaboration, complex problem solving, planning, reflection, and communication of these ideas through use of appropriate vocabulary of the domain in addition to presentation of projects to a broader audience (Conley and Darling-Hammond, 2013).*

- Developing an identity of a “disciplinary nomad” – accepting risks and ambiguity
- Establishing a virtual or physical “third space”

*Boundary crossing mechanisms are “learning potentials” that need to be activated. Their activation can be facilitated if the “trading zone” is properly created or if it occurs in “new contexts” or “third spaces”, where habits are given up and roles of participants are clear or have been made clear. (Study group)*

- New development programmes to the academic/teaching staff that are oriented to **learning other participants’ world views** through critical “conversations between disciplines, whilst retaining the integrity of those disciplines” (Davidson, 2004:302).

# Ways to address the issues 2



- **Cultural transposition** to enable cognitive and epistemological boundary crossing. Balancing *between sense-making skills (systems, critical, analytical thinking) and strange-making skills (creative, imaginative, anticipative thinking)* beside managing tensions between belonging-nonbelonging, defining-negotiating meaning, going in-out of a comfort zone, zooming in-zooming out (from details to big pictures and vice versa). (Study group)
- Integrating scientific uncertainty and philosophy of science into curricula to promote broader views and enable interdisciplinarity.
- Developing informal science education initiatives.
- **Curriculum differentiation**, rather than pedagogical differentiation, as an organisational response to the diversity of students' abilities (Gamoran et al., 1995) may make different knowledge available for different groups of students (Oakes et al., 1992).
- Providing language checklists would enable crossing the barrier of social exclusion.



# Recommendations to Open-Schooling and co-teaching

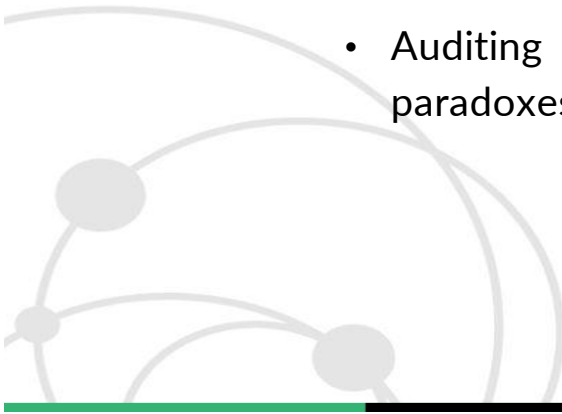



- Setting up the **trading zone** and designing a choreography to safely guide participants to “embrace the **ambiguity of interdisciplinarity**”. The spaces should also serve for coining a common language between different disciplines.
- Unpacking the skills needed to accept the risk, embrace ambiguity and managing the equilibrium between the “*sense making and strange making skills*”.
- Relating interdisciplinary experiences with the mindset of creating value to society, both as an individual characteristic and a criterion for evaluation of educational institutions performance.





# Recommendations to education policy makers

- Fostering the creation of - or the search for - locations and institutional contexts that can act as “third spaces”, that is, **spaces that do not belong to any disciplinary context** but that are inhabited in safe and creative ways.
  - Promoting a cultural change in educational institutions aimed to overcome a “**binary perspective**” (either disciplines or interdisciplinarity) and to boost “embracing uncertainty, ambiguity, sense of belonging - not belonging”, merging new professional identities that are based on interdisciplinarity.
  - Auditing organisational processes, in particular, HRM to detect gaps creating paradoxes and discouraging interdisciplinarity.
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**Thank you for your  
attention!**