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Transdisciplinarity and Microbiology Education

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INTRODUCTION

Transdisciplinarity offers interesting insights into the scientific educational environment. According to Max-Neef (14), multidisciplinary indicates the simultaneous or sequential study of more than one area of knowledge, without making any connections between them; pluridisciplinarity contemplates cooperation between disciplines, without coordination; interdisciplinary implies disciplinary cooperation between two hierarchical levels; transdisciplinarity indicates a disciplinary cooperation among the four levels of a pyramidal hierarchical discipline organization (Fig. 1).

From the bottom to the top of the pyramid we can find: i) disciplines of the empirical level, ii) disciplines that constitute the pragmatic level, iii) disciplines of the normative level, and iv) disciplines of the value level.

Disciplines at the bottom of the pyramid refer to what exists, describing the world as it is. Disciplines of the second level ask and answer the question: "What are we capable of doing?" Disciplines of the third level represent the normative level ("What do we want to do?). Finally, the top level (disciplines of the value level) asks and answers the question: "How should we do what we want to do?" As Max-Neef (14) describes it, "we travel from an empirical level, towards a purposive or pragmatic level, continuing to a normative level, and ending up at a value level." A transdisciplinary action creates multiple vertical relations encompassing all four levels.

As we know, often real problems are not categorized into disciplines. "The core idea of transdisciplinarity is different academic disciplines working jointly with practitioners to solve a real-world problem. It can be applied in a great variety of fields" (12).

In addition, sustainable development and transdisciplinarity are closely related. On the one hand, transdisciplinarity intrinsically aims at meeting the needs of the present without compromising the ability of future generations to meet their own needs (14). On the other hand, education and research for sustainable development have to be "issue-oriented and reflect diversity, complexity, and dynamics of the processes involved, as well as variability among specific problem situations" (9). From this perspective, in this contribution we argue that transdisciplinarity introduces a suitable and innovative tool in microbiology and biology education.

PROCEDURE

The pyramid (Fig. 1), as a tool, helps us in the design of practical classroom activities that deal with transdisciplinarity, microbiology, and, more generally, with biology. A transdisciplinary action/topic is any multiple vertical relation which includes all the four levels of the pyramid. Of course, not all the microbiologically related themes require and/or take advantage of this integrated perspective. In Table 1, we suggest some exemplificative transdisciplinary topics/actions of microbiological interest. As regard to classroom implementation, we propose two main practical approaches. On the one hand, we can concretize/realize transdisciplinarity through a new design of the lesson, which shall rely on a team of four teachers/professors representing disciplines from all the four levels of the pyramid. On the other hand, a class debate with a teacher–moderator shall be used as a Trojan horse to launch the insights into the newly proposed point of view. The presence of four teachers/professors provides a rigorous study of the topics together with a concretized high-quality transdisciplinarity. Conversely, the class discussion promotes student involvement and the development of critical thought.

The first approach needs considerable resources (four professors for the same lesson) and appropriate team management. The second approach necessitates a simpler organization, though it requires appropriate moderator preparation in order to "drive" the class debate in a transdisciplinary perspective. It is probably possible to find a balance integrating the two approaches, with a first brief rigorous demonstration of transdisciplinary dynamics by the four professors, and a second extensive phase of class debate (even after a division into groups) concerning other topics (e.g., those reported in Table 1). The lesson should start with an introduction of the issue, followed by an iterative process among the four levels in order to develop a viewpoint that blends the needs of all the involved stakeholders with those of future generations towards a concrete, efficient, valid, and sustainable solution.

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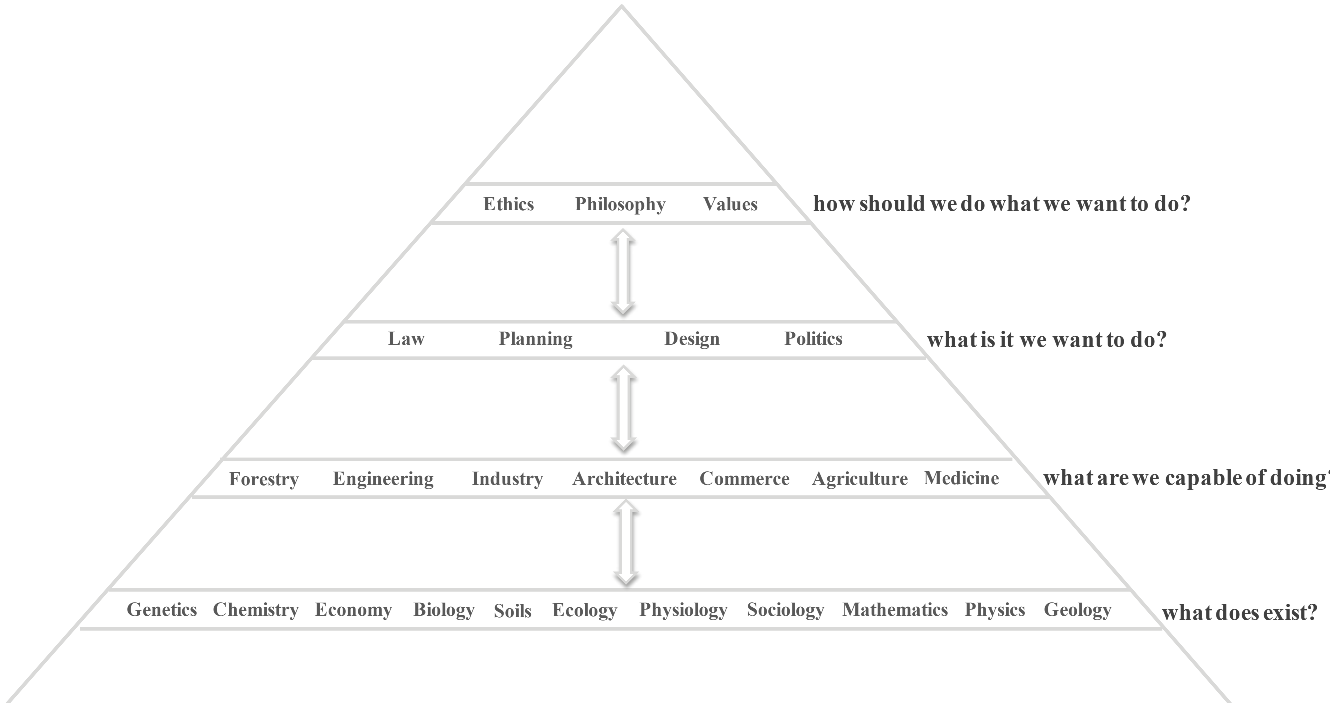

FIGURE 1. Graphical representation of the transdisciplinary pyramid, according to Max-Neef (14).

Here, we provide the exemplificative case of a lesson schedule on "Microbial Commons" (MC), in order to simulate the main possible phases of a transdisciplinary lesson. "Commons" are defined as resources that are shared by communities (8). These resources "in common," including natural resources and common lands, require shared decisions to be managed and used. "This also applies to research in microbiology, where the need to access reference materials for identification purposes, the specialization amongst collections of microbial materials, and collaborative efforts for increasing our understanding of the biodiversity of microorganisms result in interdependency amongst research communities on the global scale" (7). Thus, we use the term MC when the shared resources are of microbial nature. The four involved disciplines (eventually professors) are biology, economics, policy, and values.

The introduction of the lesson focuses on the concept of commons, with examples of biological- and commons-related milestones such as climate change, health, biodiversity, and food security (economics). After the introduction, the lesson goes on with an iterative path among the disciplines:

- The importance of microbes in human life, highlighting both positive and negative influences (biology).
- The concept of MC based on the sharing of microbiological materials and the required facilities in terms of culture collections and of Internet-based platform for data exchange (5) (economics).
- MC in practice: the importance of well-defined taxonomies of the organisms involved in the community exchanges (15), and the importance of MC in agriculture and food microbiology (7) (biology). In this section it is possible to link to other lessons on microbial taxonomy (15), rhizobia symbiotic nitrogen fixation (13), biological control in agriculture (10), networks for the diagnosis of plant pathogens (2), and the preservation and distribution of yeasts (4).
- The relevance of microbial commons for the present (economics) and future (values) generations.
- The present situation: biological resource centers (BRCs) and exchanges of microbial materials among scientists (19) (biology).
- The changing environment: world exchange increase of microbial materials, need of an appropriate quality management, and related changes in the international legal environment (7) (economics).
- The costs issue: the techniques employed and the management of a culture collection (biology).
- The scientific and ethical relevance of free exchanges of microbial materials among scientists (values), and the commercial and scientific protection (economics) under formal material transfer agreements (MTAs) (19).
- These neglected resources are the building blocks for future scientific research and have enormous value for sustaining biodiversity and local livelihoods (values).
- The importance of a systematic framework and of specific policies to improve MC management (policy).
- The major obstacles of legal (policy), institutional (values), and economic (economics) nature (for an in-depth examination, see (5) and (6)).
- The microbial resource management regimen in the patent framework.

TABLE 1.
A suggestion of transdisciplinary topics related to microbiology.

Exemplificative Topics	Transdisciplinary Dimension
microbiological commons (7, 8)	economics, law, values/ethics/philosophy
economic value of micro-biodiversity	economics, planning, values/ethics
microbial digestion for biomass energy production	industry, law, values/ethics
ethno(micro)biology and ethnomedicine	agriculture/medicine, planning, values/ethics
starter cultures for food fermentations	industry/commerce, law, values/ethics
social media in biology education (17)	economy, politics, values/ethics/philosophy
microbial ecology models for social behaviours (1)	economy, politics, values/ethics/philosophy
quorum and anti-quorum sensing	medicine, design, values/ethics
microbiological autochthonous resources regimen in food geographical indications (3)	economy, law, values
gut microbiota	medicine, design, values/ethics
kairomones, allomones, and synomones; vertebrate-prokaryote chemical communication (18)	medicine, design, values/ethics
predictive microbiology	engineering, design, values/ethics
management of microbiological safety	medicine, planning/law, values/ethics
plant growth-promoting bacteria	agriculture, design, values/ethics
forestry biotechnology	forestry, planning, values/ethics/philosophy
bacterial resistance to antibiotics	medicine, planning/politics, values/ethics
microbial fuel cells	engineering, design, values/ethics
agricultural biotechnology and the poor (16)	economics, planning, values/ethics/philosophy
microbial synthesis of hydrocarbons	engineering, design, values/ethics
systemic design in microbiological resources production	economics, design, values/ethics
ex-situ conservation of micro-biodiversity and of related microbiological genetic resources	economics/agriculture, planning, values/ethics
microbes and climate changes	economics/agriculture, politics, values/ethics/philosophy
humans and microbes in history (11)	medicine/planning/ philosophy

Note: In all cases, the first-level discipline is Biology, often coupled with other disciplines of the same level.

- Some possible drivers of innovation in MC sector (policy): deposits upon publication (according to publication policy, the authors of an original research article might make their microbial resources available to the scientific community by depositing into public collections) (7), and use of specific autochthonous strains for typical fermented food preparation (the technical procedures for the production of typical fermented foods might rely on microbial strains representing the "virtuous" microbial biodiversity deposited in microbial collections) (3).

Of course, our "case of study" presentation is not an exhaustive and rigid proposal; in fact, our only purpose is to present a possible lesson schedule. Basically, the idea is that transdisciplinarity applied to microbiology education does not necessarily change/affect the content of the lesson, but, by providing a new framework, helps to deal with complex topics with a sustainable and problem-solving oriented perspective, and with an accurate representation of stakeholders' needs. However, probably in several cases, the proposed approach will lead to consider facets that would remain unexplored with a classical coverage of the subject.

CONCLUSION

In summary, it is interesting to underline the insights of a transdisciplinary approach in microbiological education. The proposed perspective might help to:

- increase student understanding of the role of another discipline
- augment student ability to obtain and analyze information from reality
- enhance student communication skills across disciplines
- increase the consciousness of disciplinary borders and boundaries
- provide a holistic theoretical framework with which to address several complex issues in microbiology education that require advances beyond reductionism, integrating and synthesizing many different disciplinary perspectives (e.g., microbial ecology, food microbiology, environmental and applied microbiology, prevention in clinical microbiology)
- overcome the failures of joint projects and collaborative research arising from cognitive barriers between subjects from different scientific cultures (9)
- introduce an intrinsically sustainability-oriented education
- synthesize diverse fields of knowledge in the quest for a creative understanding of the problem.

Our purpose is to share criticisms, opportunities, and perspectives looking forward to a community of transdisciplinary-oriented microbiology educators.

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