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Transdisciplinary Learning: From Transversal Skills to Sustainable Development

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Abstract. The concept of transdisciplinarity has been extensively researched since the 1970s and still does not have one comprehensive definition, as it is considered highly context-dependent. Merging the knowledge synthesized by the scholars of transdisciplinary research, practice, and learning, transdisciplinary learning features have been identified and briefly elaborated on in this article, pointing out the functional and instructional nature of transdisciplinarity in modern education systems. Simultaneously, the article reflects on the connection of transdisciplinarity with the Education for Sustainable Development and transversal skills design, stating the significance of transdisciplinarity in tackling complex and uncertain social and environmental problems. As an approach, it promotes mutual and transformational learning, transcendence, problem-solving and transgression and is reflected in the values of active participation of learners and their orientation towards real-world problem-solving, blending disciplinary knowledge and constructing new knowledge, skills, competencies, and values collaboratively with peers, teachers, and the wider society.
Keywords: transdisciplinary learning, transversal skills, transformational learning, education for sustainable development.

Mokymasis: nuo universaliųjų įgūdžių iki tvaraus vystymosi

Santrauka. Transdiscipliniškumo sąvoka plačiai tiriama nuo praėjusio šimtmečio septinto dešimtmečio ir vis dar neturi vieno bendro apibrėžimo, nes manoma, kad transdiscipliniškumas labai priklauso nuo konteksto. Straipsnyje pateikiama transdisciplininių tyrimų, praktikų ir mokymosi patirčių apžvalga, identifikuojami ir trumpai aptariami transdisciplininio mokymosi bruožai atskleidžiant funkcinį ir mokomąjį transdiscipliniškumo pobūdį šiuolaikinėse švietimo sistemose. Kartu straipsnyje apmąstomas transdiscipliniškumo ryšys su darnaus vystymosi ugdymu ir universalių įgūdžių formavimu, aptariama transdiscipliniškumo reikšmė sprendžiant sudėtingas ir nevienareikšmes socialines ir aplinkos problemas. Transdiscipliniškumas kaip viena iš galimų prieigų skatina abipusį transformuojantį mokymąsi, transcendavimą, problemų sprendimą; jį rodo besimokančiųjų aktyvaus mokymosi vertybės bei siekis spręsti realaus pasaulio problemas, taip pat atskirų mokslinių disciplinų dermė ir naujų žinių, įgūdžių, kompetencijų bei vertybių formavimas bendradarbiaujant bendraamžiams, mokytojams ir platesnei visuomenei.
Pagrindiniai žodžiai: transdisciplininis mokymasis, universalūs įgūdžiai, transformuojantis mokymasis, darnaus vystymosi ugdymas.

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Introduction

Since the beginning of the 20th century, the ideas of inevitable disorder, complexity, and uncertainty have been transferred from physics to other research disciplines, such as ecology, technology, social affairs and policy, arts, and education (Nicolescu, 2010; Bernstein, 2015). Traditional discipline-based curriculums started to be challenged by more holistic approaches encountering real-world themes. Despite the attempt of scientists and practitioners to establish order and simplicity in whatever is worked on, humankind constantly faces challenges that are more complex and indefinite than expected (Morales-Lopez, 2019).

In the 1970s, when the gaps in serving environmental and social needs could not be longer ignored, transdisciplinarity started to be discussed for the first time in Western scientific circles (Fam, Palmer, Riedy, Mitchell, 2017a). The emergence of the discourse in the 1970s and the new rise of the discussion in the 1990s were facilitated by the growing fragmentation of knowledge and culture, and heavily influenced by sociopolitical justice movements where human rights were part of the agenda. The scholars researching the origins of the concept distinguished two schools of thought. Jean Piaget (Switzerland) saw the application of transdisciplinarity mainly in academia, while Erik Jantsch (Austria) insisted on the transdisciplinary approach being "dispersed throughout the community", allowing to speak about the marginalization of other ways of thinking and the gap between science and practice, Western and other traditions. However, both asked for structural changes in current social practices, which would foster an acceptance of creativity and uncertainty in self-organized structures of knowledge (Fam et al., 2017a).

The year 2000 has been declared a turning point for transdisciplinarity discourse, as joint problem-solving has been prioritized in the action-oriented rhetoric during the International Transdisciplinarity Conference in Zurich. It has become recognized that both scientific and practical paths are valid and equally important in knowledge acquisition for problem-solving (Klein, 2017). Since then, scholars pay significant attention to seeking solutions for the complex environmental and social problems by connecting different fields of studies, diverse profiles of researchers and stakeholders, unusual research, and the implementation tools and methodologies.

It took time to define transdisciplinarity (as well as multidisciplinarity and interdisciplinarity) in wider contexts, and now it is recognized as an effective approach to be applied in collaborative environmental and social research and education, including the Education for Sustainable Development (ESD), as it is both learner- and society-oriented. Derived from policy-driven patterns, ESD enables sustainable transformations in the society and environment through the employment of transversal skill sets and competencies acquired in the learning processes. It is defined as "education that encourages changes in knowledge, skills, values and attitudes to enable a more sustainable and just society for all" (Leicht, Heiss, Byun, 2018, p.7). So does transdisciplinarity, as skills, competencies, disposition, values, and attitudes are both the outcomes and inputs in successful transdisciplinary practice, enabling a proper synthesis of the content knowledge (Fam, Smith, Cordell, 2017b).

Orientation towards service-intensive industries and the emergence of new professions makes transversal skills even more valued, as they facilitate development of other content-related skills. Transversal skills and competencies, also called "generic", "21st-century", or "key" competencies (Harju, Niemi, 2017), constitute the focus of a global trend in education in shifting towards competence-based curriculums and tackling Sustainable Development Goals (SDGs). As stated by UNESCO (2017), transversal skills and competencies constitute "an interplay of knowledge, capacities and skills, motives and affective dispositions", as they cannot be taught by somebody and can rather be acquired in practice. It makes transdisciplinarity particularly supported by the UNESCO (2017), which sees it as a key approach in enhancing transversal skills and ESD results.

However, there are different frameworks and definitions of transversal skills, competencies, and dispositions, stating the evidence of effective practice-based learning, and therefore being the research focus of various scholars. There is no intention in this paper to define the exact composition of the skills necessary to tackle sustainable development problems or carry out the research and learning activities for this purpose. The author rather intends to outline the skills, competencies, and dispositions as one of the functional meanings of transdisciplinary learning, encompassing the development and maintenance of transversal skills.

Transdisciplinarity has no commonly accepted definition due to its fragmented and complex nature. Instead, it represents the complexity of ideas and conceptions from various knowledge fields or disciplines. Chris Riedy (2017, p. 104) has defined transdisciplinary research as a "bundle of interwoven social practices that take different forms in different contexts", referring to the diversity of research practices and their dependence on the environment. Nowadays, the integration between the academia and industry, public and non-governmental structures, as well as communities and individuals is an inseparable part of transdisciplinary research and practice and is discussed within the context of necessary skills, competencies, dispositions, values, attitudes, relationship management, stakeholder priorities (agendas), etc. Despite the variety of contexts and definitions of transdisciplinarity, the author of this paper focuses on four discourses of modern transdisciplinarity as summarized by Riedy (2017) based on previous works on transdisciplinarity conducted by Klein (2014), Mitchell et al. (2018) and others: (1) transcendence as the integration of knowledge across disciplines into a complete picture, (2) problem-solving as a demonstration of greater utility when working with real-world problems, including the acquisition of necessary skills and competence, and (3) transgression as a co-design, co-production, and co-dissemination by multi-stakeholder groups for more socially robust outcomes and ownership. The fourth was borrowed from a study conducted by Cynthia Mitchell et al. (2017) focusing attention on the purposeful nature of transdisciplinarity, which improves (a) a particular situation, (b) knowledge transition, (c) mutual and transformational learning. Both frameworks will be applied in this paper to examine the functional and instructional nature of transdisciplinarity in modern education systems, linking it to two emerging trends of the 21st century – Education for Sustainable Development (ESD) and transversal skills development. This paper will specifically review the transcendence, problem-solving, and transgression principles (Klein, 2015; Riedy, 2017) applied in transdisciplinary learning as forms of social and transformational learning practice (Mitchell, Cordell, Fam, 2017) that enable changes in knowledge, skills, competencies, values, as well as the sustainability of social practices.

Method

The aim of the literature analysis is to conceptualize transdisciplinary learning by defining its main features in modern educational systems. A variety of research papers and reports were reviewed bearing in mind the diversity of study fields and methodologies where the transdisciplinary approach is applicable. Literature reviews and original research included philosophical and instructional aspects of transdisciplinarity in research and pedagogy, allowing to conceptualize the meaning of transdisciplinarity in ESD and the skills development context from diverse perspectives. A literature analysis was carried out following the preliminary data selection through digital databases and secondary snowball sampling. Special attention was paid to the book *Transdisciplinary Research and Practice for Sustainability Outcomes* by Fam, Palmer, Riedy, and Mitchell (2017a), which allowed to translate transdisciplinary research concepts into educational contexts, following the methodological ideas of transdisciplinarity and the merging of disciplines, views, and concepts.

Results

Social and transformational character of transdisciplinary learning

Three main discourses of transdisciplinarity are reviewed in the context of transdisciplinary research and can be applied to characterize the concept of transdisciplinarity in the learning environment as a mutual and transformational learning experience. These are problem-solving, transcendence and transgression (Klein, 2015; Riedy, 2017). The problem-solving discourse of transdisciplinarity ensures greater utility for working with real-world sustainable development challenges and other "wicked problems", which are translated into specific research questions. Transcendence is demonstrated by integrating knowledge and perspectives across different disciplines in a more complete picture of reality, opening up to new actions and insights. Transgression, in turn, brings scholars and practitioners into multi-stakeholder discussions in order to co-design, co-produce, co-disseminate, and create a sense of ownership among parties.

Additionally, Cynthia Mitchell et al. (2017) has greatly contributed to conceptualizing three outcome spaces as purposeful results of transdisciplinary research and practice, namely (1) an improvement of the situation (field of inquiry), (2) an improvement of knowledge stocks and flows, and (3) mutual and transformational learning. The last one is particularly significant and applicable to transdisciplinary teaching and learning, enhancing the design of two other outcome groups.

Mutual and transformational learning is context-dependent, occurs in social interactions (answering the question "how?") aimed at building knowledge and often contributes to the improvement of a particular situation (answering the question "what?")

through tackling specific research questions. The improvement of a situation in this context associates with problem resolution (Mitchell et al., 2017), which is one of the core features of transdisciplinary learning. The transformation driven by mutual learning includes a wide range of changes in norms, values, institutions, or material aspects or natural systems as tangible assets. In the transdisciplinary learning process, orientation towards problem-solving means the development of particular abilities of learners, enabling learners to generate ideas and implement initiatives beneficial for particular communities. It makes learning content more relevant to the learners and increases their motivation, interest in acquiring knowledge and improves learning results (Jurgena, Keviša, 2018). Moreover, transformational learning positively affects a learner's way of thinking, as the interest is transforming into participatory actions and particular initiatives. What makes problem-solving transdisciplinary is the involvement of various stakeholders and building actionable synergies from various knowledge and competencies (*transgression*). Such a process enables the merging of disciplines and looking "beyond" the sets of acquired knowledge (*transcendence*).

Further chapters will analyze transdisciplinary learning and uncover its main features through applying a joint framework designed by Riedy (2018) and Mitchell (2017), as these demonstrate the main features and transformational character of transdisciplinarity in a learning context.

Transcendence discourse of transdisciplinarity

Taking into consideration the complexity and interdependence of modern society's problems, solving issues requires a plurality of disciplines being integrated and synthesized. It is recognized that knowledge of one discipline can be deepened through interacting with other disciplines (Takeuchi, Sengupta, P., Shanahan M.C., Adams, J.D., Hachem, 2020) by cooperating with diverse stakeholder groups and practicing certain transversal skills. Dividing themes and methods according to disciplines is no longer a viable approach, as the separation of systematic subject areas (for example, physics, chemistry, biology) contradicts the global modern trend of turning towards competence-based curricula (Flogie, Aberšek, 2015). Transcendence, therefore, as a concept characterizing transdisciplinarity is introduced by scholars who define it as the creation of a more complete picture of the whole by integrating knowledge and perspectives across results gathered in different disciplines (Klein, 2014, Riedy, 2017). The most common example of transdisciplinarity provided in pedagogical literature concerns science education, where blending chemistry, biology, geography, mathematics, and other disciplines around one theme or problem is practiced by learners. However, transdisciplinarity in education is not just about "blending" different disciplines together.

The prefix "trans-" is used to explain learning "between, across and even beyond" the disciplines (Nicolescu, 2010; Morales-Lopez, 2019; Jurgena, Keviša, 2018, Takeuchi et al., 2020) or constructing higher quality knowledge than just by combining two or more distinct disciplines with their themes, concepts, and methodologies. At the the core of transcendence, scholars of transdisciplinarity argue, is the superiority of knowledge unity over disciplinary research outputs, as the transdisciplinary approach allows interested parties to see "the big picture" and avoid the prioritization of dominant knowledge forms and the marginalization of other ways of thinking that may otherwise be neglected as being "outside the scope". Transdisciplinarity integrates the plurality of disciplines and their associated concepts, methods, and tools under one umbrella. Such an approach makes transdisciplinarity even more complex to grasp, and its developed knowledge – context-dependent, uncertain, and subjective.

To explain transdisciplinarity in relation to research and education, the comparative approach is often used by scholars (Nicolescu, 2010; Helmane, Briška, 2017; Briška, Siliņa-Jasjukeviča, 2019; Eronen, Kokko, Sormunen, 2019; Drake, Burns, 2004). The comparison in the majority of cases reviews the differences between multidisciplinarity, interdisciplinarity, and transdisciplinarity. Helmane and Briška (2017) have greatly contributed to explaining these concepts in school education and defining transdisciplinary education as the most advanced stage of integrated learning approaches. Interdisciplinary, multidisciplinary, and transdisciplinary teaching/learning concepts are based on the relationship between school subjects and science fields. All of the approaches are considered as integrated teaching/learning; however, what differentiates them is the level of integrity between the themes, concepts, and skills as the focus of a learning curriculum. The integrity criteria, in turn, are built on an understanding of reasoning strategies, mutuality of connection, and complexity of contexts (Helmane, Briška, 2017).

Transdisciplinary learning is the most advanced approach, where disciplines are not just merged and synthesized with the focus on some common themes, concepts, and skills, but also linked to real-world problems within social, economical, cultural, and ecological domains. If multidisciplinary teaching aims to increase the effectiveness of acquiring disciplinary knowledge, then interdisciplinary learning focuses on identifying and developing particular general skills, questioning the methods and approaches of teaching/learning, or the "how" question (Helmane, Briška, 2017). Instead of focusing on subjects and learners, transdisciplinarity offers a more integrated orientation towards problems, which means that learners as active agents are free to choose their own paths and methods of learning. Moreover, bigger autonomy is given in terms of themes to be studied by learners, meaning that learners' interests and concerns are taken into account when building the curriculum. Therefore, transdisciplinarity is both problem-centred and learner-centred (Helmane, Briška, 2017). However, transdisciplinary learning cannot fully substitute discipline-based knowledge acquisition, instead complementing the learning experience, so the balance of both is suggested (Eronen et al., 2019).

Problem-solving and interest in the improvement of a situation

In transdisciplinary learning, orientation towards problem-solving means the development of particular knowledge, skills, and disposition in a collaborative multi-stakeholder environment, enabling learners to think about and resolve the challenges concerning particular environmental or social problems, for instance by designing new social entrepreneurship ideas or projects addressing SDGs. The skills of identifying problems and solving them are central and unifying for ESD and transdisciplinary learning, as they both require an acceptance of complexity and uncertainty.

There are two dimensions of problem-solving within the framework of transdisciplinarity – problem-based learning and the real-world context of defined research problems. The first dimension explains integrated learning around one theme as a problem to be solved and enables individual or collaborative inquiry and natural knowledge construction across and beyond disciplines with the application of a variety of methods and concepts. The real-world context dimension ensures a stable connection between the learned theme and its application in the real-world environment. It makes learned content more relevant to students, improving their cognitive interest, motivation, and learning results (Jurgena, Keviša, 2018). The combination of both dimensions is particularly emphasized within the ESD framework, especially in the context of designing solutions to previously defined problems and acquiring competencies to be applied in various real-life contexts (Biberhofer, 2019; UNESCO, 2017; Berstein, 2015; Jurgena, Keviša, 2018).

In relation to problem-solving in ESD, the concept of "wicked problems" (Bernstein, 2015) is often used by scholars to describe the most complex and ill-structured real-life problems (Pearce and Ejderyan, 2019). Wicked problems is the reason of switching from solving problems to problem re-solution or improving the situation to some extent (Mitchell, 2017), as defined problems are often too complicated to be solved by one particular action project. Problem-based learning is an approach to be used for training a learner's problem-framing and resolution skills, as well as forming sustainable attitudes and values, that will further accompany the learner in sustainability actions, for instance, when contributing to the implementation of SDGs.

Ability to improve the situation

Complex sustainability problems (as the ones addressed by SDGs) require skillful actors to be tackled efficiently. Specific transversal skills are necessary to support the acquision of knowledge in learners and translate the knowledge into sustainable actions. However, the term "skills" is never easy to grasp, as it encompasses variety of factors affecting learning and doing within a sustainable development context.

The concept of transformational learning is introduced in close connection to ESD, and the "head-hands-heart" framework often referred to when explaining the necessity of knowledge acquirement in combination with value expansion and the practical engagement of learners with the studied issues. According to Sipos, Battisti, and Grimm (2008), three main domains of transformative (or transformational) learning are: (1) the cognitive domain, relating to knowledge acquisition and cognitive engagement, (2) the action dimension, referring to practical skill development and sharing, and (3) the existential dimension, transforming values and emotions into behaviours and new activities (Sipos et al., 2008; Biberhofer, 2019). These domains state the main prerequisites for actionable problem-solving to be taken into consideration.

By applying this framework, Fam et al. (2017b) has identified the main transdisciplinarity skills (“hands” domain) and dispositions (“heart” domain) as transversal for effective content knowledge management in transdisciplinary projects. The “Six Cs” model comprises the characteristics of curiosity, creativity, commitment, critical awareness, communication and connectedness (systemic-thinking). These abilities, in turn, relate to acceptance of uncertainty, readiness to challenge the status quo and create change, imagination, understanding behaviours of others and oneself (reflexivity), maintaining relations between the discipline perspectives and within the team, with the real world, as well as between research and practice (Fam et al., 2017b). Although developed in a context of transdisciplinary research, the “Six Cs” framework is applicable to the mutual and transformational learning process as one of three transdisciplinarity outcome spaces (Mitchell, 2017). The “Six Cs” encompass necessary orientations when planning transdisciplinary learning and learners’ practical inquiry as experiential learning.

Transformative learning and the social constructivist perspective of transdisciplinary learning (similarly to ESD) are addressing the needs for skills design and the practical application of knowledge and skills by promoting action-oriented, participatory, and self-directed learning, supported with relevant content, methodology, and a learning environment.

The practical element is still a challenge for formal education; however, as a component of experiential learning, it is crucial for the applicability of knowledge and skills in diverse real-life situations. Within the context of ESD, scholars are also refering to the necessity of shifting from teaching to learning, stressing the necessity for self-directed, problem- and action-oriented, participative, and throughout transformational process of learning (Rieckmann et al., 2017), to support SDGs (UN, 2020).

Another feature of transdisciplinary learning is the increasing motivation of learners to construct their own meanings and unique experiences; this is met by providing learners with freedom in terms of defining learning paths and strategies, and therefore learning contents depending on the interests of learners (Eronen et al., 2019; Harju, Niemi, 2017). Organising knowledge in one’s own way is especially relevant in terms of ESD, when learners often face complex and uncertain real-life challenges and are expected to tackle them creatively. Transversal skills allow learners to design and innovate solutions for a wide range of problems, much wider than the ones taught once by the teacher.

As one of the leading experts in ESD, Rieckmann (2017) defines specific transversal competencies to be developed through ESD in practice, namely the competencies of systems thinking, collaboration, strategic thinking, critical thinking, anticipatory competence, normative competence, integrated problem solving, and self-awareness (Rieckmann, Mindt, Gardiner, 2017). These transversal competencies contribute to an awaress and active role of the learner in searching for possible solutions and developing tools to tackle problem areas. Others add collaborative decision-making, taking responsibility (Leicht, 2018), cultural competence, ICT (Harju, Niemi, 2017), and other skills and dispositions relevant to the framework of ESD competencies.

Transgression discourse of transdisciplinarity

In terms of transdisciplinarity research, co-learning is crucial (Riedy, 2017). As one of the transdisciplinarity discourses, transgression is reflected in the collaborative nature of interactions among varied stakeholders of transdisciplinary action – both within the working team and with externals. These interactions are purposeful and at the same time allow great flexibility, as new, unexpected insights and discoveries may arise from transdisciplinary inquiry. However, complexity and uncertainty in these issues are inevitable, opening a discussion of what skills are necessary for the successful management of transdisciplinarity. Derived from the nature of transdisciplinary learning and social constructivism pedagogy, collaboration is recognized as one of the most crucial transversal competencies for transdisciplinarity (Norden, 2018; Mochizuki, Yarime, 2016; Eronen et al., 2019, Harju, Niemi, 2017) and a part of the communication skills "group" under the "Six Cs" framework (Fam et al., 2017b). According to Fam (2017b), communication skills require strong interpersonal skills and abilities to listen, negotiate, sympathize, trust, act on behalf of the team, speak a common language, etc.

Transdisciplinary learning supports collaboration in several ways, facilitating it (1) among learners, (2) in between learners and teachers, (3) in between learners and other external stakeholder groups of the learning process, as well as (4) among teachers.

Collaboration among learners. Transdisciplinary teaching requires teachers to enhance learner collaboration and mutual learning in teams. Collaborative teamwork allows learners to develop learning strategies independently from the teacher, finding creative and alternative solutions to the problems, developing their expression and argumentation skills, communication approaches to diverse people in the team, role-sharing, responsibility for themselves and others, self-management and critical reflection skills, etc. (Eronen et al., 2019). Peer learning is initiated by learners with diverse backgrounds, bringing new insights and knowledge through participative and even intercultural learning experiences.

Learner-teacher collaboration. Learners' cognitive interest and personal participation is strongly linked to the approach chosen by the teacher (Jurgena, Keviša, 2018). Transdisciplinarity in education requires self-directed learning to enable student inquiry and proactive participation in the learning process. It leaves the secondary role to the teachers, shifting their image from "knowledge transmitters" and "experts of a specific field" to mentors and facilitators of critical thinking (Flogie, Aberšek, 2015). In transdisciplinary learning, a teacher becomes "a partner" (supporter or mentor, rather than a lecturer) to the learner in constructing knowledge and competencies. Only a few conceptual limitations are determined by the teacher as a supporter or mentor (not a lecturer) – a timeframe, general guidelines, and expected collaborative work within teams (Eronen et al., 2019).

However, education systems still need to implement radical methodological changes. Specialized systematic training needs to be provided for teachers to be able to support learners as dominating elements (subjects) of the learning process (Jurgena, Keviša, 2018).

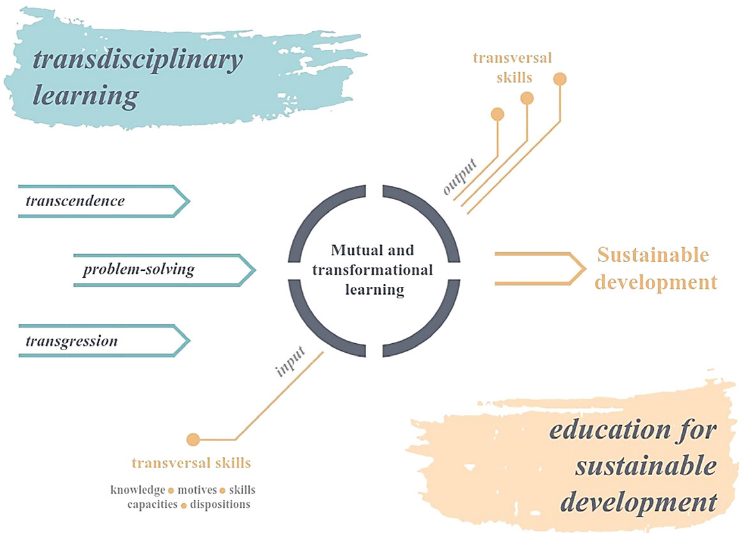
Collaboration with the larger society. Larger society engagement is the common nature of both transdisciplinary learning and ESD. Moreover, it is one of the key elements of the transdisciplinary approach, as it allows the integration of different views and disciplines to provide a whole picture on the issue learned about. In a learning process, industry, civil society organisations or community groups can act as partners in organising learning activities or as research subjects, and both will contribute to building knowledge on complex and often unsolvable problems. Collaboration with industry practitioners and communities allows learners to connect scientific knowledge on frameworks with real-life problems and solutions (Mochizuki, 2015; Pearce, Ejderyan, 2019). At this point, transdisciplinary learning falls under ESD, as the involvement of social groups of specific interest in the researched topics contributes to the design of more thoughtful solutions to the researched problems. Also, the engagement of external partners provides valuable opportunities to diversify learning environments, as learning outside the classroom has proved to increase students' interest and motivation (Echegoyen-Sanz, Ezpeleta, 2019). These environments can also be excellent places to practice transversal skills, especially if done cross-disciplinarily (Harju, Niemi, 2017).

Collaboration among teachers. The quality and dynamics of collaboration among teachers are stated as a focus of research within the transdisciplinarity context (Norden, 2018). To enhance the learning of several disciplines around one common theme or problem in a way that stresses learner agency in developing their own knowledge, skills and competencies, teachers must to be well-skilled and connected to each other institutionally, as well as with external stakeholders. Sharing ideas and practices among teachers is crucial; however, even one teacher with enough motivation can arrange an integrated learning experience (Eronen et al., 2019) if their knowledge base and facilitation skills are set appropriately.

The transgression discourse of transdisciplinary learning characterizes mutual and transformative learning within the environment of diversity. Transdisciplinary learning is highly contextualized, as new knowledge, skills, competencies and values are co-created by the stakeholders of diverse profiles, ages, statuses and interests in particular spatial contexts. The larger society is not just a final recipient of learning outcomes but is actively involved in constructing them (Klein, 2017). In reality, learning goes far beyond the learner's interests, as it also involves the learning of teachers, industry representatives, community groups, and many more.

Discussion

The functional and instructional aspects of transdisciplinarity discussed in this article lead to an understanding of learning in a wider context by connecting such learning outcomes as knowledge, skills, competencies, attitudes and values to the SDGs. Developing these abilities includes purposeful shifting "from declarative towards experiential knowledge, and from knowledge in the wide sense of the word towards suitable competencies" (Flogie, Aberšek, 2015, p.782). Skills and competencies in turn are the key elements that merge transdisciplinary learning with ESD.



Source: author's own elaboration

Although still undervalued and a challenge to implement, transdisciplinary learning has multiple positive effects for enhancing the cognitive, behavioral, and emotional domains of transformational learning. First of all, transcendence or thinking between, across and beyond limited disciplinary knowledge allows learners to explore relationships between the themes, concepts, and methods from seemingly distinct "systems" and construct a big picture on the issue learned from the systems-thinking perspective. Integrated learning allows the learner to become more aware of the relations between the study process and the real world, making more sense of what has been learned.

Secondly, an orientation towards real-world problems and solutions provides learners with a space for independent inquiry and trial actions, facilitating the development of transversal skills. These are considered crucial both as outcomes of transdisciplinary learning and the means for conducting successful transdisciplinary actions that can rather be learned in practice than overtaken from the teacher.

Although there was no intention to explore specific transversal skills to be developed through transdisciplinary learning, the author of this paper has identified several frameworks defining transversal skills in transdisciplinarity and ESD within the cognitive, behavioral, and emotional domains. These are curiosity, creativity, commitment, critical awareness, communication, and connectedness, conceptualized by Fam et al. (2017) as skills necessary to conduct transdisciplinary research. Similar, but not identical, cross-cutting competencies have been reflected by Rieckmann et al. (2017) as necessary for achieving Sustainable Development Goals – systems-thinking, the ability to create visions (the anticipatory competency) and to think critically, the ability to reflect on values (the normative competency), collaboration, self-awareness, and problem-solving. However, the area of transversal skills constitutes a separate and broad topic deserving further inquiry.

Thirdly, connectedness to real-world problems is supported by widening the scope of stakeholders involved in transdisciplinary learning and opening up to external stakeholders to learn from. Communication and collaboration skills are central here, as a collaboration among learners, with teachers (as learning partners) and the community, is necessary to develop new knowledge, skills and dispositions. The proximal development theory of Vygotsky (1978) also points out the benefits of learners' interactions with more knowledgeable peers and adults (*transgression*), which allows developing the abilities of independent problem-solving (*problem-solving*) and implementing certain tasks.

Also, according to Vygotsky (1984), productive learning is implemented when new knowledge is actively constructed by the learner step-by-step, based on previous knowledge and assumptions (Piskunova, 2018; Vygotsky, 1984). The construction process in its nature excludes disciplinary boundaries (*transcendence*) and demonstrates learning as a fluent and socially determined process. Similarly to transdisciplinary learning, it promotes an active inquiry process, when a research question is posed first and then knowledge is constructed in a team of peers or/and with the teacher to be conceptualized and applied to various life situations (Piskunova, 2018; Vygotsky, 1984). Taking into consideration the social component of transdisciplinarity, making a shift from traditional classroom settings towards more collaborative environments, where freedom of inquiry, reflection and discussions are commonly encouraged, has the potential to open up learners, as well as teachers, to more data and knowledge without the limits of a specific subject area or discipline. The openness is the driving need to foster more mutual and transformational learning within, across, and beyond educational settings and systems. Although the review of the transdisciplinary learning environment's criteria was not the aim of the author, it is a significant determinant in shaping transdisciplinary learning experiences and needs to be stressed out as a dimension of learning contextualization. Klein (2017) has pointed out the necessity for learning settings that are "safe" for collaborative interactions, namely spaces free of power relations and disciplinary dominance, therefore supportive and enhancing active and independent inquiry. According to the reviewed authors, the environment is as important as the instructional meaning of transdisciplinary learning; therefore, it has to be studied in detail.

Despite the benefits of reinforcing transversal skills development and orientation towards SDGs, the transdisciplinary approach is often criticized for limiting content knowledge delivery within formal educational institutions and turning to more general or transversal skills. Such a view is supported by the research on innovative transdisciplinary study modules (for instance, Eronen's (2019) case study of a transdisciplinary study course for Finnish eight-graders), where students report low levels of content-related knowledge gained in a learning process, instead focusing attention on teamwork, problem-solving, and expression skills. The problem indicates the need for a systemic shift, as transdisciplinary learning cannot only be focused on "how" the content is acquired but also requires a strategic view on "what" has to be learned. A balance between the need for acquiring standardized knowledge and the need for a competence-based approach is necessary. Moreover, appropriate training has to be provided for teachers, who have traditionally been prepared to "teach", not to "guide" learners in their inquiry.

Conclusions

With the aim of examining the functional and instructional nature of transdisciplinarity in modern educational systems and linking the concept to ESD and transversal skills development, the main features of transdisciplinary learning were identified. As a transformational activity, learning can be considered transdisciplinary if it integrates knowledge across and beyond the disciplines and society stakeholders, enhances collaborative inquiry and practical solution design, and bases these around specific real-world problems with the purpose of acquiring transversal skills, competencies, attitudes, and values to be employed for tackling sustainable development issues. The practical applicability of transdisciplinary outcomes states the functional domain of transdisciplinary learning, while orientation towards problem-based and collaborative learning with no disciplinary boundaries characterizes the instructional domain.

Transdisciplinary learning, as mutual and transformation learning, can be characterized by problem-solving, transcendence, and transgression, leading to improved learning results, cognitive interest, motivation, transversal skills, as well as higher applicability of the knowledge acquired. These are facilitated by the learner- and problem-centered nature of transdisciplinary learning, which provides higher autonomy to the learner as an active agent of the learning process and organizes the learning around complex problems to be considered and solved. First of all, it makes learning content and strategies more relevant to the learner and requires the development of certain transversal skills, knowledge, and dispositions for practical work on defined problems. Secondly, transdisciplinarity calls for learners to identify and work on real-world problems that include several disciplines at once, facilitating the development of higher quality of knowledge and abilities to apply them in different contexts. Finally, the component of mutual learning in transdisciplinarity is demonstrated by the learners' communication and collaboration with their peers, teachers, and external stakeholders, which is required for an in-depth understanding of issues researched. Transdisciplinarity as an approach is considered specifically significant for ESD, as both focus on the development and practicing of transversal skills and associated dispositions. Here transversal skills are applied to train and validate the abilities of learners to actively engage with real-life situations by applying gained experience and skills and competencies practiced during the learning process. Similar to the transdisciplinary approach, orientation towards complex and often uncertain challenges is the core of ESD, framing the themes under SDGs and transferring them to the learning objectives, methodologies and practically applicable outcomes.

Transdisciplinary learning for transversal skills design is still a novel concept that can only be positively perceived when thought of in specific categories. These categories can be characterized by accepting the complexity, diversity and uncertainty of the reality, meaning that healthy educational systems cannot implement a complete switch from disciplinary to transdisciplinary learning without serious negative consequences, as individual effort is still required for cognitive processing. Thus, a balance should be established by applying several levels of integrative learning. Discipline-based learning should provide a basis for acquiring knowledge, and transdisciplinary learning constitutes the next level in education – learning how to apply knowledge and practice of 21st century skills as universal competencies.

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