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Artículos científicos

Hacia la transformación de los estudiantes: un proceso transdisciplinario para la educación superior

Towards the transformation of students: a transdisciplinary process for higher education

Rumo à transformação dos alunos: um processo transdisciplinar para o ensino superior

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Resumen

Configurar un mundo sostenible requiere nuevas formas de pensar y actuar donde la educación para el desarrollo sostenible sea una propuesta para el cambio. Esto, sin embargo, trae consigo retos para la educación superior, ya que implica formar estudiantes con competencias transdisciplinarias. Por eso, el objetivo de esta investigación fue diseñar un proceso transdisciplinario para la educación superior centrado en el estudiante y en el vínculo IES, industria y sociedad, con base en la teoría holónica, la metodología de los sistemas suaves y la metodología de *stage-gates* con el fin de desarrollar el pensamiento sistémico, el trabajo colaborativo y la creatividad en los futuros profesionales y responsables de la construcción del tejido social en un mundo sostenible. Para ello, se diseñó una investigación



cuantitativa, de tipo documental, la cual se llevó a cabo en dos fases: en la primera se efectuó una revisión de la frontera del conocimiento en las publicaciones relativas a la transdisciplina y la educación superior en la *Web of Science* de los últimos cuatro años, mientras que en la segunda se desarrolló el proceso, el cual se configuró en siete etapas, cimentado en el sustento teórico del constructivismo y el sustento pedagógico del enfoque por competencias. Se obtuvo como resultado el proceso transdisciplinario para la educación superior (PTD-ES), configurado por cuatro momentos que abarcan desde lo simple hasta lo complejo: I) disciplinario, II) multidisciplinario, III) interdisciplinario, IV) transdisciplinario; y tres compuertas para valorar el nivel de competencia que desarrollaron los estudiantes en cada momento.

Palabras clave: competencias transdisciplinarias, desarrollo sostenible, disciplinariedad, enseñanza superior.

Abstract

Shaping a sustainable world requires new ways of thinking and acting, so education for sustainable development is a proposal for change, yet it brings with it challenges for higher education, since it involves training students with transdisciplinary skills. So it is objective of this research, to design a transdisciplinary process for higher education, focused on the student and the higher education, industry and society link, based on holistic theory, soft systems methodology and stage-gates methodology, to develop systemic thinking, collaborative work and creativity in future professionals and those responsible for building a sustainable world. It is a qualitative research, documentary type, which was carried out in two phases: the first, was a review at the frontier of knowledge, in publications related to transdiscipline and higher education in the Web of Science of the last four years; and the second, was the design of the process, which was shaped in seven stages, based on the theoretical support of constructivism and the pedagogical support of the approach by competencies The result was the Transdisciplinary Process for Higher Education (PTD-ES), configured for four moments, ranging from the simple to the complex: I) disciplinary, II) multidisciplinary, III) interdisciplinarian, IV) transdisciplinary; and three gates to assess the level of skills that students developed at each point.

Keywords: transdisciplinary skills, sustainable development, disciplinary, higher education.

Resumo

A construção de um mundo sustentável requer novas formas de pensar e agir, onde a educação para o desenvolvimento sustentável é uma proposta de mudança. Isso, no entanto, traz consigo desafios para o ensino superior, pois implica formar alunos com competências transdisciplinares. Portanto, o objetivo desta pesquisa foi delinear um processo transdisciplinar para o ensino superior centrado no aluno e na articulação entre a IES, a indústria e a sociedade, com base na teoria holônica, na metodologia dos soft systems e na metodologia dos stage-gates ordenados. desenvolver o pensamento sistêmico, o trabalho colaborativo e a criatividade dos futuros profissionais e responsáveis pela construção do tecido social em um mundo sustentável. Para tanto, foi elaborada uma pesquisa qualitativa, do tipo documental, realizada em duas fases: na primeira, uma revisão da fronteira do conhecimento em publicações relacionadas à transdisciplina e ao ensino superior na Web of Science das quatro últimas anos, enquanto na segunda foi desenvolvido o processo, que se configurou em sete etapas, com base no suporte teórico do construtivismo e no suporte pedagógico da abordagem por competências. O resultado foi o processo transdisciplinar para o ensino superior (PTD-ES), configurado por quatro momentos que vão do simples ao complexo: I) disciplinar, II) multidisciplinar, III) interdisciplinar, IV) transdisciplinar; e três portas para avaliar o nível de competência que os alunos desenvolveram a cada momento.

Palavras-chave: competências transdisciplinares, desenvolvimento sustentável, disciplinaridade, ensino superior.

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Introduction

It is undeniable that the world in which we live today is immersed in various problems that are placing society at risk of disappearing. Issues such as poverty, unemployment, migration, school dropouts, trade deficits, international drug trafficking, global warming or the appearance of new diseases (currently, SARS-CoV-2) can no longer be conceived as something isolated, but rather as part of a dynamic and complex system, of which we are part, as far as “everyone” is concerned to learn to live together in a sustainable way (United Nations Educational, Scientific and Cultural Organization [Unesco], 2020). However, what we see depends on how we are prepared to see it (Kant, 2003).

Undoubtedly, education is the vital force for development, since through it it is possible to preserve and transmit its spiritual and physical particularity of a society (Jaeger, 2001). A proposal to transition to a sustainable world is education for sustainable development (ESD), which promotes a transformative and comprehensive training, which includes pedagogy, content, results and learning environments (Unesco, 2020), where the institutions of Higher education (HEI) play a transcendental role in promoting it (Rammel, Velázquez & Mader, 2015) because they are considered main sources in the generation of knowledge to respond to the current changes caused by the progressive complexity of society (Jantsch, 1972; Klein, 2004).

However, generating more disciplinary knowledge, innovation and having more educated experts who transfer knowledge is not enough to move towards sustainability, since it is necessary to incorporate dialogue between the different areas of knowledge, values, participation and social learning (Unesco, 2020). The structure and interdependence of society's problems go beyond disciplinary prisms, which leads to the questioning of how to train students in this unprecedented economic and social transformation (Klein, 2004; Morin, 1996).

This represents a challenge for higher education (HE), since to understand this "complex world" it is essential to conceive human rationality from another perspective, which requires changes in the way of educating that lead to another way of thinking, understanding and value "beyond" (Nicolescu, 1999). Faced with this reality, transdiscipline (TD) appears as a solution (Lang et al., 2012) to the current problems of society (Jantsch, 1972; Nicolescu, 1999).

Although DT in the science of sustainability is increasingly relevant and effective where technical, economic and social developments are interrelated with values and cultures (Klein, 2004), in HE it is still conceived in a limited way (Fiala et al., 2018). Therefore, it is necessary that the teaching and learning process be reconfigured with a transdisciplinary approach (Acevedo Osorio, Hofmann Souki and Cruz Morales, 2020), which must be linked to ESD, and both be a conceptual and systemic part of the educational culture of HE (Biberhofer and Rammel, 2017).

However, TD is not easy to achieve (Lang et al., 2012). Although "disciplinarity, multidisciplinarity, interdisciplinarity and transdisciplinarity are four arrows of a single bow: that of knowledge" (Nicolescu, 1999, p. 37), DT faces a variety of obstacles, mainly when it

comes to “Single thought” of disciplinary, which is not adversarial, but complementary (Nicolescu, 1999).

It is clear that TD research differs from disciplinary work, so specific competencies must be developed (Lang et al., 2012; Fiala et al., 2018), which leads to implementing forms of education that they develop in students and teachers interdisciplinary and DT terms, as well as the capacity for judgment in complex and dynamic situations (Klein, 2004), which can hardly be developed in traditional learning formats (Acevedo-Osorio *et al.*, 2020).

TD and ESD: competencies they promote in students

The transdisciplinary concept emerges in the first International Seminar on Interdisciplinarity, which was held in 1979 co-sponsored by the Organization for Economic Cooperation and Development (OECD), with reflections such as that of Jean Piaget and Erich Jantsch (Klein, 2004) about the way in which the disciplinary vision fragments knowledge, making it impossible to understand the realities of the complex world (Piaget, 1972) and the need to develop a system for DT education, focused on the systemic combination of multiple levels of research, education and innovation (Jantsch, 1972).

DT, therefore, is configured under the concern of what begins in the disciplines, interrelates them and passes them to understand the current world (Nicolescu, 1999), so they are considered levels of DT: discipline, multidiscipline and interdiscipline. At the disciplinary level, a research topic is studied from a single field of study and level of reality, through simple thought. In the multidisciplinary, several disciplines pursue a common goal, under their methodological, epistemological and conceptual independence. In the interdisciplinarity, methodologies are transferred from one discipline to another that may have a degree of application, epistemology or generation of new disciplines. And in DT it is globally open, since it requires unity of knowledge and a new perspective to coexist (Nicolescu, 1999).

Given that ESD emphasizes the need to develop a different way of teaching and learning between different disciplines, and beyond them, in such a way that a new vision is developed to build a sustainable world (Unesco, 2020), this reflects itself a TD approach (Biberhofer & Rammel, 2017). Thus, DT is conceived as a transformative posture of education, which ensures that students learn to be, learn to know, learn to do, learn to live together and, mainly, learn to transform themselves and society (Unesco, 2020). To apply it,

a dynamic environment is required that is conducive to the learning environment, fundamentally configured in problem-based learning, the interconnection between and beyond disciplines and the integration of stakeholders. (Biberhofer y Rammel, 2017).

Transformative teaching seeks to encourage students to explore epistemic change, so it cannot be limited only to HE, but encompass the entire TD environment between science and society, in such a way that scientific knowledge is shared and exchanged and not scientist among stakeholders to address sustainability challenges. For this reason, teaching cannot be limited to the acquisition of knowledge and cognitive intervention, since it is essential that it include the exchange and improvement of practical skills along with the translation of values (Sipos, Battisti & Grimm, 2008).

Given that education is capable of transforming and creating new ways of living (Morin, 1999), it is expected that the teaching and learning processes in SE will develop individuals capable of addressing multifaceted social problems (Mokhele and Pinfold, 2020) to face the sustainability challenges (UNESCO, 2020). From the constructivist approach, these processes must take place in authentic learning environments linked to problems (Piaget, 1972).

On the other hand, the pedagogical approach by competencies proposes that educational institutions configure interdisciplinary, flexible, broad and content-focused curricula that promote reasoning, open to the contributions of those who learn and that manage to integrate formal and informal learning. In other words, that allow the development of the essential competencies for life and work, that is, creativity, the capacity for entrepreneurship, reflection, communication, critical thinking, problem solving, collaboration, risk-taking, innovation and metaknowledge (Scott, 2015).

Thus, it is considered that students must develop, through TD research, four capacities (Muhar, Visser and van Breda, 2013): the capacity for integration, which implies valuing the various disciplinary and non-disciplinary contributions; communication skills, which involves generating and negotiating new concepts and representations for collective understanding; the innovative methodological capacity, which requires the incorporation of methodologies, and the capacity for reciprocal learning in various contexts and fields of knowledge, without neglecting systemic thinking with which a holistic perspective of the complexity of the world's existing problems is achieved and the connection of disciplines, landscapes and knowledge.

Therefore, today more than ever students must develop the ability to go beyond the facts to visualize the forces that shape change, which requires a systemic and holistic reasoning to find the appropriate course of action to be taken. take (Wilber, 1996).

The systemic idea is the rationale for universalization, and it is crucial because it provides a foundation for morality (Jackson, 1994). Thus, moral and ethical events arise in the relative tension between the world and life, law and rupture, obedience and resistance, utopia and reality; For this reason, it is said that “we inherit one world, but we configure another” (Bárcena and Mélich, 2014). This leads us to think of new forms of pedagogical and social relationship and co-responsibility, conceiving that the link between students, school and society is configured from the historical-everyday (Salgado, 2015).

Theories and methodologies applicable to TD

For the present research, the holonic theory of Wilber (1996), the methodology of soft systems of Checkland (2000) and the stage-gate methodology of Cooper (2008) were considered. Holonic theory proposes that discipline constitutes the lowest level of structural organization of DT, in such a way that multidiscipline includes and transcends discipline, while interdiscipline transcends and includes multidiscipline, therefore transdiscipline includes and transcends interdiscipline. In other words, each of the moments of the process not only constitutes a totality that must retain its individuality, but is also part of another moment of TD. Each moment has a transdisciplinary level, defined by the degree of scope and depth with which a problem is approached, which increases as consciousness does (Wilber, 1996).

The soft systems methodology (SSM) is an approach to address problematic (social) and complex situations, which are conceived as non-static and contain multiple interacting perceptions of reality. It is supported by a research process in which, through social learning, collaborators or participants learn to know and understand complex situations, as well as to consider multiple perspectives, to carry out processes of analysis, debate and to make decisions to improve it. Therefore, it is conceived as an endless learning cycle (Checkland, 2000).

SSM is defined by seven principles: i) a perceived problematic situation, ii) perceived differently by people with different worldviews, iii) it will contain people trying to act on purpose, iv) therefore modeling of purposeful activity as perceived by different world views,

v) use the model as a source of questions to pose the problematic situation, thus structuring a discussion, vi) find versions of the situation to change with different world views could live with vii) implement changes to improve (be ready to start the process again). These seven principles clearly underlie the four actions that define the SSM form: 1) find out about a problem situation; 2) make models relevant to explore based on different worldviews; 3) question the situation using the models in order to find a desirable and possible change, and 4) define / take action to change the situation for the better. The seventh principle defines by itself a fifth action that guarantees the cycle around the first four, that is, critical reflection on the entire process. This fifth action is on a different level from the other four. It is the activity that ensures that the lessons learned are captured (Checkland, 2000).

On the other hand, the proposal of the stage-gate methodology—even when it is focused on improving the effectiveness and efficiency of the management of the new product process— may well be applied to TD. It is a methodology that consists of a series of stages (stage), where the project team performs the work, obtains the necessary information and performs the integration and analysis of data to take the project to the next starting or decision point, followed by gates, where decisions are made to continue to the next stage or repeat, for which it is necessary to define what has to be delivered, the criteria to evaluate the project and the final result together with an action plan for the next stage (Cooper, 2008).

Previous research

From the literature review carried out in the WoS, in the publications, in a general way, a shared vision is perceived by the authors on the need to promote in the HE a TD teaching and learning process that encourages students to discovery and critical reflection to move towards sustainability. Said publications were classified, according to their proposal, into four categories: the first is made up of those that propose a design of a program or course of studies, such as proposals that integrate modern management techniques and concepts of sustainability with the dynamics of industry and society (Century, Ferris and Zuo, 2020; Contreras, Jiménez, Browne and Oliva-Figueroa, 2020; Mkhize, 2019; Mokhele and Pinfeld, 2020; Oliva-Figueroa et al., 2018; Roysen and Cruz, 2020 ; Rupnik and Avsec, 2020; Serviss and Voss, 2019).

Likewise, proposals focused on project-based learning (Marcos, De Castro and Martín-Peña, 2020; Tasdemir and Gazo, 2020), focused on developing in students the essential

skills to carry out TD research (Acevedo Osorio et al., 2020; Echevoyen-Sanz and Martin Ezpeleta, 2019), and in which practice is integrated with politics, science and technology (Fiala et al., 2018).

The second category integrates proposals focused on institutionalizing DT in HE, among these, an investigation that analyzes the institutionalization process of DT in universities from a neo-institutionalist perspective (Baptista and Rojas-Castro, 2020). Likewise, a proposal that reflects on the implications of inter and DT as a methodological approach where the current crisis of disciplinary knowledge is discussed as a matter of substance (Khoo et al., 2018). Others about the effectiveness of the application of the transdisciplinary approach (Barakhsanova et al., 2020; Garutsa and Mahlangu, 2019), and about the effectiveness of TD modules when taught in line with moderate constructivist theories (based mainly on Jean Piaget and John Dewey), in line with transdisciplinary theories and through a combination of both theories (Keller et al., 2019), as well as on the variations in which teachers of different subjects experience collaborative teaching in the context of a whole project of school educational development (Norden, 2018).

The third category corresponds to the proposals on the TD and the linkage of the HE. This contains papers that examine the challenges related to sustainability in Austria and analyzes opportunities for HE to address these challenges through transdisciplinary collaboration between science and society, that is, stakeholders in sustainable change (Biberhofer & Rammel, 2017), in innovative training sessions for university educators (Meyer et al., 2017). In addition, a proposal for a transdisciplinary research coordination model is identified using the TD public health initiative in the United States (Holhl, Knerr & Thompson, 2019).

On the other hand, there is a work that analyzes and describes how the TD research centers - Real-world Laboratories (RwLs) - favor learning and transformation processes through a hybrid space that facilitates the exchange of knowledge between the academic sphere and others from society (Beecroft, 2018).

The fourth category includes proposals on DT and the integration of knowledge, among these is the one that visualizes practical educational environmental DT, conceptual and applied spaces, in the context of knowledge-based society / economy (KBS / E) (Pop, Fotea and Fotea, 2018). In addition, a proposal that conceptualizes the constellations of TD practices created on a social practice perspective, in which knowledge and learning are

carried out in interrelated practices that can cover multiple fields such as professional, educational and research (Laasch et al. al., 2020).

Likewise, proposals about the influence of trust in the exchange of knowledge among the members of a transdisciplinary community of practice (technological-educational) (Hernández-Soto, Rodríguez-Medina and Gutiérrez-Ortega, 2020). And finally, proposals that identify the existing asymmetries that hinder a co-production of mutual knowledge in inter and TD research (Schmidt and Neuburger, 2017), as well as fundamental questions about how transdisciplinary learning is conceptualized, and it is widely inferred about big data and what this represents in practice (Lodge *et al.*, 2017).

Well, in a general way, they are proposals - mostly courses and programs - in which it is intended that students apply their skills and their various knowledge in realistic and transdisciplinary environments to solve complex non-trivial problems (Czaplinski et al., 2019) from the design of methodologies to structure courses, didactic methods, systems or models with a TD approach. Some of the most relevant for this research are the six-step methodology proposed by Beecroft (2018), which goes from preparation to completion of a TD project, where students work as a team and are assigned key tasks in each phase. The description of didactic methods for the courses made by Fiala et al. (2018). The system of Jia et al. (2019), which includes modules and courses based on the focus of key competencies in sustainability, such as interpersonal competence, systemic thinking, strategic competence, anticipatory competence and normative competence. Likewise, the Acevedo-Osorio et al. (2020), which shows the phases of TD projects and the implications of actors and learning cycles in inter and TD spaces. And the model of Khoo et al. (2018), which conceptualizes inter and DT from convergences, divergences and emergencies.

Although TD progress in HE is increasingly significant (Laasch et al., 2020), the proposals that detail the phases to transition from disciplinary level to TD are still not very visible. Likewise, no comprehensive systemic models are identified in which student change is visualized. Regarding the development of TD competencies, the proposals do not show precisely how students evolve.

Therefore, the objective of this research was to design a transdisciplinary process for HE focused on the student and on the link between HEI, industry and society, based on holonic theory, the methodology of soft systems and the methodology of stage- gates, in order to develop systemic thinking, collaborative work and creativity in future professionals, citizens and those responsible for the construction of the social fabric in a sustainable world.

Methodology

This is a qualitative research (Creswell and Creswell, 2018), documentary type, which was carried out in two phases. In the first, a review was made of the frontier of knowledge in publications on DT and higher education as significant elements in the construction of the social fabric. The review of the literature (Jesson, Mathenson & Lacey, 2011; Snyder, 2019) consisted of scientific articles indexed in the Web of Science (WoS), published from January 2017 to January 2021. In this process, it was determined which was the purpose of the article and what was the methodology used (Jesson, Mathenson & Lacey, 2011). This work consisted of the following:

1. **Compilation of information:** Scientific articles indexed in WoS with the transdisciplinary theme were searched. Subsequently, the search was refined based on two criteria: title (transdisciplinary) and subject (high education). The articles were then located and downloaded for individual review.
2. **Analysis of the information:** The publications in which the purpose of the article, the author, the country of origin and the methodology used were identified were reviewed.
3. **Information results:** Authors' coincidences and shortcomings in research on DT and higher education were identified in order to design the transdisciplinary process for higher education (PTD-ES).

In the second phase, the PTD-ES was designed, which was configured in seven stages based on the theoretical review:

1. **Definition of the moments of the process:** Disciplinary, multidisciplinary, interdisciplinary and TD from the TD levels of Nicolescu (1999).
2. **Definition of the identity and complexity of each moment of the process** based on the evolutionary process of Wilber's holonic theory (1996), where each moment is conceived as a holon that is integrated into the next moment, generating a new identity.
3. **Determination of the TD competencies to be developed in the students at each moment of the process**, in accordance with the ESD (Unesco, 2020), the proposal of Muhar, Visser and van Breda (2013) and Wilber (1996).
4. **Determination of gates between each moment of the process** based on the stage-gates methodology of Cooper (2008).

5. Determination of the activities for TD research for each moment of the process from the methodology of the soft systems of Checkland (2000).
6. Definition of teaching and learning methods for the development of TD competencies based on the constructivist approach of Piaget (1972) and Freire (1983).
7. Integration of the substantive processes of the proposal: research, training and connection with society.

Results

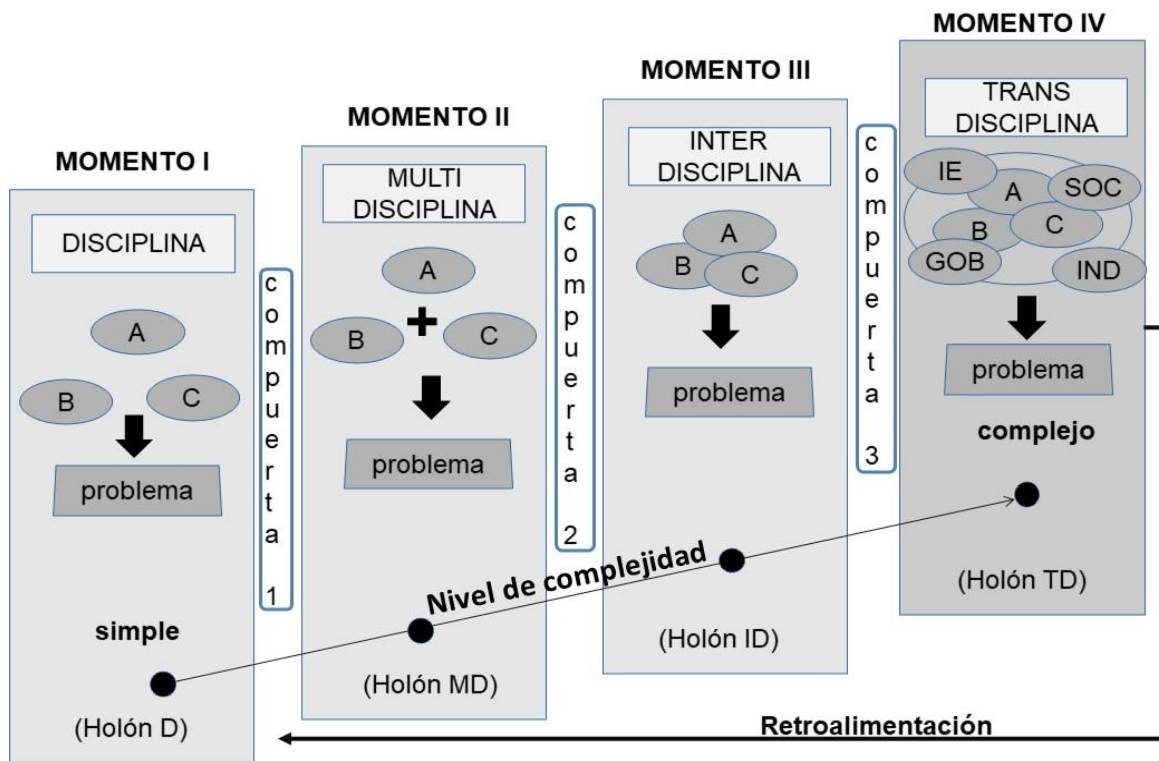
Transdisciplinary process for higher education (PTD-ES)

Based on the need to train professionals and critical citizens who provide solutions to the problems of this complex society, it is imperative to promote environments that help students develop the ability to reflect on their role in the world and the meaning of what study and their goals in life (Pop, Fotea and Fotea, 2018; Roysen and Cruz, 2020). For this, the key to sustainable development and ESD is to promote collective participation (Mokhele and Pinfold, 2020) and the integration of knowledge that leads to a new configuration of thought (Morin, 1996).

In other words, proposals are required focused on the formation of transdisciplinary competences of HE students through theory and practice (Fiala et al., 2018), where the participating agents assume the role of subjects of the process that work jointly, in such a way that education is seen as the problematization of human beings in their interactions with the world (Freire, 1983).

In response to these needs, the transdisciplinary process for higher education (PTD-ES) is configured in order for students to develop the ability to collectively address professional and social problems. Therefore, it is a student-centered proposal, that is, based on constructivism, the competency approach, as well as the holonic approach and the methodology of soft systems, as seen in Figure 1.

Figura 1. Proceso transdisciplinario para la ES



Fuente: Elaboración propia

The process is made up of four moments: I) discipline, II) multidisciplinary, III) interdisciplinary, and, IV) transdisciplinary. Each moment has defined activities, based on the methodology of Checkland (2000), which contribute to the student developing a level of competence necessary to move on to the next moment, so that each moment is conceived as a holon in which one goes generating a new identity (Wilber, 1996). It is a cyclical process in which the last moment feeds back to the first.

It should be noted that between each moment there is a gate that is used to verify that students have developed the professional skills expected from the immediate previous moment. From an evaluation carried out by the teacher and the students, it is determined if they have the level of TD skills necessary to move to the next moment or if it is necessary to restart.

As shown in figure 1, at moment I the problem is dealt with from each discipline, so it is represented by the letters A, B and C, which work in isolation. At moment II, the disciplines, represented by the same letters as at moment I, address the same problem, that is, they add up to solve it from their discipline, that is why the summation symbol (+) appears.

At moment III, the disciplines are interrelated to address the same problem. And at moment IV, the disciplines are interrelated to address the problem together with higher education institutions (IES), industry (IND), government (GOB) and society (SOC), conceiving the multidimensional and referential context.

The central axis of the PTD-ES is to promote DT research through the strengthening of systemic thinking, collaborative work and creativity, as well as the link between IES, industry and society, in a space of hybrid interaction between academia and society (Beecroft, 2018). The configuration of the link is the means to attend and understand the context, in such a way that the process develops in the complex, multidimensional and multireferential reality where the TD dialogue between participants is essential to solve such complex problems of the current world and for development sustainable (Lang et al., 2012; Fiala et al., 2018). For this reason, problem-based learning (Thomas, 2009), teamwork (Ingram and Desombre, 1999; Tobón, 2013), induction to the referential scheme (Calviño, 2005), discussion (Freire, 1983) and information literacy (Association of College and Research Libraries [ACRL], 2000).

To carry out the TD research project, five participants are considered: i) Facilitator. It acts as a process manager, establishing and re-evaluating the knowledge agreements between the participating agents, and maintaining an independent position and without any personal interest in the investigation itself. He is able to analyze a phenomenon and help others in essential activities such as reflection to find a solution. A facilitator often acts as an action researcher or consultant (Giebels et al., 2020). It is recommended that you be the teacher. ii) Experts of a discipline. They are those actors trained for specific knowledge. They are considered essential when planning research (Giebels et al., 2020). It is recommended that they be students of different disciplines. iii) Systems expert. They are those actors trained for specific knowledge. It can be the scientific expert or a technical specialist trained to interpret the needs of the participants in characteristics of an integrative model. The added value of a systems expert has also been attributed to his external position (Giebels et al., 2020). It is recommended that you be an investigator. iv) Key industry / government / society participant. They are people, groups or organizations interested in collaboratively participating in research. These parts may not be exactly the same in other educational institutions, but the stakeholder identification process is necessary in course planning. (Reme et al., 2015).

Moments of the PTD-ES

Given that transdisciplinary practice goes from the conception of disciplinary research to the elaboration of a society project, the process of the PTD-ES is based on the levels of transdisciplinarity where each one differs from the other by the degree of integration of the visions, the study of reality and complexity, which implies moving from a simple thought to a complex one. It should be emphasized that it is a cyclical process, that is, when the TD moment is reached, the process starts again at the disciplinary moment with the new knowledge and skills.

As can be seen in Figure 1, the first level of TD concerns the disciplines themselves, where all can be encouraged by the TD attitude, as Nicolescu (1999) correctly states: “There is no one discipline that is favored in relation to another. from the point of view of transdisciplinarity (...). It is said that there may be levels of transdisciplinarity, but there cannot be disciplines with a transdisciplinary nature”(p. 35). Therefore, the TD methodology does not replace the methodology of each discipline, and sustainability serves as an integrating image. Thus, the moments that constitute the PTD-ES are based on the TD levels (Nicolescu, 1999), the holonic theory (Wilber, 1996), the stage-gates methodology (Cooper, 2008) and on the Checkland methodology (2000) that uses an ordered sequence of five process steps that can be repeated in case it is necessary to make adjustments to previous steps or to the information.

The four moments of the PTD-ES with their respective gate are described below:

Moment I: Discipline. It begins with the preparation of the TD research project, so it is important to plan who will be the participants or “practice partners” of the project and the place where it will take place in order to facilitate initial contact and familiarize the research team. work, since it is essential that there is trust to commit to cooperation, knowledge exchange and mutual understanding of the respective interests in the project (Baumber et al., 2020; Hernández-Soto, Rodríguez-Medina and Gutiérrez-Ortega , 2020). Likewise, the preface of the TD research project is developed, so it is necessary to introduce students to the sustainability aspects related to the discipline they study and the project methodology, reflective and mutual clarification of the interests and objectives of the students. students (Baumber et al., 2020).

Subsequently, the students carry out the research from their field of knowledge in order to strengthen and / or develop the scientific and methodological knowledge of their

discipline for their subsequent participation and contribution to the TD project. It should be noted that it is intended that the student understand, from a simple thought and a level of reality, the research problem.

Teaching and learning methods are key to the professional performance of students, since they are the means by which they develop their cognitive, behavioral and affective capacities (Cooper, 1999). The essential didactic methods at all times of the PTD-ES are problem-based learning, in order that students learn to think rather than what to think within the framework of sustainability (Thomas, 2009). Induce the identification and inquiry of the referential scheme, since, based on their experiences and knowledge, students think, act and perceive the phenomena of the world (Calviño, 2005). The information literacy of both teachers and students, since the access, quantity and diversity of information resources do not guarantee their quality and good use. Therefore, it is essential to have elements of judgment and technical skills to make this process efficient and effective (ACRL, 2000). The discussion considers educational action as a dialogic communication with reality, with others and with one's own conscience (Freire, 1983). And teamwork, since from the configuration of a work team it is sought that students commit to a common goal and achieve greater learning and development, which includes collaborative work, communication, respect reciprocal, shared knowledge and problem solving (Ingram and Desombre, 1999; Tobón, 2013). It should be noted that they are methods that should be used in the classroom, and the teacher must be conceived not only as "the one who teaches", but as the one who continues to learn in a collective effort (Freire, 1983).

Gate 1. Based on the disciplinary project prepared by the students and the results obtained by the didactic methods, it is valued that the student has developed six essential capacities to move to moment II, which are: i) disciplinary theoretical knowledge necessary to develop the TD project. ii) Ability to recognize the need for information and the ability to locate it, in such a way that it is sufficient, current, valid and pertinent (ACRL, 2000). iii) Ability to communicate with the members of the disciplinary team and with the teacher. iv) Ability to connect theory with research and practice. v) Ability to work with people of the same level of studies and discipline. vi) Ability to approach and analyze the problems of the world from a simple thought and a single level of reality (Choi and Pak, 2006; Nicolescu, 1999). It is expected that at the conclusion of the next multidisciplinary moment, the student will improve the level of the competencies developed in the disciplinary moment.

Moment II: Multidiscipline. It is focused on studying the problem of TD research from several disciplines simultaneously under the research framework of each discipline (Nicolescu, 1999). To develop this moment, the collaboration of all the participants of the TD project is required. It is recommended to work together with other disciplines, whether from the same IES or from others.

Because they all come from different platforms, and their way of thinking and paradigms are uneven, it is necessary to start by defining the key concepts and the coincidence of paradigms, with the intention of achieving cooperation and understanding for the development of research. It is suggested to articulate the terms and concepts from a disciplinary perspective through a Delphi approach (Checkland, 2000).

Starting from the configuration of the key concepts and a common objective, the participants work, independently and from their discipline, the research problem (Checkland, 2000). Consequently, students carry out research with methodological, conceptual and epistemological independence of their discipline, with the help of the teacher.

During this time, it is recommended to use the teaching and learning methods in the classroom that are proposed in the first moment: problem-based learning, information literacy, class discussion and teamwork. It is important to note that even though they are the same methods, the intention is to improve the students' competencies.

Gate 2. At the end of the investigation, an assessment is made of the level of competencies of the students, which is necessary to decide if they can move on to the next moment of the process or restart the moment. Four essential skills are identified: i) mastery of key disciplinary knowledge for TD research, ii) ability to search, locate, evaluate and use information (sufficient, current, valid and pertinent), iii) ability to communicate and work with people of various disciplines, iv) ability to approach, analyze and solve world problems, in parallel with other disciplines, from a simple thought and conceiving a single level of reality (Choi and Pak, 2006; Nicolescu, 1999). It is expected that at the end of the next interdisciplinary moment, the student will improve the level of the competencies developed in the multidisciplinary moment.

Moment III: Interdiscipline. It consists of transferring methods from one discipline to another. Considering that interdisciplinarity has three degrees - application, epistemological and generation of new disciplines (Nicolescu, 1999) -, the PTD-ES focuses on the level of application while still striving to achieve the other two, since the last degree contributes to the “disciplinary big bang” (Nicolescu, 1999).

It is important to emphasize that this moment is not to coordinate results from the previous moment, but is conceived as a process, so the research team remains multidisciplinary, only an interdisciplinary methodology will be used that forces the study of a complex system, which can only be achieved with shared epistemic, conceptual and methodological frameworks. Thus, the methodology must serve to analyze the processes of the system, understand its behavior and evolution as an organized whole. (García, 2006).

Therefore, the first activity is the framing and scope of the TD research, for which the collaboration of all the participants of the TD project is necessary. It is an activity in which the problem is previously identified and structured without allowing any disciplinary ideology or values of the participants to dominate (Checkland, 2000).

Subsequently, a holistic panorama is configured that identifies the central system; For this, a rigorous review of the specific literature of the discipline concerning the topic to be investigated must be carried out, which will be perfected by expert debates (Checkland, 2000), in such a way that the participants, in particular the students, infer the attributes and dimensions of the investigation from their individual discipline and experience. It is recommended to use the integrated morphological box technique as a platform for discussion (Zwicky, 1969), in which collaboration is key to define the most precise characteristics of the system and the corresponding limits (Checkland, 2000). After this, the most important activities are identified from the decomposition of the complex problem, for which the participants of the TD project have to break down the processes, sub-processes and finally the activities (Checkland, 2000). Therefore, the participation of the systems expert is key to the development of this activity.

During this time, the teaching and learning methods in the classroom are also used, such as problem-based learning, information literacy, class discussion, teamwork and the integration of knowledge in order to raise the level of knowledge. the competences developed by the students in the multidisciplinary moment.

Gate 3. The assessment of the level of competencies is carried out, mainly, based on the participation that students had in inferring the attributes and dimensions of the investigation. Six capacities are evaluated: i) ability to master their discipline and incorporate knowledge from other disciplines (Choi and Pak, 2006; Nicolescu, 1999), ii) ability to provide information for the generation of knowledge, iii) communication ability (configured from the thought-language-context or reality relationship), iv) ability to work collaboratively with people from different fields of knowledge, v) ability to think about reality from different

perspectives under open and complex thinking (Nicolescu, 1999; Choi and Pak, 2006), and vi) assess their participation in the construction of the social fabric. It is expected that at the end of the next transdisciplinary moment the student will improve the level of the competencies developed in the interdisciplinary moment.

Moment IV: Transdiscipline. It is focused on analyzing interrelated phenomena from multiple levels of reality and the logic of the third party included, which implies going through disciplinary, multidisciplinary and interdisciplinary knowledge (Nicolescu, 1999). The first activity consists of identifying the relationships between activities, which were determined at time three.

Assuming that the processes determine the functioning of a complex system, and that these are the result of the convergence of various interacting factors (García, 2006), it is necessary that all the participants of the TD research, especially the students, achieve identify the interdependencies and feedback loops between activities, of which those that are most important and the reciprocal relationships they have must be recognized (Checkland, 2000).

Subsequently, the information and decision requirements of the parts of the system must be determined. It is an activity that entails, on the one hand, examining new information of a global and local nature, of a quantitative and qualitative nature, and, on the other hand, studying the system and its activities from the perspective of each field of knowledge in order to recognize and collect all the factors and parameters that influence this (Checkland, 2000).

Since DT is concerned with studying the dynamics generated by the synchronous action of various levels of reality (Nicolescu, 1999), it is impossible to explain a complex system from independent studies that are being added (García, 2006). Hence the need to work collectively, which is why the integration of the participants is key (Klein, 2004), committing them to act at different levels of abstraction, which facilitates dialogue in conflict situations. Therefore, it is essential that there is communication and understanding to configure the image of the system under study and understand its operation (Checkland, 2000), so it is considered that the IES-industry-society link is key to effectiveness and efficiency of the PTD-ES.

Finally, the TD moment concludes with the configuration of a proposed solution to the research problem, based on the complex conception of reality and integration of theoretical and practical knowledge. The socialization of this new knowledge will be the basis to start the PTD-ES again, since it is a cyclical process.

During this time, it is intended that students, from their participation in TD research and the application of teaching and learning methods, develop, mainly, six competences: the first, to be able to work collaboratively with people who have different knowledge, ways of thinking and seeing the world. The second is to be able to examine the arguments, integrate and evaluate the information. The third, have the ability to synthesize, produce and generate new ideas. The fourth, use the discussion to develop critical, reflective and emancipatory thinking that allows questioning themselves and the world (Jantsch, 1972; Freire, 1983), for which the informational culture will allow them to interpret and make informed judgments, in addition to become generators of information (Badwen, 2002). And the sixth, to be able to see reality as a whole and then in parts (Choi and Pak, 2006; Nicolescu, 1999).

In short, through research it is intended to build social processes in which both students and teachers understand and attend to the challenges and problems of the current world from the classroom and the link with industry and society, which is fundamental for the generation of knowledge collectively for the construction of the social fabric. Finally, DT is focused on self-knowledge and knowledge integration, which leads to self-transformation (Nicolescu, 1999) with the intention of configuring a sustainable society.

Discussion

There are models and methodologies to understand and conceptualize the inter and TD, as well as proposals for TD programs and courses for higher education, such as the Beecroft (2018) methodology that identifies six phases for the TD project, the didactic methods for TD courses proposed by Fiala et al. (2018), the system of Jia et al. (2019) based on the approach of key competences in sustainability, the model of Acevedo-Osorio et al. (2020) that proposes phases of TD projects and implications of actors and learning cycles in inter and TD spaces, the model of Khoo et al. (2018) that determines convergences, divergences and emergencies of the inter and the TD, among others.

In this context, the PTD-ES is built from the levels of TD (Nicolescu, 1999), the holonic theory (Wilber, 1996), the stage-gates methodology (Cooper, 2008) and the Checkland methodology (2000). In other words, teaching and learning methods are integrated, as well as TD competencies that students of HE must develop at each moment of the process. The PTD-ES is student-centered without neglecting the teacher, as both are

expected to learn in the process. In addition, it is binding, capable of being perfected with its practice, objective, configuration of the HEIs and with the organization of the participants.

Finally, it should be noted that among the limitations of the PTD-ES it stands out that it has not yet been launched, so its validation is pending. It is a process that does not address the barriers that affect the effectiveness and efficiency of DT, such as the domain of disciplinary thinking in HE, the individualistic and selfish culture of teachers, the organizational structure of HEIs and their lack of interest and commitment to DT, as well as disengagement with other institutions, industry and society, among others.

Conclusions

The objective set for this investigation was satisfactorily met. For this reason, the design of a process based on transdisciplinarity is proposed, centered on students and on the IES-industry-society link, which is divided into four moments, ranging from the simple to the complex, given by the conception of the reality with which the problems of the world are approached, analyzed and answered.

Each moment has specific activities for the student to participate and develop TD skills; mainly, systemic thinking, collaborative work and creativity, which allow you to understand and address complex problems in the world. Therefore, it is proposed that the teacher guide and accompany the student at all times.

Research is the basis for teaching and learning, which can be reinforced with the didactic methods of problem-based learning, discussion, information literacy, identification and inquiry of the referential scheme, and teamwork. At each moment of the process, the student develops a level of competence, which gives him a new identity, necessary to move to the next moment until reaching the TD.

Finally, derived from the review of the literature and the results of this research, it is suggested to consider educational action in HEIs as something dynamic linked with research, reality and with "everyone" who is involved in the construction of the society. In this sense, the TD training of HE students is essential for their personal development, their integration into the world of work, their contribution to the country's economic growth and, mainly, their participation in shaping a sustainable world.

Future lines of research

It is proposed as future research to put the PTD-ES into practice, to improve the proposal of the process from a more comprehensive systemic thinking, as well as to design an instrument for measuring TD competencies. However, this process has implications. In general, investment in high-impact databases, developing an informational culture, training teachers under the TD approach, adapting the organizational structure of HEIs and promoting research is visualized.

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Rol de Contribución	Autor (es)
Conceptualización	Graciela Salgado-Escobar «principal»
Metodología	Graciela Salgado-Escobar «principal»
Software	No aplica.
Validación	Graciela Salgado-Escobar «igual» Mario Aguilar-Fernández «igual»
Análisis Formal	Graciela Salgado-Escobar «igual» Mario Aguilar-Fernández «igual»
Investigación	Graciela Salgado-Escobar «principal» Mario Aguilar-Fernández «que apoya»
Recursos	Graciela Salgado-Escobar «igual» Mario Aguilar-Fernández «igual»
Curación de datos	Graciela Salgado-Escobar «igual» Mario Aguilar-Fernández «igual»
Escritura - Preparación del borrador original	Graciela Salgado-Escobar «principal» Mario Aguilar-Fernández «que apoya»
Escritura - Revisión y edición	Graciela Salgado-Escobar «principal» Mario Aguilar-Fernández «que apoya»
Visualización	Graciela Salgado-Escobar «principal» Mario Aguilar-Fernández «que apoya»
Supervisión	Graciela Salgado-Escobar «principal» Mario Aguilar-Fernández «que apoya»
Administración de Proyectos	Graciela Salgado-Escobar «principal» Mario Aguilar-Fernández «que apoya»
Adquisición de fondos	Graciela Salgado-Escobar «igual» Mario Aguilar-Fernández «igual»