ESTUDOS EM DESIGN
DESIGN ARTICLES

Design de sistemas e processos satisfatórios: uma abordagem transdisciplinar em ambientes acadêmicos e industriais

Designing satisfying systems and processes: a transdisciplinary approach to academic and industrial environments

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Resumo
O objetivo deste artigo é investigar e discutir as considerações gerais sobre o design de sistemas e processos que vão além dos aspectos "técnicos". Este artigo é um estudo qualitativo resultante da experiência dos autores em ambientes acadêmicos e industriais. É uma experiência combinada de mais de quarenta anos em diferentes profissões, circunstâncias e localizações geográficas (em diferentes continentes). Os resultados sugerem que a velocidade e a complexidade da vida moderna sobrecarregam as pessoas a ponto de se tornarem dependentes de sistemas e processos desnecessários. Os sistemas devem ser projetados com um nível de flexibilidade para permitir que os processos sejam dinâmicos e se adaptem com o tempo. Isto é conseguido através de um processo de aprendizagem focado em informações relevantes em bem embasadas combinado a uma abordagem transdisciplinar.

Palavras-chave: Design, Educação, Gestão, Transdisciplinaridade

Abstract
The aim of this paper is to inquire and discuss the overall considerations concerning the design of systems and processes beyond the "technical" aspects. This article is a qualitative study resulting from the experience of the authors in both academic and industrial environments. It is a combined experience of over forty years in different professions, circumstances, and geographical locations (spanning continents). Results suggest that the speed and complexity of modern life overwhelms people to the point that they become dependent on redundant systems and processes. Systems should be designed with a level of flexibility to allow processes to be dynamic and to adapt with time. This is achieved through a focused learning process based on strong and relevant information combined with a transdisciplinary approach.

Keywords: *Design, Education, Management, Transdisciplinarity*

1. Introduction

The human brain is still generally considered by far the most complex and capable thinking mechanism in the world. Without it, individuals (or groups), would never progress or improve their quality of life. Unfortunately however, individuals often fall short of using its full capability and capacity. At a singular level the results are simply binary – a person creates good or bad project, design or result. When considering multiple brains working together, the possibilities of multiple and excellent results are significantly enhanced. The authors believe that one of the keys to successful design is transdisciplinarity. In this work, the authors aim to show through clear examples and arguments, how a transdisciplinary approach including both technical and emotional aspects is essential in the design of objects, educational systems and business processes (amongst other things). Key to the understanding, is to think about one's design processes as multiple "realities" or "levels" all complementary to each other, yet all running contemporarily and all integrated. It is an exciting field of research not only blending expertise from "traditional cousins" such as "Physics" and "Chemistry", but driving and challenging designers, educators, and leaders to apply traditionally "unrelated" areas of expertise such as "Psychology" and "Materials" at the same time. The results are shown to be flexible and satisfactory not just for those who enjoy the outcome but also those who participated in the process.

2. Background and Purpose of Work

Systems and processes can exist in physical and non-physical nature. Intellectual, software, physical, productive, and social systems often need to be designed to do more than just operate a single "rigid" process. They should be capable of adapting to the situation at hand, considering the needs of the "customer" who is expecting the output. Therefore, has society allowed for enough angles, within certain systems, to produce a true and matching solution? Are the inputs or outputs operated within the systems flexible enough to cater to different needs or requirements?

Taking into account the richness and complexity of these questions, they became quite challenging in fields such as education, research, and business. Disciplinary, multi- and inter-disciplinary studies partially help resolve these questions. A transdisciplinary approach, however, provides the most degrees of freedom for analysis and an environment in which the inputs or outputs can be considered in a complementary and contemporary manner. The understanding derives from studies in both academic and industrial environments.

What can one do to remove the constraints in any given task and development process, and so improve their performance towards their original aims and objectives? Processes and social systems should address society's real needs and not exist just "to have a process in place". Certainly much more can be achieved regarding human and environmental needs by embracing a transdisciplinary approach.

Damasio (1994) says that reasoning and decision-making are a collection of systems in the human brain consistently dedicated to goal-oriented thinking and to response selection, especially in the personal and social domains. This same collection of systems is also involved in emotion and feeling, and is partly dedicated to processing body signals. A system includes three interdependent concepts: system, interaction, and organization (MORIN, 1992).

Norman (2004) has illustrated that the relationship between processes and systems are very much connected. The best way to discover people's needs is through observation, when the product is used naturally, and not only regarding a nonsense and arbitrary request to "show us how you would do x" (NORMAN, 2004, p. 81).

The purpose of this work is to comprehend the basis and implications of the approach to designing processes and systems, taking in consideration academic and industrial experiences in Brazil and Europe respectively. The authors also inquire that, by using a transdisciplinary approach to researching, one can better understand the technical, emotional, and logical aspects of processes or systems – that is, to picture the implications all in one single approach with a wider context.

2. Understanding the transdisciplinary approach

This study was developed taking into consideration the concept of transdisciplinarity. In addition to the disciplines, takes into consideration what is between, across and beyond them (NICOLESCU, 1997). Freitas, Nicolescu, and Morin (1994) and the participants of the First World Congress of Transdisciplinarity (1994) stated: "Transdisciplinarity complements disciplinary approaches. […] It offers us a new vision of nature and reality. Transdisciplinarity does not strive for mastery of several disciplines but aims to open all disciplines to that which they share and to that which lies beyond them" (Article 3 - Charter of Transdisciplinarity). Disciplinary and transdisciplinary approaches do not oppose but instead complement each other.

According to Max-Neef (2005), transdisciplinarity is how one perceives the world, systemic and holistic. He explains it using a pyramid distribution of four levels, from disciplines like mathematics, physics, chemistry, genetics, and geology at the base through disciplines such as engineering, architecture, and agriculture at the third level. Design and law, for example, take place on the second level and, finally, values, ethics and philos are the top of the hierarchical distribution.

Transdisciplinarity can also be interpreted as "a critical and self-reflexive research approach that relates societal with scientific problems; […] its aim is to contribute to both societal and scientific progress; […], hitherto non-existent connection between the distinct epistemic, social–organizational, and communicative entities that make up the given problem context" (Jahn et al., 2012:8-9). Spreng (2014) says that transdisciplinary research involves interdisciplinarity plus a participator. Moreover, the transdisciplinary approach often shows advantages over others. Academic research groups using the transdisciplinary approach are very motivated and curious, developing special interaction skills, and challenging themselves and others to find a new way to solve problems.

Concerned about a sustainable future, Cilliers and Nicolescu (2012) took under consideration complexity and transdisciplinarity research fields to discuss related attributes and characteristics to find a cohesive theory. One of their conclusions is that “[c]omplex transdisciplinary reality is plastic” (CILIERS, NICOLESCU, 2012, p.717). Everyone is responsible for any event and decisions made. People’s feelings, thoughts, and way of thinking and acting change in time and in space, so reality inside and outside one changes, leading to create a very dynamic environment.

The transdisciplinary thinking followed by Mishra, Koehler, and Henriksen (2011) was based on the conceptual work of Root-Bernstein and Root-Bernstein (1999), which later appears in M. Root-Bernstein, M. Root-Bernstein, and R. Root-Bernstein (2014). The seven selected cognitive tools are “perceiving, patterning, abstracting, embodied thinking, modelling, play, and synthesizing” (MISHRA, KOEHLER, HENRIKSEN, 2011, p. 24). They suggested seven learning skills or transdisciplinary tools capable of helping teachers to think of the learning process in a more versatile way including, for example, technological tools to make the activities more interesting for students and to give them creative and satisfactory learning experiences. Highly innovative and skilled teachers used these same seven transdisciplinary tools. Although it was an exploratory study, the findings have shown that the transdisciplinary way of thinking is quite a significant approach in teaching (HENRIKSEN, 2016).

In a conversation between Poerksen and Maturana (2006), Poerksen expresses that teaching is more a way of life, of interacting with each other, and of getting along, and by the course of the time spent together the learning process will naturally begin. It is during a more holistic process that languages, mathematics, or the laws of physics shall be acquired. Delors (1999) emphasizes four pillars of a new kind of education: learning to know, learning to do, learning to live together with, and learning to be. For Papanek (1984), the concept of education is based on learning skills, developing talents, understanding the concepts and theories that build the required skills, and, finally, being conscious of the learning process. The skills that are taught are too often heavily related to only technical processes and working methods.

Considering projects as part of the learning process, Lee (2009) has concluded that projects offer a number of possibilities of expanding learning experiences. Actually, she points out that with the delivery of projects, the level of independence rises, presenting the dynamic and complex aspects that involve a significant number of variables in and beyond the curriculum. This delivery process represents a significant effect on every aspect of the student experience. However, Popescu and Stan (2015) have an interesting point of view concerning the transdisciplinary educator role, suggesting a model in which teacher and student have a genuine connection. The educator sees and understands the human being whom he or she is working with.

3. Experiences

3.1 Teaching and research

The following case study addresses the social aspect as part of the system, paying attention to processes that exist and operate "in between" the disciplines. Active participation, direct observation, and a transdisciplinary approach were tools used in this research.

One of the authors (with a background in education and research in Brazil) learned from the practical experience of "living" the education process to adjust her approach while teaching. During her university education, she noticed that good constructive criticism was essential from both others and self. Students were challenged to think "outside of the box", which is a good principle. Unfortunately, often the subjects that students were given to investigate were not well designed or stimulating, and lacked the transdisciplinary "connection". This resulted in students losing the drive to achieve and the satisfaction in making a significant contribution to themselves or others.

Having started the career in teaching, the author was assigned to teach materials science and technology to undergraduate and graduate design students. Right away, the aim was to develop a process for teaching the subject in a more palatable and enjoyable way. Experience from past lectures had evidenced that students are more active and productive in a robust and sustainable way when they connect with what they are doing. With a strong will to prepare a relevant teaching plan, and by providing appropriate wider context using both disciplinary and transdisciplinary principles, the education process the author put as a goal and into use, is itself a continuous improvement process. The following seven principles are key to following the system under study:

(1) The general processes are governed by the overall university system, which is often segmented and does not allow the flexibility to support the learning process for all students.

(2) Engaging in a transdisciplinary approach which also incorporates awareness of the educators' responsibilities, including the ethical and emotional aspects of teaching. Moreover, regarding to research, with an "open spirit to transdisciplinary possibilities" (KINDLEIN JÚNIOR 2014, p. 126).

(3) Clear and relevant undergraduate and graduate courses which are organized professionally and have an overall context that links one to another.

Sometimes in universities, the approach to education can become polarized by the teaching of several disciplines in parallel which do not integrate with each other. Students can obtain excellent results in each discipline, but they do not realize, until they enter an actual working environment, that all disciplines must often be taken and applied together – then Eureka!

(4) Ensuring a good mix of theoretical and practical classes. To integrate practical lessons, this could involve setting up and carrying out laboratory experiments and tests or technical visits within the theoretical approach. These elements or some of them could be combined into a larger project, such as a related applied research study. This could motivate students' creativity and lead to innovation.

This approach not only ensures a link between theory and practice but also engages students more "emotionally" and directly into the subject, easing the learning process and giving a stronger sense of the meaning and engagement.

(5) Contextualization of the knowledge – to have in mind that gathering and managing information as well as pursuing flexible and critical thinking is important to fully understand any modern system or process, and how one piece of knowledge may relate to another.

Ab Kadir (2017), in his latest research of 21st century education, shows that curricular reforms should focus on developing and teaching critical thinking. More specifically, what affects the learning process is the "critical thinking pedagogical content knowledge" of the teacher rather than his or her "pedagogical content knowledge" (AB KADIR 2017, p. 82, 87). In contemporary education, according to Barak & Levenberg (2016) a model of flexible thinking is based on three cornerstones: having an open-mind, being able to adjust and find solutions in diverse circumstances, and using the available technologies for good with the purpose of learning something meaningful.

(6) Teachers' continuous learning to perceive what should change about the teaching process. To guarantee that learning goes on, Wang, Ho, and Chang (2015) claim it is normal and even important for the teacher to review ideas to better assist their students during the learning process.

(7) Treating the undergraduate students as "professionals in training". After all, learning how to act professionally is also part of the learning process. Therefore, an assertive and encouraging attitude from the teacher is important. The general idea is to develop self-motivation and proactive behaviour. At this point, the students' feedback may be helpful.

From an early stage in undergraduate courses, students should have support from the educator to ensure that they have made an informed choice to develop their knowledge and skills in their chosen disciplines. It is important that they begin to develop a professional attitude to learning since students "choose" to follow a career by making their own decisions.

Aware of the complexity of the system and having the transdisciplinary model in mind while starting to understand the profound implication of its propositions, it is clear that there is still a great deal to learn and areas for improvement. The process, on one hand, brings some uncertainty and can feel intimidating because it is a constant challenge when the "human" aspect is there.

It is essential, however, to consider this approach with an open mind without constraint for fear of change or hard work. In other words, the challenge should not be considered a burden, but instead may actually create a strong desire to improve education and research systems (Figure 1).

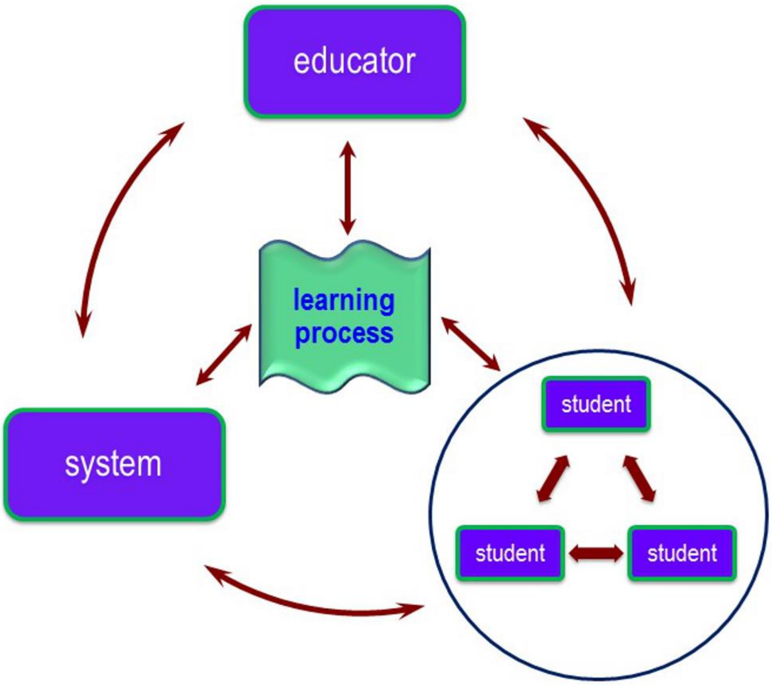


Figure 1: Transdisciplinary circuit that connects the learning process.

The learning process is transdisciplinary; the goal is not simply to transmit some content but rather to interact and teach students to use knowledge, intuition, and emotion as tools. As Papanek (1984) defines quite well, “education is a process in which the environment changes the learner, and the learner changes the environment” (PAPANEK, 1984, p. 287). Both student and subject, as well the education system, other subjects, and teacher, are part of a self-regenerating system.

Agreement can be made with the Max-Neef (2005) statement that universities are disciplinary organizations having practically no knowledge of what transdisciplinarity is. The best scenario is that interdisciplinary efforts may be recognized, but they are not integrated into the university system.

3.2 Business improvement within industry

The other author (with an industry background in Europe) presented two cases to illustrate the improvements that can occur within industry. The two examples were chosen to best demonstrate some key concepts: the first is regarding a manufacturing and distribution system, the second a design and development process.

3.2.1 Manufacturing tyres and steel wheels

The company under study manufactures tyres and steel wheels and distributes them through a European network. With increased volume of sales and customers, the company had to resolve a problem regarding the distribution of steel wheels. The company had many systems in place linked together to try to manage the distribution:

(1) Materials requirements system at each trading site (up to 11 sites around Europe).
(2) Internet-based central information database.
(3) Local ad hoc planning tools.
(4) Materials requirements system at production site.
(5) Production planning tools at production site.

Many people were also involved in the process:

(1) Customer sales representatives at each trading site – placing orders.
(2) Purchasing/logistics teams – analysing sales and calculating purchase orders.
(3) Warehousing and production staff at each trading site – receiving wheels, mounting tyres, shipping mounted wheels, making stock adjustments.
(4) Logistics team at production site – analysing incoming orders from all trading sites, calculating production orders for steel wheels, organizing capacity and scheduling.
(5) Senior management, purchasing, and sales staff at all sites – setting and achieving goals.
(6) Production staff at production site, making day-to-day, hour-to-hour scheduling.

Even though at least five systems and many people were involved in this planning “super-system”:

(1) The trading sites were not receiving what was required, when it was required.
(2) The production sites were not using resources efficiently and were having to resort on a regular basis to overtime and weekend working, as well as extra staffing.
(3) The final customers were often not receiving maximum service.

The enterprise looked at the information and material flow for their products and realized that they had exaggerated by building system upon system to try and manage a complex problem instead of making the problem simpler. Every time a new process or another person was introduced into the system, it slowed down or confused the transmission of the information from its source to where it was required the most. In other words, the company had built a maze of processes through which “consumption/requirement” information had to travel to reach the point where something could be done about replenishing it. If one “untangled” this maze and applied a timeline to it, it became apparent that replacement products could require months to become available. It was realized that the overall system could become much simpler and more flexible by removing most of the original processes in operation. The key was recognizing that the people on the production machines in Croatia had to know as quickly as possible when someone in the shipping area at the trading sites had sold some product. It was so simple that previously the team had been “blind” to it. The solution then involved the following:

(1) Purchasing/sales team setting overall consumption requirements once per quarter.

(2) Shipping person at trading sites sending standard consumption tickets via fax or email to production planner at production sites.

(3) Production planner collecting the data and putting it into production before shipping the material back to the trading site.

Within a few months of operating the new simplified system, the capacity on the production machines became much easier to manage with less overtime and cost. The trading sites received more of what was required, when it was required. The huge amount of excessive communication passed between various people in the supply chain disappeared completely and was no longer wasted.

Therefore, the key learning points from this case study are to get back to basics and:

(1) Really understand what the aim of the overall process is.

(2) Discover the quickest and most efficient way of connecting the two important points of the process together in communication, removing all the waste in the middle.

(3) Make use of a transdisciplinary leader to see the "total context" and promote interactions between individual working disciplines to find the optimal integrated solution.

Although this is an example of a manufacturing and supply process, the issues it illustrates can also be found in many other environments. The following case study demonstrates this.

3.2.2 Design and configuration in helicopter manufacture

During the design of an aircraft, the product goes through thousands of development processes before it is safe to fly in. In one helicopter company, a concession and engineering change process (CECP) was being implemented during the design phase of a new helicopter transmission. Since a helicopter is a very complicated integration of many individual systems, every time a change is made to one element of a system that interfaces with another, it is necessary to check that such a change does not adversely affect another part of the aircraft.

The CECP within the company coordinated these checks to ensure a complete and thorough treatment of any modifications made. The input to the process, for example, was a document completed by a transmission designer identifying the change, and the output of the process was the same document, approved by several leaders who were responsible for different systems within the aircraft. This process was time-intensive and complicated.

In effect, the evaluation of the modification was passed consecutively from one discipline to another. Often a suggestion that one design leader made had to be taken back to another who had just signed off on his area of competence, as it adversely affected his colleagues' disciplinary area.

After analysing the process, a "round table" (applying a transdisciplinary basis) with periodic timing, was organized to unite all the leaders together and "pass the parcel" of design change documents around the table one by one. When a question was generated from one design leader, his counterpart was able to respond immediately. If the question could not be answered, it was taken away and answered before the next meeting. Very often colleagues from non-related disciplines were able to contribute relevant information or questions which optimized the decision process, allowing it to flow better.

The new process promoted a team approach to the design, as everyone could see how many changes needed authorizing and worked towards reducing them. The result was that in a few weeks, a large number of changes which had accumulated were quickly reduced and the development project proceeded with far more speed towards completion.

As in the previous case study, the key was identifying the quickest and simplest form of communicating the information. This turned out to be the flexibility of having all the leaders together at the same time in a transdisciplinary forum so that each could answer questions in real time and share different perspectives. Working in this way also led to a far more efficient and better solution, as the assembled group of leaders could bounce opinions and ideas off each other in real time.

Although this study addresses a transdisciplinary approach the research concurred with Sadia (2018). Studying a group model building in Israel, his research indicates that workers social and cultural backgrounds as well as their educational levels, standing career and work conditions impact directly the managing process.

4. Discussion

Based on the researcher's experience, a system is the "overall umbrella" (or boundary) within which an input is transformed step by step through a series of processes to give an output. This helps teachers and managers become aware of the real context and background of the indicated tasks and the needs of the students or working group. In other words, processes must have a system in which to run. In this way, by observation of how systems and processes work within a wider context (while keeping in mind the real end goal), one can develop more practical, simple, and intelligent solutions to achieve the desired outcomes.

Any system may be designed but people will always add an emotional element to it. The result may be fantastic for doing the job, but if it does not look or "feel" the part, people will not work well with it psychologically. Spear and Bowen (1999), by studying the Toyota Production System showed that, even in a rigid production environment, the existence of a scientific method stimulates workers' experimentation, integrating new production processes into the system.

If systems are looked at in relation to processes, systems are generally static, but processes can be dynamic, that is, they change from one thing to another over a period. Therefore:

(1) The system processes the input to produce the output (or at least that is the objective).

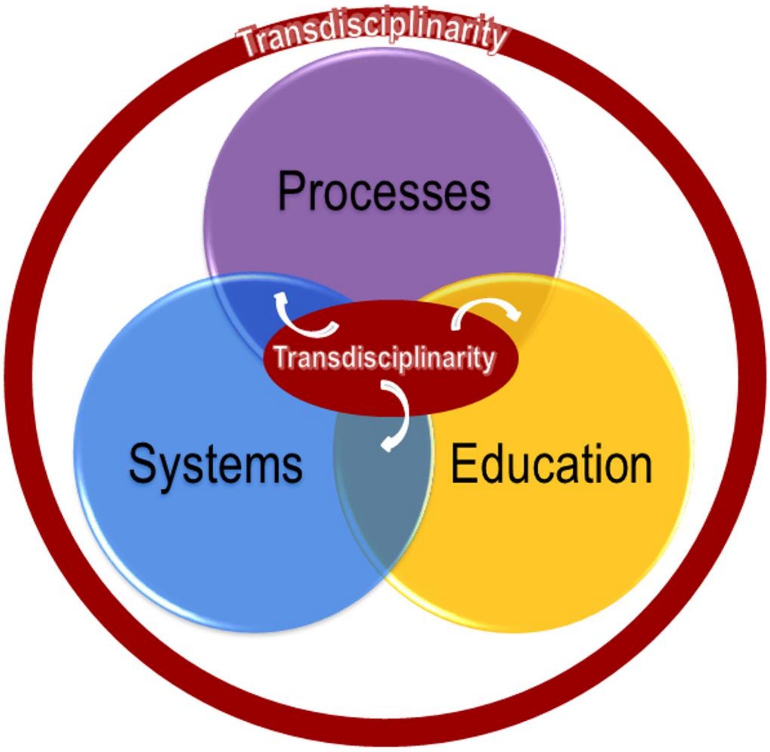
(2) The same system will process different inputs to produce different outputs.

(3) A system can be considered to be made of elements that have boundaries and limits. Very often these are fixed but can be changed. The boundaries and limits to a system are defined by the parameters in a system. As the parameters change, the boundaries and limits may also change.

(4) Some parameters may not be under control by the person operating the system; hence, these are considered variables.

Often variables are related to human emotion or the psychological nature of the system. Although it is possible to concentrate on purely technical elements within a system, if the human element is not recognized, all the drive and extraordinary proposals that could develop may be blocked simply because "someone does not like it" without logical explanation.

Therefore, over and above the technical considerations, when it comes to designing



processes or systems, a high level of ethics, human understanding, and professionalism are required.

Fig. 2 illustrates the concept of how the transdisciplinary approach is understood here, in this case more focused on education.

Figure 2: Levels of transdisciplinary: interaction between and beyond processes, systems, and education.

To help anyone understand what is required to actually learn a subject, it is essential that professional educators become more than just technically minded people who concentrate on a single discipline. For that, engagement is essential among participants, as in any process or in any system. Therefore, transdisciplinary actions are necessary; for example, educators at universities cannot solely concentrate on the content of their subjects, but must also recognize themselves and others in the process to stimulate students to become excellent professionals.

Designers, for instance, do not become good designers because technically on paper they earned high scores; they become good designers because in addition to their scores, they have developed a passion and grit for finding and understanding knowledge which helps them to provide excellent and appropriate solutions to real-life problems. And educators have a fundamental role in this process.

Transdisciplinarity is also demonstrated as a requirement in the industrial environment. To demonstrate this, Lawrence (2015) synthesizes his work presenting different fields such as urban, land, and climate studies. Agreeing with Serna (2015), a team of information technologists cannot solve a distribution problem with IT solutions alone. The design and application of transdisciplinary actions depend on a group decision-making process engaged in a growth mindset with a good level of drive and synergy.

5. Conclusions

The transdisciplinary approach is relevant because it offers simultaneously a continual focus on the goals and the context to all involved when designing systems. By recognizing that there can be emotional variables in systems, it is understandable that the same system may produce different outputs even if the “physical” inputs look to be the same. When people are involved in the input, process, and output of the system, events can be rather variable. Attention has to be given to all of the events required to produce the desired output. If one does not recognize the human “emotional variable” during implementation and use, he or she may misunderstand any system malfunctions or poor outcomes, which can even lead to disagreement or unfair results. It could be considered in many cases that the way of managing, and educational approach is pulling us away from a good balance between technical and personal aspects, placing more weight on the non-emotional factors. To increase the possibility of favourable outcomes in the execution of systems in general, critical thinking is relevant – the modern definition includes a transdisciplinary proposition (Critical Thinking Community, 2017). Accordingly, awareness of the context provides everyone with critical thinking and also a more stable “emotional” state.

It is understood that a correct design requires the use of an approach that understands the overall requirements and expectations which will generate satisfaction, and gives drive and focus to the project from start to finish to achieve the best possible results. Operating with transdisciplinarity actions and understanding context ensures that communication of information is controlled and directed in the most efficient way to the people who need to know it. It is always possible to realize by stepping back and taking a look at one’s systems and processes, that by providing people with too much useless information also stimulates the emotional variable in a negative way – “I don’t want to do this because it is getting too complicated”. This transdisciplinary approach is an important step in developing and maintaining an environment in terms of ecocentric management. Therefore, this proposition begins to be effective when the educator or leader offers more than systems and methods; he or she is mindful of the process of learning. In fact, the concept is simple but is not easy to implement. The outcome is that grit, ethics, interdependence, and love for what one does are intrinsic to processes and systems.

The upgrading of knowledge and consciousness brings the understanding that processes and systems must be as simple as they can be, flexible and adaptable, because the ultimate goal is the general well-being of all who participate in designing the systems and those who use and interact with them. Both university and industry experiences showed that during the learning process or decision-making focusing on pure "technical" analysis is not sufficient. In other words, being aware of the need to include emotions, personal interaction, and intuition is intrinsic and fundamental in design education and research. Decisions are made based on cognitive and affective responses.

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