

Sharp Teacher Training and the New Constructal Pedagogical Supervision Theory for Sustainable Development

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ABSTRACT

We live in the information age but we can only increase the benefit if we look to permanently promote more efficiently the use of the cyberspace for creative thinking; pedagogical innovation; sustainable development education; the new constructal pedagogical supervision; scientific, technological, and engineering advances share like the constructal law, green chemistry, and green energy; Portuguese Cultural Heritage; economic growth; and biotechnology through the quality pedagogical resources and Web 2.0 already putted in place in there and all those that are to come available. So more “state-of-the-art” teachers training for continuous update are needed, and we know too that adequate training can lead to better judgments and better performance. In Portugal, the pedagogical supervision theories thrive with lots of different institutions like universities and polytechnics offering MSc. and PhD programs in these subjects, to these theories is add now the constructal pedagogical supervision theory for sustainable development. New training courses are needed for teachers so can have a bigger variety for their choices, while achieving the United Nations goals for sustainable development.

Keywords: teacher training, constructal pedagogical supervision, sustainable development

INTRODUCTION

In our information society, it is of vital importance to share and use dynamically the knowledge innovation produced, to tackle many of the today’s broadcasted modern dilemmas like sustainable development education, pandemic emergencies such as COVID-19; climate change and extreme weather; pollution; food production and security; energy production and security; economy innovation and growth (Bejan, 2009, 2012b; Bejan et al., 2013; Hepbasli, 2008; Horta, 2005a, 2006b; Hugues, 2006); computer modelling has been use for a long time in lots of different sectors in industry and science like when some biologists try to model the infection of a bacteria *escherichia coli* (Gibbs, 2001); meanwhile the Web 2.0 provides highly valuable pedagogical resources, sciences virtual laboratories, for us to find, select and integrate in innovative pedagogical contexts in basic, secondary and post-secondary classrooms, and/or in teachers training courses (Horta, 2005a, 2007b, 2009, 2010, 2011a).

Therefore education systems could deliver more frequently “state-of-the-art” continuous teachers training update about latest advances on chemistry, biology, natural sciences to implement with the cyberspace like constructal theory; artificial intelligence; astrochemistry, astrobiology; space exploration; good practices for safety and management of

school laboratories and physics and chemistry education innovation; biomaterials; green energy, green chemistry, biotechnology, nanotechnology; and Portuguese Cultural Heritage, just to name a few examples, which can fuel inspirational creativity for new approaches and methodologies in education; and for better judgments and better performance (Bailey and Ollis, 1986; Chang, 2012; Horta, 2005b, 2005c, 2006b, 2008b, 2009, 2011b, 2011c; Langer and Peppas, 2003).

In Portugal, the pedagogical supervision theories are widespread, with many institutions like universities and polytechnics offering MSc. and PhD programs in these subjects, all these theories can be in a field for constructal improvement. Moreover, like in economics where there are many index tools to measure considerations (Bailey and Ollis, 1986; Bejan, 2012b), we can use mathematical tools delivering different perspectives from educational sources and pedagogical supervision excellence and providing more insights; thus, we present a set of measurement mathematical tools in both schools professorship supervision context and teachers training centers within the new *constructal pedagogical supervision theory*; relating evidences about the delivering of innovative pedagogical contexts in information age, the embracement of the modern science teacher training course design with sharp teacher trainer profiles for the United Nations goals for sustainable development (Horta, 2009, 2010, 2011a, 2011c; UN, 2021), can change the world.

THE CONSTRUCTAL LAW OF THERMODYNAMICS IN SCIENCE TEACHERS TRAINING INNOVATION

Coming from the engineering field and spreading, the thermodynamic formulation of the constructal law is an opportunity for more pedagogical innovation and creative inspiration for the benefit of mankind; this 4th law of thermodynamics states that “for a finite-size (flow) system to persist in time (to live), its configuration must evolve such that it provides easier and easier access to its currents” (Bejan, 2000; Bejan and Lorente, 2010), so, we can look all around us or far out for evidences (like at your circulatory system, or rivers at a distant planet).

There are plenty and very interesting recent developments related to constructal law, reported in lots of different places like web available papers, books or Web 2.0, some examples are sports (Lorente et al., 2012), river basins (Bejan and Lorente, 2003, 2010), transports and economical structure (Bejan, 2000), biomaterials (Horta, 2011b), wetlands (Horta, 2009), running and swimming of animals (Bejan and Lorente, 2011a), botanic trees (Bejan and Lorente, 2010), lungs (Bejan, 2000), circulatory system (Bejan, 2000), and wind flow and global climate change (Clausse et al., 2012). Just like we do with a Newton law or with the Lavoisier law, we should deliver more pedagogical conceptual examples and applications (virtual and real) of the constructal law (Horta, 2011a); and with the existing resources on constructal theory in cyberspace available for finding (Borders, 2010; Horta, 2003, 2005a, 2008b) to investigate and to discuss in teacher training (and after in classes with students) can rethink and reevaluate its applications in all knowledge areas, providing new learning contexts and opportunities for pedagogical innovation, to better understand its scientific connections and gather more provocative ideas for scrutiny and discussion, promoting update on all this new knowledge (Horta, 2005b, 2009, 2011a). Within this teacher training course, the energy sustainable production and consumption along with green energy security and constructal theory can be explored through the elaboration of conceptual examples or utility models (Horta, 2005a; Serway and Jewett, 2013) that include the information technologies along the scrutiny and debate; that can too generate awareness for sustainable development issues while instruction on several physics and chemistry concepts from the national curricula and also hoping to benefit a democratic society and entrepreneur education too. Starting from the pedagogical conceptual example about an energy settlement (Horta, 2008b, 2010) and making a slightly different pedagogical approach. Here, in this pedagogical example the teacher can in class create two teams that will use the outfit of entrepreneurs, the scenario is the same triangle *Paul-Barco-Coutada*, one team will propose the settlement of a nuclear power plant and the other team will propose the settlement of a hydropower; the moderator can be a selected student. Before the debate the team of students “entrepreneurs” that argues for the investment in a nuclear power plant settlement will search as in the web space as in books about benefits and advantages of the nuclear technology; the constructal law; possible storage of radioactive waste in the close *Sabugal*

region mines; what are the main implications on local societal structures; it is the best if the nearby energy security, food safety and health field get nuclear energy training abroad in different places like USA, France, UK, Japan, and Ukraine? What are the key concepts in the official curricula to better understand nuclear energy? What is a Geiger counter? What are the benefits for the local economy, the environment and the Portuguese Cultural Heritage treasures (Horta, 2006b)? The other students “entrepreneurs” team would do the same kind of preparation before arguing for the hydropower settlement (Cervantes, 2005; Dalquist et al., 2007).

The debate is clocked and in the end the student’s listeners will ask questions to the team’s speakers and then vote to choose which of the power plants is more suitable for that place according to the arguments listened. This teacher training course designed by me can be delivered as a workshop (*Oficina de Formação*) and is intended to teachers from all education levels, and specially recommended to biology and geology teachers; physics and chemistry teachers; natural sciences teachers; physical education teachers, and informatics teachers.

ALONG WITH PARTICLE COLISION, CONSTRUCTAL ONCOLOGY AND THE STRUCTURE OF THE UNIVERSE

Delivering a single teacher training course that reunites the origin of the chemical elements and its relative abundance in the sun and in several places in the universe; the molecular chemistry in space and the spotting and identification of molecules outside planet Earth; how to search in the Web 2.0 and correct selection of information on perspectives in astrochemistry and in the astrobiology; the chemicals of life, essential microbiology and molecular genetics; how nature takes shape (constructal theory); examples of chemistry applied to biology; the history of 50 years of space exploration, the physiology in aviation, high altitude and in space; debate the present and future of space exploration and sustainable development and if we are alone in the universe (Aires-Barros, 2005; Bailey and Ollis, 1986; Bejan and Marden, 2009; Bernstein et al., 2000, 2005; Brownlee et al., 2003; Campos, 1999; Horta, 2007a; Kreuzer, 2002; Sandford et al., 2001; Stanford, 2007); we strongly believe that we can promote opportunities for more creative thinking and pedagogical innovation.

When we think of particle physics and particle collisions, we can train teachers to develop more pedagogical examples when looking for answers for provocative questions like, do we see constructal law in the Higgs boson decay since the big bang? Looking at the traces after the particle collision experiments drawn by the sub particles, are those in tree shape with the emission of energy? And from the debate then generated. In another hand we can focus on series of radioactive decay and inquire about the design of the decay and debate then also the nature of the atoms, and how they are made within the universe (Aires-Barros, 2005; CERN, 2011; Dutch, 1999; Horta, 2007a, 2008a, 2008c, 2011a; Serway et al., 2013).

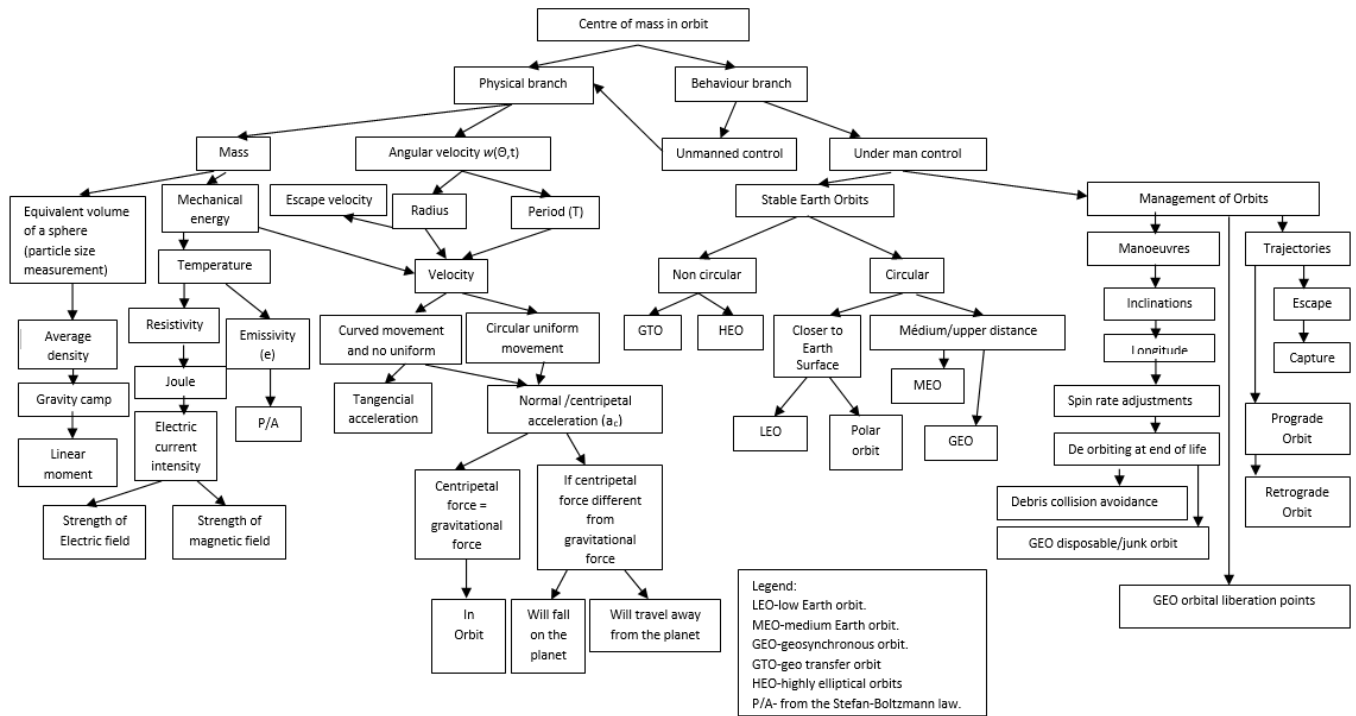


Figure 1. A satellite constructal taxonomy

We are all well aware of the huge number of web pages devoted to the periodic table of chemical elements, from the most “traditional” to the most “visual”. The periodic table is today an icon of chemistry education, since its appearance by the hand of Mendeleev, much evolution and many approaches have been presented. We can look up at the internet for lots of different tables, many so beautiful.

There are among those periodic tables, many showing the relative amount of the elements present in different contexts (Dutch, 1999; Horta, 2007a) like within the Universe, in Earth’s crust, in the moon, in the sun, in human body and in the human cell, providing opportunities for us to compare compositions in a context of teaching.

In teacher training the creation of several pedagogical conceptual examples and motivational contexts can be triggered using all that information available, to relate to the amounts of atoms of the elements present in the human cell vs. the tumours cell, and ask is there any element present in one that is not present in the other? Or to ask if we can starve tumours and/or slowing down its metabolism, depleting from our diet some key chemical elements (or molecules) or prevents the appearance of tumours? Or with the knowledge that the constructal law applies to the circulatory systems, debating if in cancer battle can we adopt strategies that will obstruct and/or inhibit the tumour vascularisation, like putting less atoms in our diet that are more prevalent in the tumour cell, and/or discuss if the lack of chemical elements that are not in the human normal cell’s needs could eventually make the tumours channelling defective, and how that can contribute to people’s health? (Bejan, 2000, 2012a; Bejan and Lorente, 2011a; Campos, 1999; Dai et al., 2006; Kim et al., 2008; Kreuzer, 2002), conceptual examples can be also developed from the discussion of the universe expansion, from investigating that the milky way being within a galaxies cluster, the galaxies found in galaxies clusters, and the giant

galaxies clusters that are within filaments, spots of the universe that looked live are totally void or filled with dark matter (Bernstein et al., 2000, 2005; Brownlee et al., 2003; Horta, 2007a; Sandford et al., 2001)?; we can question and scrutiny the constructal law in energy and matter flows (like the snow flake, to lighting, computer heat flow optimization, the solar flares outbursts), along with the reported that galaxies are spreading apart at increasing speed (Bejan and Lorente, 2006, 2011b; Ciobanas et al., 2006; Horta, 2005b, 2006b, 2011a, 2011b, 2011c; Kim et al., 2008), looking answers for: are the spreading of galaxies (in an even bigger picture, the filaments spreading) an evolution of tree shapes of increasing complexity throughout the expansion of the universe, obeying to the S logistics curve of spreading and consolidation of flows in view of the constructal design?

This teacher training course designed by me can be delivered as a workshop (*Oficina de Formação*) and is intended to the biology and geology teachers, to the physics and chemistry teachers, and to the physical education teachers.

CONSTRUCTAL TAXONOMY ANALISYS OF ORBITAL SATELLITE (AND/OR SPACE OBJECT)

The interstellar visitor “Oumuamua” created a lot of discussion relating to its origin (Griffin, 2017; Loeb, 2018; Planet Today, 2021). In this idea of taxonomy, we propose the constructal theory (Bejan, 2000) approach; the first two branches are the physical parameters and behavior parameters (Figure 1).

The constructal theory (Bejan, 2000) allows to organize the flow of information with more ease and better understanding, the construct presented can be optimized with the constructal

law, can be latter updated: the physical parameters give us information of the physical evolution of the object in orbit; while the artificial satellite being an extension of the human genius has then minded orbital behavior based on Earth (Brown and Harris, n. d.; CNES, 2015a, 2015b; EMEA Satellite Operators Association, 2017; Earth Observatory, 2009; Montenbruck, 2013; NASA, 2018; Roshni, n. d.; Steel, 2015; The Physics Classroom, n. d.). This teacher training course designed by me can be delivered as a workshop (*Oficina de Formação*) and is intended to the physics and chemistry teachers.

PEDAGOGICAL EXPERIMENTS DESIGN WITH CONSTRUCTAL LAW

One of the many challenges is to adapt the constructal law in laboratory experiments design (real and virtual) for basic and secondary education, one example is the constructal wetland (Horta, 2009), for water purification; other can be the constructal optimization of electric circuitry for energy efficiency optimization (Hristov and Anacleto, 2012), presented at the Portuguese national science fair held at the electricity museum in Lisbon (*Mostra Nacional de Ciência*). For the teacher is relevant the school laboratory work to design and develop its own pedagogical laboratory experiments innovation for education (Horta, 2006a, 2011a, 2011c); and to develop school projects with students; at the same time should be aware on the best lab design requirements and the environmental implications of teachers' choices and how the knowledge about green chemistry is important (Doxsee and Hutchinson, 2003; Horta, 2005b, 2006b; Martinho Simões et al., 2008). On each and both chemistry and physics laboratories management, the look for optimizations are assets; and we should not forget those are the stage for many different laboratory teaching methodologies to apply and to innovate (Arnas, 2009, 2016).

We cannot ignore all the specific technical requirements and the ability to understand complex scientific and technical issues regarding effective risk management of workplace chemicals that both school chemistry laboratory (Doxsee and Hutchinson, 2003; Horta, 2005b, 2006b; Martinho Simões et al., 2008) and physics laboratory (Abreu et al., 1994; Horta, 2006a) safety require, and there is too the need to enquire, identify and evaluate existing local constrains too, like the laboratories have the best design possible for that purpose? Or is there any recent knowledge/technical development on this field that deserves updating? (Bejan and Lorente, 2012). We believe should be done only by someone from the field: the chemistry and physics teachers. The training for constant lookup for update on science and technology for improvement and optimization of good practices for safety and management of each and both chemistry school laboratories and physics school laboratories available at schools should be stimulated along with the cyberspace and the green chemistry body of knowledge (Bejan and Lorente, 2012; Doxsee and Hutchinson, 2003; Horta, 2005b, 2006b; Martinho Simões et al., 2008).

This teacher training course elaborated by me can be delivered as a workshop (*Oficina de Formação*) or as a course and it is intended for the physics and chemistry teachers.

APPLYING THE NEW CONSTRUCTAL PEDAGOGICAL SUPERVISION THEORY

Pedagogical supervision theory and models have evolved over time, we can in a sense say that they can be looked as constructs evolving in time and they coexist; its selection and applying can depend on which one is better regarding the circumstances and the people involved. However, I also believe in another and new step towards excellence in pedagogical supervision with constructal theory—the new *constructal pedagogical supervision theory*. The world is in need (Horta, 2006b), in the 21st century problems accumulate and tend to increase. From global warming and energy production and security; to water scarcity; pollution; global food production and supply; the COVID-19 pandemics that shows how fragile we are in facing global health problems; migrations flows with horrible tragedies associated like in the Mediterranean; the miseries, tragedies and horrors of war; just to mention some examples, which makes more imperative to achieve the United Nations seventeen global goals for sustainable education. We can change the world with education; and with the *constructal pedagogical supervision theory* contribution.

In this new *constructal pedagogical supervision theory*, schools and teachers training centres are smart institutions that morph in the way that provides easier and easier access to flows of new science, technology, management and pedagogical developments and eco innovation currents, while implementing the official curricula's (Bejan and Lorente, 2012). In the *constructal pedagogical supervision theory*, both supervised and supervisor have profiles that evolve over time, desirably in the direction of better; we believe this another supervision model will lead to more creativity and recognition of creativity, the develop and optimization of autonomous, participative, innovative and sharing attitudes, based on several concepts like reflexive thinking, autonomy, personal discovery (Bejan and Lorente, 2010, 2012).

In the *constructal pedagogical supervision theory*, reflexive thinking concept is considered the capability of a teacher to make the assessment of what is going well and what is not, and actively in that moment take appropriate approaches, steps, actions to improve things, mobilizing his/her knowledge and at the same time understands his role (patters, influences, training, perspective, etc.) he is playing on the current outcome, in the different aspects of his professorship and how to grow; that allows more flexibility to change and to adapt, awareness of his/her impact and influence, among other benefits, which is deeper than just to do the reflective approach (Barret, 2021; Parenta, 2019). The autonomy of the teacher, for his teacher practice and continuous teacher training choosing, after his assessment for his training needs, and for that is of high importance the *Bejan Quanta (BQ)* for sustainable development from a teacher training center, which gives crucial information for the teacher; students will benefit with all that all new knowledge for sustainable development and that can change the world for the better. The personal discovery, which allows the teacher to understand better his/her strengths, potential, purpose in life, core principals, weaknesses, developing high level of critical thinking, which is

great for professional grow (Destinys Odyssey, n. d.; Jackson, 2015; Robert, 1990).

This new *constructal pedagogical supervision theory*, considers that the supervision act must be based on the legitimacy of the supervisor's knowledge, then supervision is really effective, and that only those who master the subjects are really creative, so a pedagogical supervisor with higher *Higgs Quantum* more easily will recognize the supervisees' creativity, their strengths and weaknesses and will give the supervisee the necessary freedom to create and implement classes. The *Higgs Quantum* of a teacher profile is not static, each profile evolves over time; so the teacher being supervised and the teacher supervisor can swap roles according to the *Higgs Quantum* parameters. This pedagogical supervision model looks for the achievement of the sustainable development goals with the planet urgency, to promote the efficiency of schools and teachers training centres, to encourage teachers to perfect themselves and promotes the respect for their ideas and for their initiatives, to facilitate the flows of good science, technology and pedagogical ideas according to the constructal law, contributes for the improvement of the conditions of students, teachers, schools, teachers training centres and owner planet.

This *constructal pedagogical supervision* model for sustainable development is democratic, with the functions, objectives, goals, behavior roles, participants and supervision process must be well established; teachers working together to achieve better results in teaching and learning, facilitating the flows of good science, technology and pedagogical ideas for sustainable development, in all educational activities, with everyone in the learning process. In this model, the supervisor will have a vision for sustainable development that is inspiring and his/her example, with discipline, responsibility, will guide the team of supervised teachers to make that vision a reality; his supervising teachers' activity includes to teach and train, to plan, to organize, to challenge, to solve problems, to share concepts and change attitudes and behaviors for sustainable development, to lead teachers and students to achieve good results, to suggest teacher training with the *Bejan Quanta*, to suggest continuous teacher training centers with the *Horta Quanta*, to motivate supervised teachers to be creative or innovative in their teaching practice, to evaluate and control. Promotes the team of teachers' analysis and reflection on educational practices and their context, exchanging experiences, allows teachers to discuss and debate towards sustainable development.

For the *constructal pedagogical supervision theory* and for teacher training many are the possible developments and diversification of smart tools for measurement: science teachers' trainer profile; teachers training center profile; pedagogical supervisor profile; supervised teacher profile. Next, we present one set of measuring tools with the *constructal pedagogical supervision* and teacher training for sustainable development in the information age. We define the *Higgs Quantum* (H_o) has the constructal index for sustainable development education from an education specialist profile: a teacher trainer profile, a pedagogical supervisor profile and a supervised teacher profile; for the sustainable development, in this information age, scaled from minus ten to ten; that relates nine criteria which values

qualifications, training taken (after obtained the degree), published creative work with peer review, scientific societies links, and it's mathematically defined by Equation (1):

$$H_o = \frac{\sum_{i=1}^{10} N_i}{20} \quad (1)$$

To the *Higgs Quantum* in pedagogical supervision and teacher training for sustainable development in the information age equation we use the punctuations from the **Table 1**, nine out of ten criteria score positive; the 10th criteria is only to be applied to a pedagogical supervisor profile and when verified it does not affect the final score but when not verified will score negative diminishing the final index, penalising resistance to flows of good science, technology and pedagogical ideas for sustainable development, accordingly with the *constructal pedagogical supervision theory*. In Portugal, the institution that does the recognition of teacher trainer qualification in the different fields of performance is the *Conselho Científico Pedagógico da Formação Contínua (CCPFC)* – the Portuguese Scientific and Pedagogical Council for Continuous Education (Bejan and Lorente, 2012; Conselho Científico Pedagógico da Formação Contínua [Scientific Pedagogical Council for Continuing Education], 2010).

After the *Higgs Quantum* index being calculated from a teacher trainer profile we can then apply it in a teachers training center. To determine the average of the *Higgs Quantum* indexes of the teacher trainers' profiles from a specific teacher training center, and therefore mathematically obtain the average strength, we have then the *Horta Quanta of a Teacher Training Centre (HQ)*:

$$HQ = \frac{\sum_{n=1}^n H_{o_n}}{n} \quad (2)$$

Looking at a Teacher Training Center offered courses schedule, we can analyse the teacher training design, the associated teacher trainer *Higgs Quantum* index, in every training present of the planning, and we look for sustainable development education training. Subjects that are relevant for sustainable development and already subject of analysis and debate, in bibliography, conferences, studies, quick examples are astrochemistry (Aires-Barros, 2005; Bernstein et al., 2005; Horta, 2006b, 2007a), constructal theory (Bejan, 2000; Horta, 2006b, 2007b, 2008a, 2008b, 2008c, 2009), climate change (Clausse et al., 2012; Horta, 2016), green energy (Cengel, 2006; Cervantes, 2005; Dalquist et al., 2007; Horta, 2006b, 2008b; Midilli et al., 2005), green chemistry (Doxsee and Hutchinson, 2003; Horta, 2005b, 2006b), hygiene and security in educational chemistry laboratories (Horta, 2005b; Martinho Simões et al., 2008), interactive internet (Horta, 2003, 2005a, 2005c, 2006b), biomaterials and biotechnology (Horta, 2011b, 2011c; Ratner, 1996), radioactivity history (Horta, 2005c, 2006b), food chemistry (Mills, 2003; Videira, 2011), exergy (Arnas, 2016; Bejan et al., 2013; Horta, 2010), Portuguese Cultural Heritage (Horta, 2006a, 2006b, 2008b), biospectroscopy (Benko, 2005; Horta, 2009), health physics (Horta, 2008b), medical physiology (Horta, 2006b, 2008b), neurochemistry in behavioural sciences (Smith, 2001; Stanford, 2007), and women in science (European Communities, 2009; Horta, 2005c).

Table 1. How to score the Higgs quantum index?

Criteria	Punctuation	Evidence	Score
Credited trainer of chemistry	N ₁ =15		
Credited trainer of physics and/or biology and/or geology	N ₂ =15		
Credited trainer of natural sciences/nature sciences and/or environmental sciences and/or environmental education	N ₃ =15	Credited (teacher) trainer certificate	Result of the sum: 60, 45, 30, 15, or 0
Credited trainer of educational technologies and/or technology and educational communication	N ₄ =15		
	18 publications or more then N ₅ =50		
Author of published creative literary work with technical and scientific peer review	7 publications or more, and less than 18 then N ₅ =15 No publications or less than 7 publications then N ₅ =0	Conference proceedings, book of abstracts, magazines, books, etc.	Best score stands 50, 15, or 0
Holding a formal pedagogic supervision credited training taken at a superior school of education or taken at a university	N ₆ =10	A certificate of at least 25 hours (1 or more credits)	Best score stands 10 or 0
Holding a five years <i>Licenciatura</i> designed for teaching (before the European Bologna agreement) from a university ranked then among the 700 best of the world at least once; or a three-year <i>Licenciatura</i> +2 years Master designed for teaching, both from a university ranked then among the 700 best of the world at least once	N ₇ =50	The university certificate of 5 years <i>Licenciatura</i> ; or the university certificates of 3 years <i>Licenciatura</i> and 2 years master A recognized world ranking	Best score stands 50 or 0
Being member of three or more scientific societies	N ₈ =15	A document issued by each scientific society	Best score stands 15 or 0
Attendance to at least 25 scientific international, national or regional meetings, and/or congresses, and/or scientific advanced short courses	N ₉ =15	Certificates of attendance	Best score stands 15 or 0
Pedagogical supervisor encourages a supervised teacher that have author careers of published creative literary work with peer review doing presentations in scientific meetings, congress, etc. (at home country or internationally); also creates opportunities to integrate their professorship goals in the school's mission and objectives	For a supervisor: N ₁₀ =0 when verified or N ₁₀ =-200 when not verified	Examples for N ₁₀ =-200: Difficulties of any kind to teacher travel and/or to be at the scheduled national and/or international meetings or congresses Supervised teacher work and/or professional qualities without adequate recognition Lack of reliable support Unjustified faults marked on the supervised teacher individual career records	Best score stands 0 or -200

The *Bejan Quanta* (BQ) for sustainable development from a teacher training center is mathematically defined through the following expression:

$$BQ = \frac{\sum_i^n NC_i \cdot F_i \cdot Ho_i}{\sum_i^n NC_i} \quad (3)$$

where, NC is number of credits of each teacher training course (and we account all the teachers' training courses offered by the teachers training centre), the F is the relevance for sustainable development (0 or 1) and Ho is the *Higgs Quantum* index of the corresponding science teacher trainer that is supposed to lecture the teacher training course (Bejan and Lorente, 2012). For each training design that is compliant with what we stated before and therefore relevant to sustainable development we attribute a factor F of 1. For each training design that is not relevant for sustainable development we attribute a factor F of zero.

The UN goals for sustainable development are seventeen, and for each one, a symbol was created, within the 2030 agenda for sustainable development adopted by all member states

back in 2015 (United Nations, 2015). We ask if in each course offered by the continuous teacher training centres there is the policy to include any of signal(s) regarding the UN objectives for sustainable development, which we believe it could facilitate the teachers choosing and the implementation of the UN goals too; also, how much each teacher training score for the *Higgs Quantum*, the *Horta Quanta*; and the *Bejan Quanta*, with the information about the continuous teachers training offer in this last year by continuous teachers training centers available in the their websites; if is there enough information available for the public published in each continuous teacher training website so we can determine the *Higgs Quantum*, the *Horta Quanta* and the *Bejan Quanta*. Using a computer; internet connection, calculus spread sheet software; considering the population the total number of continuous teachers training centres credited by the Portuguese Council of Scientific-Pedagogical for Continuous Education, which is around three hundred and twenty-four (Stanford, 2007), and a sample taken, twelve Portuguese school associations' teachers

training centres selected randomly and blindly analysed, among those that are with web presence. After looking blindly at the teachers training centers websites sample, 25% of the teacher training plans provided the names of teachers' trainers associated to some of the training planed while others were missing; 58% provided all the names of the teachers' trainers associated to part of the training planed; 17% of the teacher training plans did not provided the names of the teachers' trainers associated to the training planed. In the sample none of the teachers training plans on-line provided the teacher trainers certificate registry number; none provided the areas and dominium registered on each teacher trainer certificate and/or any other curriculum element of interest for the calculus of the *Higgs Quantum*. So, with the information available in the websites of the teachers training centres it is not possible to determine immediately the *Higgs Quantum*, the *Horta Quanta* and the *Bejan Quanta*. Also, none had any of the symbols of the seventeen goals for sustainable development in the sample of teacher training centre courses plans presented on-line.

CONCLUSIONS

The 4th law of thermodynamics provides lots of different opportunities for education, for new pedagogical and scientific breakthroughs in this information age; it's necessary permanent teachers training design update on the evolution of science, technology and laboratory management optimization for each of the scientific disciplines lectured; pursuing the ideal of best laboratory design and equipment for each of the discipline taught, and to help stimulus more pedagogical laboratory innovation.

There is a need for more adequate science teachers training, so we can face better the modern challenges; promote creative thinking, sustainable development and Portuguese Cultural Heritage treasures; and allow teachers update opportunity with new knowledge and more technological and engineering innovations. We strongly believe that the "state-of-the-art" science teachers training design courses like these must be a priority that include science teacher trainers with the best profiles for sustainable development in the information age. Due to this pandemic years, we think it is more visible the need for the teacher training described here, and for more, like educational laboratories biosafety for natural sciences teachers and for biology teachers.

In the new field of the pedagogical supervision theory that thrives in Portugal, we now have one more theory, the *constructal pedagogical supervision theory*, where there are indexes that express relations between scientific and educational data for analysis and discussion; like measured teacher profiles (supervisor, supervised, and teacher trainer) and teacher training centres courses for the sustainable development education in the information age; this is like looking to the reality in a different light spectrum and then seeing more and better.

Future studies can be plenty like the determination of the *Higgs Quantum*, the *Horta Quantum*, and the *Bejan Quantum*, by sending to the teachers training centres on-line inquiries using different digital tools like google forms, Microsoft forms,

etc; many other future studies can be like analysing for several years and publish the best rankings of the teacher trainers' *Higgs Quantum* indexes within the teacher training centers and even see the evolution of the *Horta Quanta* indexes and the *Bejan Quanta* indexes for sustainable development education from each teacher training centers and publish the rankings and add then more new elements for future studies, scrutiny and discuss like how effective looks the training available for true change in an adequate timing for sustainable development and climate change.

A suggestion is that alongside the accreditation of the teacher training courses with the Portuguese CCPFC, it would be advantageous that each training course be attributed one or more symbols of the UN seventeen goals for sustainable development. That could be done also by the Portuguese CCPFC and also the evolution of that UN symbols on each teacher training centres accreditations could be subject of more future studies.

We believe that by applying these mathematical tools within the new *constructal pedagogical supervision theory*, as with other tools to be developed, we can promote more creative thinking, systems thinking, pedagogical innovation, and the achievement of the UN sustainable goals for sustainable development in this information age; increase the effort to achieve excellence in pedagogical supervision, and can change the world.

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Availability of data and materials: All data generated or analyzed during this study are available for sharing when appropriate request is directed to the author.

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