REVISTA INTERNACIONAL DE FORMAÇÃO DE PROFESSORES

PROPOSAL FOR AN ASSESSMENT SYSTEM OF ENVIRONMENTAL EDUCATION PROCESSES BASED ON COMPLEXITY EXPRESSIONS SCENARIOS.

PROPOSTA DE SISTEMA DE AVALIAÇÃO DOS PROCESSOS DE EDUCAÇÃO AMBIENTAL, COM BASE EM CENÁRIOS DE EXPRESSÕES DE COMPLEXIDADE.

PROPUESTA DE SISTEMA DE EVALUACIÓN DE PROCESOS DE EDUCACIÓN AMBIENTAL BASADO EN ESCENARIOS DE EXPRESIONES DE LA COMPLEJIDAD.

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Abstract: Assessment is a way to improve environmental education (EE) processes. But there are no frequent assessment systems with a theoretical environmental educational foundation, adaptable to the contexts and that assess other scenarios in addition to learning. We propose a system based on the Complex Environmental Formation Theory. The proposal describes six scenarios in which EE processes express their complexity. We qualitatively study a school orchard experience and assess three of the scenarios. The results show an intermediate level of complexity. The conclusions are that the system is adaptable, and the case provides transferable elements.
Keywords: Assessment. Environmental Education. Complexity. Competence.

Resumo: A avaliação é uma forma de aprimorar os processos de educação ambiental (EA). Não são frequentes os sistemas de avaliação com embasamento teórico-educacional ambiental, adaptáveis aos contextos e que avaliem outros cenários além da aprendizagem. Propomos um sistema baseado na Teoria do Treinamento Ambiental Complexo. A proposta descreve seis cenários nos quais a complexidade dos processos de EA é expressa. Uma experiência de horta escolar é estudada qualitativamente e três dos cenários são avaliados. Os resultados mostram um nível intermediário de complexidade. Conclui-se que o sistema é adaptável e o caso fornece elementos transferíveis.
Palavras-chave: Avaliação. Educação Ambiental. Complexidade. Competência.

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Resumen: La evaluación es una forma de mejorar los procesos de educación ambiental (EA). Pero no son frecuentes sistemas de evaluación con fundamento teórico educativo ambiental, adaptables a los contextos y que evalúen otros escenarios además del aprendizaje. Proponemos un sistema basado en la Teoría de Formación Ambiental Compleja. La propuesta describe seis escenarios en los que se expresa la complejidad en procesos de EA. Se estudia cualitativamente una experiencia de huerta escolar y se evalúan tres de los escenarios. Los resultados muestran un nivel de complejidad intermedio. Se concluye que el sistema es adaptable y el caso aporta elementos transferibles.
Palabras-clave: Evaluación. Educación Ambiental. Complejidad. Competencia.

Submetido 05/09/2020 **Aceito 02/11/2020** **Publicado 02/11/2020**

Introduction

A complexity-based assessment system potentially broadens the view of EE processes beyond the student's learning goal. For Ardoin, Bowers, Wyman and Holthuis (2018), EE has to do with transformative relationships, processes and actions. Thus, an assessment focused on standardized tests and only on students' learning achievement is limited. Standardized tests make uniform the vision of learning and strip it of pedagogical background (Díaz, 2006) and contexts (Ríos & Herrera, 2017). The identification of these limitations is in line with Scott (2009), who studies EE-research after 30 years of Tbilisi. The author points out the need to expand the field to new references and more inclusive epistemologies. This revitalises the proposal of Jörg, Davisc and Nickmans (2007) regarding the development of a complex educational theory that describes learning, teaching and evaluation. We propose an assessment system of EE processes based on the Complex Environmental Formation Theory (Tovar-Gálvez, 2020).

Through the complexity-based assessment system, EE process leaders might contextualize, planning and regulate the experiences' development. Besides, they will have a guide to direct the actors of the educational community towards new thought, institutional and action dynamics. Therefore, they are able to transform their ways of existing and thus build viable socio-biophysical environments.

According to our review of assessment in EE, it is evident that many assessment proposals do not have support on an environmental educational theory (Galván & Gutiérrez, 2018; Jeovanio-Silva, Jeovanio-Silva & Cardoso, 2018; Kostova & Atasoy, 2008; Measure, Heras & Magin, 2016; Paredes-Curin, 2016; Ponomarenko, Yessaliev, Kenzhebekova, et al. 2016; Roczen, Kaiser, Bogner & Wilson, 2014; Tomazello & Ferreira, 2001; Ximing & Chunzhao, 2011). In many other cases, there are theoretical bases, but they are not explicit as a theory or do not guide the assessment design (De La Cruz, Ovalle, Cervantes, Villamil & Rivera, 2018; Coronel & Lozano, 2019; Hernández, 2013; Hernández, 2016; Herrera & Ríos, 2017; Jeovanio-Silva, et al. 2018; Wals, & Van der Leij, 1997).

Likewise, several proposals assess through tests, surveys, scales (De La Cruz, et al., 2018, Galván & Gutiérrez, 2018; Hernández, 2013; Measure, et al., 2016; Roczen, et al., 2014; Saraiva, Almeida, Bragança & Barbosa, 2019). These have the limitations of the standard

models since they do not allow communities to assess according to their needs, so they are not contextual. Finally, the regularity in the proposals is to assess the student learning (Albareda-Tiana, et al., 2019; De La Cruz, et al., 2018; Galván & Gutiérrez, 2018; Hernández, 2016; Kostova & Atasoy, 2008; Paredes-Curin, 2016; Ponomarenko, et al., 2016; Roczen, et al., 2014; Saraiva, et al., 2019; Tomazello & Ferreira, 2001), ignoring other expressions of the educational process.

This article aims to propose an assessment system for EE processes. Taking the review into account, the system should have an environmental educational theoretical background. Additionally, the system should be adaptable to contexts and assess other aspects in addition to learning. For this purpose, we first present a synthesis of the Complex Environmental Formation Theory (Tovar-Gálvez, 2020). The theory provides the ontological, epistemological, pedagogical and didactic bases for the assessment system. Next, we present the assessment system, which consists of six complexity expressions in educational processes. The assessment focus is on identifying how these scenarios contribute to learning. In the experimental part, we reconstruct an experience in a school in Colombia and use the system to assess three of the six complexity expression scenarios.

Framework

Meta-theoretical and theoretical context of the complex assessment system

The assessment system in development is part of the didactic level of the Complex Environmental Formation Theory –CEFT- (Tovar-Gálvez, 2020, based on Morin, 1996, 1998 and 2004). The CEFT consists of a meta-theoretical or ontological/epistemological level (Colom, 2005) and a theoretical or pedagogical/didactic level (Biesta, 2013; Wüst, 2011). Those levels have a basis on the self-eco-organization of systems. This structure guides teachers to incorporate the complex conception of the environment into the curriculum, expressing it as a learning goal, as a reference for teaching and as an assessment system.

Ontologically, the CEFT proposes the environment as a constructed reality. Environmental phenomena emerge from the self-eco-organization among the social system and the biophysical system. Each system has internal (auto) and external (eco) dynamics, which make them interdependent and inseparable. The emerging environmental phenomenon depends

on the decisions made by humans regarding the way they want to live in the biophysical system. Decisions are made based on one's own knowledge, emotions, values, experiences, beliefs and interests, determining ways of relating to oneself and others. These relationships constitute the set of components of culture: education, institutions, organization forms, civilization ways, ethical codes, religions, politics, etc. In this order, culture is a construction that varies and, consequently, the ways of living in the biophysical system also vary. The complex action of the being consists of transforming these ways of living, aware of their incidence in the construction of environmental realities.

At the epistemological level, the CEFT proposes that knowledge is a human, provisional, relative and emergent construction of each culture. The self-eco-organization of individuals' thought leads to the self-eco-organization of knowledge. Thought/knowledge has an internal (self) dynamic that constitutes the structure and production form of the disciplines or ways of seeing the world. Thought/knowledge has an external dynamic (echo), which consist of relationships between disciplines and ways of seeing the world. The ecologies of the multidisciplinary, interdisciplinary, transdisciplinary and inter-epistemological illustrate such a dynamic.

At the pedagogical level, the CEFT proposes education as a dynamic mobilization of culture (transmission, recovery, construction, transformation, criticism, etc.). When communities reflect on and direct this mobilization intentionally, then it is a pedagogical process. Therefore, for complex environmental pedagogy, the educational purpose is the self-eco-organization of individuals' action, based on the self-eco-organization of their thought, to transform environmental realities. To reach this, we need to understand communities, institutions and the curriculum as self-eco-organized systems, aimed at the construction of the citizen profile.

At the didactic level, the CEFT proposes to understand teaching, learning and assessment as emergencies of the self-eco-organization of educational actors. Thus, for complex environmental didactics, learning is a process modelled by the Complex Environmental Competence (CEC). The CEC represents the articulation of multiple attributes (components) of being to act self-eco-organized, to transform environmental realities. The CEC describes the relationship between the cognitive, metacognitive, social, contextual, factual and

identity components of being. Some of these components, additionally, are the relationship of several dimensions, such as the cognitive, metacognitive and social components. This model describes attributes of the being that direct their self-eco-organized action but adapts to the contexts when communities define the performance of students. Chart 1 displays an example of students' performances for higher education.

Chart 1. Complex Environmental Competence Model: components, dimensions and possible students' performances

Complex Environmental Competence for higher education		
Student leads processes of community education and management of socio-biophysical processes, based on professional and community knowledge, seeking environmental transformation.		
Components	Component dimensions	Students' performances
Cognitive	Conceptual	Student describes environmentally non-viable situations, making use of professional and community knowledge.
	Procedural	Student manages resources, information, processes, actions, etc., to achieve environmentally viable ways of living.
	Altitudinal	Student critically reflects on the implications of his/her profession at the environmental level.
	Communicative	Student communicates his/her learning about environmentally viable ways of living, according to the language of the profession.
	Epistemic	Student participates self-eco-organized in the project to build the own CEC.
Metacognitive	Reflection	Student evaluates his/her cognitive possibilities in terms of how they contribute to environmentally viable forms of relationship.
	Administration	
	Evaluation	
Social	Cooperative work	Student develops processes to teach others his/her learnings about environmentally viable ways of living.
	Collective learning	
Contextual		Student addresses environmentally problematic situations in his/her place of study and at home.
Factual		Student reports evidence of contributions to environmental transformation in his/her place of study and at home.

Identity		Student expresses her/his professional and civic role, facing the type of environment she/he wishes to help build.

Source: taken and adapted from Tovar-Gálvez (2020).

Likewise, the complex environmental didactics proposes the construction of such a CEC through projects. And it is to be expected that this complexity-based teaching-learning process, will be regulated, studied and directed from a complex assessment system, such as the one formulated below.

Complexity expression scenarios as an assessment system for EE processes

The assessment system is a set of scenarios in which educational experiences express their complexity. Through the Complex Environmental Formation Theory, we describe six of these scenarios: learning, teaching, curriculum, interpretation of reality, impact, and autonomy. We propose to assess each one through indicators that describe their contribution to CEC as a realization of learning. A scale guides educational leaders to describe the accomplished complexity level by scenario. The indicators do not impose specific content, but rather describe relationships, presences and absences of elements and processes. When educational participants act following the indicators, it is possible to say that they reached a complexity level of self-eco-organization. If the actions do not fully agree with the indicators, then it is possible to say that they are at an intermediate complexity level. If the actions are well below the indicators, then the level of complexity is restricted.

Complexity expressed in learning

The learning process is an individual and social construction, which takes place in different directions, environs, organizational forms, and complexity levels. Through the Complex Environmental Competence -CEC- (Tovar-Gálvez, 2020), we model the learning process. The CEC is the subjects' self-eco-organized action to transform environmental realities. Individuals act through different aspects that compose the CEC: a) cognitive, which integrates conceptual, procedural, attitudinal, communicative and epistemic dimensions of knowledge of the thought systems, b) metacognitive, which consists of the dimensions of

reflection, administration and evaluation that subjects practice on their own learning, c) social, which includes the dimensions of joint learning and cooperative action, d) contextual, which implies the recognition of the context and the community, e) factual, which means the impact on the individuals and the context, and f) identity, which corresponds to personal, citizen and professional commitments. See chart 2:

Chart 2. Levels of complexity and indicators on learning

Level	Indicators. Learning is characterized because…
Self-eco-organization	It is self-organized because: • It integrates the multiple dimensions of the knowledge towards a goal (cognitive), • It is self-managed by the student (metacognition), and • It contributes to the student self-determination (identity).
	It is eco-organized because: • It is a dialogue among different thought systems (cognitive), • It is a cooperative and collective construction (social), and • It happens in specific settings (contextual) and practically (factual).
Intermediate	• Some dimension of knowledge (cognitive) is not promoted, and/or • The multiple dimensions of knowledge are not articulated for one goal (cognitive).
	Some component –metacognitive, social, contextual, factual and identity, is not promoted or is partially promoted.
Restricted	• Any/some dimension(s) of knowledge is/are not promoted (cognitive), and/or • The multiple dimensions of knowledge are not articulated for one goal (cognitive).
	The components –metacognitive, social, contextual, factual and identity, are not promoted.

Source: own elaboration.

Complexity expressed in teaching

Teaching is a process that aims self-eco-organize the subject's action, leading the components of their being towards the transformation of environmental reality. Projects have the potential to guide communities to reach this kind of learning. Projects are self-organized formation processes (cooperative relations at the institutional level) and eco-organized

(cooperative relations at the extra-institutional level) and seek to integrate all the components of the CEC to build environmental contexts (Tovar-Gálvez, 2020). See chart 3:

Chart 3. Levels of complexity and indicators in teaching

Level	Indicators. Teaching is characterized because...
Self-eco-organization	A project integrates all the components of the CEC.
	It is self-organized because the project is the product of the coherence, harmony and commitment of all sectors, estates, resources, settings, processes, policies, etc., at the internal level (institutional).
	It is eco-organized because the project is the product of the coherence, harmony and commitment of all sectors, estates, resources, settings, processes, policies, etc., at the external level (with respect to other institutions, communities and sectors).
Intermediate	The project integrates only some components of the CEC or integrates them without fully promoting them.
	The project is the product of the coherence, harmony and commitment of only some institutional sectors.
	The project does not articulate external communities or their participation is limited.
Restricted	The project integrates only some components of the CEC or integrates them without fully promoting them.
	The project is the product of only who teaches.
	The project does not articulate external communities.

Source: own elaboration.

Complexity expressed in the curriculum

The curriculum is a set of administrative, normative, epistemological, pedagogical, didactic, and organizational, etc. decisions that self-eco-organize the educational institution for the progressive and contextualized construction of the CEC (Tovar-Gálvez, 2020). Self-organization refers to the relationships between the institutional constituents to contribute to the construction of the CEC. Eco-organization refers to the institution's relationships with other communities and institutions for students to contribute to real environmental contexts. See chart 4:

Chart 4. Levels of complexity and indicators in the curriculum

Level	Indicators. The curriculum is characterized because...
Self-eco-organization	It is self-organized because it integrates all the institutional elements (estates, processes, resources, subjects, foundations, actions, values, subjects, etc.) with coherence, harmony and commitment for the progressive construction of the students' CEC.
	It is eco-organized because it links the institution with external communities and other institutions so that the students' CEC is nurtured and contributed to real environmental contexts.
Intermediate	It integrates only some institutional elements (estates, processes, resources, subjects, foundations, actions, values, subjects, etc.) with coherence, harmony and commitment for the progressive construction of the students' CEC.
	It does not fully link the institution with external communities and other institutions for students to nurture their CEC and contribute to real environmental contexts.
Restricted	Only a course, a subject, a project, or a teacher commits to the progressive construction of the students' CEC.
	The institution does not link with external communities and other institutions for students to nurture their CEC and contribute to real environmental contexts.

Source: own elaboration.

Complexity expressed in the interpretation of reality

Individuals and communities might interpret reality through the self-eco-organization of the knowledge that constitutes the CEC (Tovar-Gálvez, 2020). Self-organization refers to the relationship between the multiple dimensions of knowledge within a field or discipline to transform environmental realities. Eco-organization remits to the relationship between different disciplines or positions, within the same cultural tradition, or between different cultural traditions to transform environmental realities. See chart 5:

Chart 5. Levels of complexity and indicators on interpretation of reality

Level	Indicators. The interpretation of reality is characterized because...
Self-eco-organization	It is self-organized because it integrates multiple dimensions of knowledge (conceptual, procedural, attitudinal, communicative and epistemic) within a specific discipline or vision to build the CEC.
	It is eco-organized because it integrates knowledge from different disciplines of the same cultural tradition to build the CEC.

	It is eco-organized because it integrates knowledge of diverse epistemologies from different nature (ontology) and cultural tradition to build the CEC.
Intermediate	It integrates all or some of the dimensions of knowledge within a discipline or vision to build the CEC.
	It privileges the knowledge of one of the various disciplines within the same cultural tradition to build the CEC.
	It privileges the knowledge of one of the various epistemologies from different nature (ontology) and cultural tradition to build the CEC.
Restricted	It integrates some dimensions of knowledge within a discipline or vision to build the CEC.
	It does not integrate different disciplines within the same cultural tradition to build the CEC.
	It does not integrate various epistemologies from different nature (ontology) and cultural tradition to build the CEC.

Source: own elaboration.

Complexity expressed in autonomy

Autonomy is the ability of subjects, teams, institutions and communities to self-recognize self-manage and self-evaluate (Tovar-Gálvez & Cárdenas, 2009). Autonomy as a self-organizing process occurs when the project members design and make use of evaluation systems that lead them to build knowledge on the educational processes and redirect them. Autonomy as an eco-organizational process occurs when the evaluation system leads the process participants to recognize themselves as part of communities outside the school and to establish cooperative relationships. See chart 6:

Chart 6. Levels of complexity and indicators on autonomy

Level	Indicators. Autonomy is characterized because…
Self-eco-organization	It is the self-organization of participants around an evaluation system to self-recognize, self-manage and self-evaluation, to direct the processes of CEC construction.
	It is the eco-organization of participants around an evaluation system to recognize themselves as a community beyond the geographical limits of the school and to establish cooperative relationships.
Intermediate	Some participants use an evaluation system to recognize, manage and evaluate the educational process, with the aim of directing the construction of the CEC.

	Some participants use an evaluation system to recognize themselves as a community beyond the geographical limits of the school and to establish cooperative relationships.
Restricted	Only who directs teaching uses an evaluation system to recognize, manage and evaluate the educational process, with the aim of directing the construction of the CEC.
	Any participant uses an evaluation system to recognize him/herself as part of a community beyond the geographical limits of the school and to establish cooperative relationships.

Source: own elaboration.

Complexity expressed in impact

The impact of education is the incidence of educational institutions on some dimension of reality (UNESCO, 2002). The impact on environmental reality has a self-organized level when there is a socio-biophysical transformation within the educational institution. And an eco-organized level when there is a socio-biophysical transformation outside the institution. See chart 7:

Chart 7. Complexity levels and impact indicators

Level	Indicators. The impact is characterized because…
Self-eco-organization	It is self-organized because the process participants transformed the immediate school environmental reality.
	It is eco-organized because the process participants transformed the environmental reality outside the institutional geographical limits.
Intermediate	The transformation of the immediate school environmental reality is temporary, or it is not complete.
	The transformation of environmental realities, outside the institutional geographic limits, is indirect, temporary or incomplete.
Restricted	Only hypothetical problems are studied or solved in the classroom.
	The transformation of realities external to the institution is nil.

Source: own elaboration.

Methodology

The experience to assess is about a school orchard from the narrative of one of the project's teachers. The description includes the organization and development in 3 phases. From there, we reconstruct the planning carried out by the teachers, the actions developed with the

students around work in the orchard and the presentation of results obtained by the teachers according to their objectives. The description provides detailed information in an attempt to be loyal to the experience.

The experience was not designed from the CEFT. We assess the experience from the CEFT, using three of the six complexity expression scenarios in EE processes: teaching, curriculum and impact. Through the indicators already presented in the theoretical framework, we identify the contribution of each of these three scenarios to the construction of Complex Environmental Competence (see chart 1). Likewise, we determine the complexity level achieved by the community in each scenario: self-eco-organized, intermediate or restricted (Charts 3, 4 and 7).

Case study (reconstruction of the experience)

The case is the systematization of the educational experience "the orchard as a didactic strategy for teaching science". This project is carried out in the District Educational Institution (DEI) El Minuto de Buenos Aires. We systematize the experience through in-depth interviews with one of the teachers participating in the project.

Approximately 70 students were part of the project. They belong to two seventh class groups with ages ranging between 11 and 15 years. The project was developed in the natural science sessions of the afternoon shift (1 hour and a half per week) and extra-class spaces such as breaks and contrary shift. The project was supported by two teachers from the subject-area, as well as financing by the school rectory and technical advice by the Botanical Garden. This institution contributed to the project regarding: a) technical advice to teachers and students regarding urban agriculture and logistics issues to develop the orchard, b) arrangement of seedlings and organization of seedbeds, and c) arrangement of garden products. The DEI administration provided a budget for tools and materials.

Teachers planning in the orchard project

The teachers establish three phases (chart 8): they develop simultaneously the first two, which are practical in the field and theoretical at the classroom with the data collected. The last phase is an evaluation of the project by the teachers and students.

Chart 8. Planning school orchard project

Phases	Description
Work in classroom	a) Use of learning tools and evaluation guides to recognize the plants to be sown (taxonomy, growth and development, allelopathies) and interaction between living beings and environ, b) use of description tables to recognize physical characteristics of the sowing soil, c) use of inventories of organisms to recognize fauna associated with the orchard, d) problem situations analysis regarding the food security issue and e) debates on the viability of orchards as a strategy for access certain types of food from homes.
Adequacy and sowing	a) Process of sowing and collecting seeds and consequent marking and labelling, b) preservation of seeds and transplantation of seedlings, c) maintenance of the orchard and compost, d) harvesting and disposition of seeds, foliage and fruits.
Results presentation	School exhibition for Science Day regarding the process of adaptation and development of the orchard, as well as the learning obtained in the process.

Source: own elaboration from the interview with the teacher.

Development of the school orchard project

The interviewed teacher describes the three phases of the school orchard project:

Phase 1. Classroom work: The students recognized the growth and development processes of the plants and the relationship among plants and substrate through the identification of the physical characteristics of the soil. Additionally, they critically reflected on aspects related to food safety. Advised by the teachers, the students took field data (consistency, texture and soil moisture). Through the work guides designed by the teachers, they established an overview of the substrate where the sowing process is carried out. And they related the type of soil identified with some conditions: a) stable structures that allow plants a greater growth potential, and b) amount of articulated material that allows optimal water storage capacity, as well as free movement of the nutrient solution from the ground to the root.

In other activities, the students recognized macro-organisms typical of the orchard soil and processes of symbiosis between the individuals and the sowed plants. They also discussed how these animals possibly interact with the substrate for: the incorporation of organic matter,

porosity and aggregation of the soil, and the maintenance of the balance of populations of other species.

They discussed the issue of food safety. The problem situations were addressed in work-tables, based on readings on: a) use of chemical pesticides in agricultural production and their effects, b) genetic manipulation of plants for consumption, and c) home orchards as a strategy to minimize costs of the market basket and stimulation of the consumption of organic products. The work groups identified the pros and cons of each situation and presented it to the group. From this, the teachers stimulated the discussion of the ethical and economic implications identified by the students.

Phase 2. Adaptation and planting in the school orchard: In this phase the students formed work groups to divide tasks around: a) removal of accompanying vegetation and plough, b) adaptation and application of organic fertilizer, c) consolidation, levelling and preparation of the land, and d) sowing seeds.

During the process of removing weeds and ploughing, the teachers took up some concepts and processes regarding the characteristics of the soil. This allowed the students to establish relationships between soil type, optimal humidity / temperature conditions, plough shape, and plant growth. As well as the consequences of allowing accompanying vegetation (weeds) that by competing with the orchard plants for water, nutrients and other resources slows their development. The students were guided to carry out a manual plough, through which they could identify how the soil can conserve moisture in times of drought.

For the adaptation and application of the organic fertilizer, the students had the organic waste supplied by the school cafeteria. Thus, they were able to determine the benefits of this type of fertilizer in the garden. With the work guide, the students compared between the degradation processes of plant and animal matter, as well as the presence of macro-fauna in the soil before and after fertilization. This because edaphic organisms increased (in richness, but not in diversity), improving soil conditions and accelerating the decomposition and mineralization of organic matter.

With the first planting of seedlings, the students obtained the seeds for the formation of the seedbed. They adapted a space for the location of the seedlings in appropriate containers for

the maintenance of latency, marking and labelling (name, place of collection, month and year of collection). Once the plants are born, they are relocated in the space assigned for their growth. Students built data charts in which they registered data such as temperature, humidity, names, sowing date, physical conditions, and daily measurement of the size of the seedlings, among others. With this process, the students understood the importance of labelling and marking based on the recognition of the seedlings, since the younger the plant, the greater the difficulties for its differentiation and subsequent transfer to the orchard.

To maintain the orchard's humidity, the students permanently deposited water in soda bottles with several perforations along their length, to ensure evenly distributed irrigation. In this way they resolved the risk of less irrigation than the crop requirement, this being a limiting factor of productivity. Thus, they determined the importance of water in the autotrophic nutrition of plants (aspect theoretically addressed in class).

In order to prevent the proliferation of certain pests and weeds, students sowed allelopathic plants that produce biochemical compounds that help keep pests away and suppress nutrient competitors. Planting these types of vegetables allowed students to recognize that some plants can produce substances that ward off invertebrate predators.

During the maintenance of the orchard, the students developed conservation campaigns through communicative billboards, to reduce the amount of solid waste thrown in the planting area and request respect for this place. These requests were only met by the students who worked in the orchard and by a very small group of students from other courses. Despite the multiple efforts of the members of the project, the majority of students of the institution did not assume the commitment.

The school regulations do not allow teachers and students to entry to the educational institution during the period when there are no classes. For this reason, the harvest was not maintained any longer. So the students distributed the harvest among who wanted to take home the products.

Phase 3. Presentation of results by students: This phase was during the first week of October, for Science Day. There, during a guided tour, the students explained the step by step for the formation and maintenance of the orchard, exposing the types of plants sowed and their

morpho-physiological characteristics. Also, the students explained to the attendees the importance of the soil physical aspects for the development and growth of the chosen species. Likewise, they presented the data charts and argued the importance of the registration and interpretation of the information for a correct planting of seedlings and seeds, as well as the strategies for the maintenance of the orchard. To conclude, the students displayed diverse strategies to develop home orchards, taking advantage of reduced physical spaces. And they proposed different recipes to use the plants sown in nutritious meals.

Experience analysis from the theoretical framework

Complexity expressed in teaching

According to the indicators in the framework to describe the complexity expressed in teaching from the CEC, we can say that the school orchard project reached an intermediate level because:

From the cognitive component of the CEC, the process of design and application of the orchard as a didactic strategy for science teaching points to project-based education. From the beginning of the project, the teachers propose to address the topics from the competences' framework. They promote conceptual knowledge, encouraging students to establish relationships between theory and practice, without focusing on memorizing terms and definitions.

The teachers promoted the conceptual and epistemic dimension within the cognitive component of the CEC since they engaged the students in the work and proceeding of biology. In the same way, the development of the project involves students in ethical reflections on the agrochemicals, genetic manipulation and food safety. Likewise, the teachers make use of the available resources and motivate students to study a biophysical context in which they live every day. This indicates that the teaching practice seeks to promote the attitudinal dimension since the students integrate their multiple learning around an objective in a context: the orchard.

The teachers involved the students in the procedural dimension, through data collection, planning of strategies for the maintenance of the orchard and execution of action plans for planting. For this, students interpreted theory through material designed by the teachers (workshops and evaluation guides). Similarly, students' communicative knowledge was also

fostered by practice and during the socialization with the educational community. And also when students developed activities focused on the public (guided tour, plants description and presentation of charts, etc.).

On the other hand, within the teaching action described, there is no evidence about the explicit promotion of the metacognitive component on students' CEC. There are no specific activities to motivate students to reflect on the achievements and opportunities for improving their multiple learnings and on how they are using such learning to study and maintain the orchard. The activities described demonstrating that the students reflected on the best ways to achieve their goal with the orchard, and made decisions about it, but did not consciously reflect on their learning.

Regarding the social component of the students' CEC through the project, the teachers promote other ways of building knowledge, learning and relationships between students in the biophysical context of the orchard. This is made evident by teamwork, with specific tasks and responsibilities in the adaptation, planting and maintenance processes, among others. Such dynamics are a possibility for collective learning and deepening procedural knowledge (methods for the maintenance of the garden).

Speaking of the contextual component of the CEC, the teachers contribute to the students' involvement in working with a physical space that was previously underused in the institution. The students approached a portion of their biophysical context and evidenced the social relationships between students, teachers, trustees, and other institutions; as well as a possible replication in their homes. In this same direction, the teachers promote the factual component of the CEC, since the students relate their multiple learnings to a real case and thus contribute to transforming their reality.

The teachers stimulate the contextual and identity components of the students' CEC when they guide the students to question some products and practices of expansive agriculture; as well as the need to link the community through the campaign for reflection and care of the garden space.

The institutional commitment on the part of the school managers was partial. They focused only on financial support for the acquisition of tools and materials at the beginning of the process, but without considering the possibility of accessing the planting area during school

holidays. This situation meant that the project declined due to a lack of maintenance in that period.

This limitation in the commitment of other institutional sectors, different from the teachers, was a determining factor in the motivation of the students. It also restricted the possibility of linking other students, teachers, families and the community around the school. This is the most influential event in limiting the factual component of the CEC (transformation of the socio-biophysical context) and the self-eco-organization of the action through the project.

Complexity expressed in the curriculum

According to the levels in the framework to describe the complexity expressed in the curriculum, we can say that the school orchard project reached an intermediate level because:

Internally, that is, at self-organization level, the construction of the students' CEC is presented exclusively in two spaces directed by the teachers: classroom and orchard. They do not involve biophysical contexts outside the educational institution.

Other subject-areas do not directly and explicitly contribute to the project as a process for the construction of the CEC. This is evident because teachers from other areas, different from natural sciences, do not participate in the project. This situation brings as a consequence that: a) students accessed to fragmented knowledge, b) institutional cross-cutting projects are not carried out and c) the inclusion of a larger population in the project is limited.

The administrative and managerial sectors participate in the self-organization level. However, the economic resources are restricted, and entry to the orchard during the holiday period is not possible. This lack of harmony and coherence between these sectors and the academic one hinders the construction of the students' CEC. The project does not have the necessary amplitude, or the expected continuity. The commitments and socialization process fall directly and exclusively on the students and teachers of the project. The construction of the student's CEC for the transformation of relationships that involve socio-biophysically viable environmental phenomena in their immediate context is partially achieved.

Externally, that is, at eco-organization level, the construction of the CEC is partially supported by the linkage of the Botanical Garden and is very limited in terms of linking to the external community. The advice focused on the beginnings of the garden with technical support.

There was no follow-up process (analysis and evaluation of the results) and the possibility of socializing the work outside the institution.

Consequently, the exchange of experiences with other educational institutions that also had the advice of the Botanical Garden is limited. With this, the construction of the students' CEC loses opportunities for recognition, discussion, feedback and exchange of knowledge with other teams and similar experiences. This also implies a lack of inter-institutional networking.

Regarding community involvement, part of the surrounding population and the families of the students are farmers who possess knowledge of interest to the orchard project. Despite this, only two groups of students and two teachers participated in the project. Not including other sectors of the external community (population near the institution and students' families) means that project participants lose the opportunity to access knowledge and experiences that can contribute to the construction of the students' CEC.

Complexity expressed in impact

Taking into account the levels of complexity expressed in the impact, the school orchard project is at the intermediate level due to:

Teachers defined aims for the project in terms of relationships between subjects and in contexts understood as systems. However, the project is restricted to natural sciences, without taking into account the possibility of involving the reading of the environment from other subject-areas. The teachers focus the biology learning towards changes in the thinking and action of the students. But the conditions (limitations due to regulations and apathy of other members of the community) do not allow the integration of other individuals who could contribute and take part in that change in reality.

The actions developed through the project have the potential to transform the environmental context. This is evident since the teachers linked conceptual, procedural, attitudinal, communicative, individual and collective knowledge to work in the orchard. In other words, each action was supported by knowledge and critical reflection, and additionally articulated as a project under specific aims. Likewise, making use of a place at the institution and confronting the issue of food security puts the actions in context and gives them a sense.

A determining limitation in the complexity of the project is that exerted by the administrative and institutional management sector. Failure to recognize the impact that each part of the institution has on the curricular process, triggered the orchard not being tended permanently. The lack of continuity caused the educational actions and strategies built throughout the project to dissipate over time.

The impact of the orchard project mainly involves the participating students and the two teachers. There is not enough evidence on how many students were reached by the campaign for reflection and care of the orchard. As we already pointed out, other teachers, students and managers do not participate in the project. The project's external impact would be achieved through the students who make use of the knowledge and experience gained at home and daily life. But there is no information about it.

The teachers do not consider the participation of parents and adults in charge of the students for the development of the orchard. This restricts the project impact. More than half of the families that constitute the educational institution come from agricultural areas, but they are not included. In this way, the project participants lose the opportunity to access other knowledge and experiences, as well as to contribute to the transformation of the reality of this other part of the community.

Likewise, the participants lose the opportunity to obtain feedback from diverse perspectives that lead them to overcome difficulties and identify differences between the planning and enactment. Additionally, they miss elements to better impacting the context.

Conclusions

An EE process assessment system should have an environmental educational theoretical background, be adaptable to contexts and evaluate other aspects in addition to learning. The state of the art evidenced that not all proposals have an environmental educational base. Likewise, many assessment systems are standardized tests, limiting adaptation to contexts. And many proposals focus on only assessing learning. Although there are advances, there is not a single proposal that meets the three qualities mentioned. For this reason, we formulate an assessment system based on the Complex Environmental Formation Theory (CEFT). The proposal consists of different scenarios which express the complexity of educational

experiences. Not only learning is assessed. The system describes relationships, as well as the presence and absence of processes. Therefore, it does not impose content and allows taking into account the contexts.

Analysing the school orchard experience from the assessment system based on the CEFT, we identify that the complexity expressed in teaching reached an intermediate level. From the metacognitive component, it is evident that the project did not encourage students to reflect on their learning. Likewise, the complexity expressed in the curriculum and the impact reached an intermediate level. There are difficulties in the institutional commitment at the financial level and permanence of the project. There are also limitations and absences of other institutional and community sectors. This implies little incidence of the project in the institution and outside it, as well as a lack of integration between subject-areas and socialization in settings outside the institution.

Given this and for future projects, EE experience leaders might design activities aimed at motivating students to reflect on how they use the knowledge built in the development and maintenance of the orchard. Take into account greater integration between administrative, managerial and academic levels. Integrate and strengthen the permanence of educational agents such as the Botanical Garden. Socialize the educational experience with other educational institutions and communities. Encourage the participation of other subject-areas and the knowledge of parents and the communities surrounding the institution.

The findings demonstrate that the assessment based on the CEFT is adaptable to the EE experiences in their contexts. This system makes it possible to identify aspects that potentially contribute or hinder educational communities approaching self-eco-organization to transform their environmental realities. Other communities might contextualize this assessment system to their educational settings. So this framework is a reference for designing, developing and assessing diverse EE experiences.

References

ALBAREDA-TIANA, S.; AZCÁRATE-GODED, P.; MUÑOZ-RODRÍGUEZ, J. M.; VALDERRAMA-HERNÁNDEZ, R.; RUIZ-MORALES, J. Evaluar competencias en sostenibilidad en los grados y posgrados de educación: propuesta de un instrumento. **Revista Enseñanza de las ciencias**, v. 37, n. 3, p. 11-29. 2019.

ARDOIN, N.; BOWERS, A.; WYMAN, N.; HOLTHUIS, N. Environmental education and K-12 student outcomes: a review and analysis of research. **The Journal of Environmental Education**, v. 49, n. 1, p. 1-17. 2018.

BIESTA, J. On the idea of educational theory. In Irby, B., Brown, G., Lara-Alecio, R. & Jackson, S. (Eds). **The handbook of the educational theories**, Charlotte: Information Age Publishing, 2013, p. 5-15.

COLOM, A. La teoría de la educación: contexto actual de los estudios pedagógicos. En Colom, A., Bernabéu, J. Domínguez, E. & Sarramona, J. (coord.). **Teorías e instituciones contemporáneas de la educación**. Barcelona: Ariel. 2005, p. 151-162.

CORONEL, G.; LOZANO, M. La formación de competencias y la realización pedagógica desde la educación ambiental en el contexto ecuatoriano. **Revista Conrado**, v. 15, n. 67, p. 333-340. 2019.

DE LA CRUZ, W.; OVALLE, V.; CERVANTES, M.; VILLAMIL, J.; RIVERA, A. Las competencias ciudadanas como generadoras de cultura ambiental. **Cultura. Educación y Sociedad**, v. 9, n. 2, p. 67-76. 2018.

DÍAZ, A. El enfoque de competencias en la educación: ¿Una alternativa o un disfraz de cambio?. **Revista Perfiles educativos**, v. 28, n. 111, p. 7-36. 2006.

GALVÁN, L.; GUTIÉRREZ, J. Los mapas conceptuales como instrumento de evaluación: Una experiencia de educación ambiental centrada en el estudio de ecosistemas acuáticos. **Revista Actualidades Investigativas en educación**, v. 18, n. 1, p. 442-477. 2018.

HERNÁNDEZ, M. Evaluación del programa de educación ambiental formal "aula al aire libre", Reserva Los Coyotes. **Revista Actualidades Investigativas En Educación**, v. 13, n. 2, p. 1-32. 2013.

HERNÁNDEZ, G. La evaluación de la educación ambiental en las escuelas cubanas. Algunas consideraciones. **Amazonia Investiga**, v. 5, n. 8, p. 67-76. 2016.

HERRERA, D; RÍOS, D. Educación ambiental y cultura evaluativa: Algunas reflexiones para la construcción de eco-consciencias. **Revista Estudios pedagógicos**, v. 43, n. 1, p. 389-403. 2017.

JEOVANIO-SILVA, V. R. M; JEOVANIO-SILVA, A. L; CARDOSO, S. P. Um olhar docente sobre as dificuldades do trabalho da educação ambiental na escola. **Revista de Ensino de Ciências e Matemática** (REnCiMa), v. 9, n. 5, p. 256-272. 2018.

JÖRG, T., DAVIS, B; NICKMANS, G. Towards a new, complexity science of learning and education. **Educational Research Review**, v. 2, n. 2, p. 145–156. 2007.

KOSTOVA, Z.; ATASOY, E. Methods of Successful Learning in Environmental Education. **Journal of Theory and Practice in Education**, v. 4, n. 1, p. 49-78. 2008.

MEDIR, R.; HERAS, R.; MAGIN, C. Una propuesta evaluativa para actividades de educación ambiental para la sostenibilidad (1). **Educación XXI**, v. 19, n. 1, p. 331-355. 2016

MORIN, Edgar. El pensamiento ecologizado. **Gazeta de Antropología**, 12, 1996.

_____. **Introducción al pensamiento complejo**. Barcelona: Gedisa. 1998.

_____. Epistemología de la complejidad. **Gazeta de Antropología**, v. 20, p. 1-15. 2004.

PAREDES-CURIN, C. Aprendizaje basado en problemas (ABP): Una estrategia de enseñanza de la educación ambiental, en estudiantes de un liceo municipal de Cañete. **Revista Electrónica Educare**, v. 20, n. 1, p. 119-144. 2016.

PONOMARENKO, Y.; YESSALIEV, A.; KENZHEBEKOVA, R.; MOLDABEK, K.; LARCHEKOVA, L.; DAIRBEKOV, S.; ASAMBAEVA, L. Students' Environmental Competence Formation as a Pedagogical Problem. **International journal of environmental & science education**, v. 11, n. 18, p. 11735-11750. 2016.

RÍOS, D.; HERRERA, D. Los desafíos de la evaluación por competencias en el ámbito educativo. **Educação e Pesquisa**, v. 43, n. 4, p. 1073-1086. 2017.

ROCZEN, N.; KAISER, F.; BOGNER, F.; WILSON, M. A. Competence Model for Environmental Education. **Environment and Behavior**, v. 46, n. 8, p. 972–992. 2014.

SARAIVA, T. S.; ALMEIDA, M.; BRAGANÇA, L.; BARBOSA, M. T. The inclusion of a sustainability awareness indicator in assessment tools for high school buildings. **Sustainability**, v. 11, n. 2, p. 387. 2019.

SCOTT, W. Environmental education research: 30 years on from Tbilisi. **Environmental Education Research**, v. 15, n 2, p. 155-164. 2009.

TOMAZELLO, M. G. C.; FERREIRA, T. R. Educação ambiental: que critérios adotar para avaliar a adequação pedagógica de seus projetos?. **Ciência & Educação**, v. 7, n. 2, p. 199-207. 2001

TOVAR-GÁLVEZ, J. C.; CÁRDENAS, N. Perspectivas en enseñanza-aprendizaje: formación en competencias y metacognición a través de proyectos. **Revista Espíritu Científico en Acción**, v. 5, n. 10, p. 22-34. 2009.

TOVAR-GÁLVEZ, J. C. Currículo de educación ambiental desde la complejidad: construcción de la competencia ambiental a través de proyectos. En A. Hernández; R. Ramírez; O. Escobar. (Ed.). **Educación ambiental en el siglo XXI: del trayecto de construcción a la imperiosa necesidad**. Hermosillo: CIAD-CONACYT. 2020, p. 105-140.

UNESCO. **Panorama educativo de las américas. Informe regional**. Santiago: UNESCO. 2009.

WALS, A.; VAN DER LEIJ, T. Alternatives to national standards for environmental education: Process-based quality assessment. **Canadian Journal of Environmental Education (CJEE)**, v. 2, n. 1, p. 7-27. 2009.

WÜST, A. Über das Selbstverständnis der Pädagogik als Wissenschaft. In Mikhail, T. (Dir.). **Zeitlose Probleme der Pädagogik - Pädagogik als zeitloses Problem?** Karlsruhe: KIT Scientific Publishing. 2011.

XIMING, S.; CHUNZHAO, L. Survey of environmental education (EE): case study of higher education institutions in Ningbo. **Energy Procedia**, v. 5, p. 1820-1826. 2011.