BEYOND NONLINEAR (ORGANISATIONAL) LEARNING. THE IMPACT OF SUSTAINABLE INFRASTRUCTURE TO TEACH SUSTAINABILITY

Key words: Nonlinear organisational learning; Sustainable Infrastructure; Complex Adaptive System; Education for Sustainability.

Dr. Pedro Pablo Cardoso Castro[1] p.p.cardoso-castro@leedsbeckett.ac.uk Leeds Beckett University. Business School. UK.

Liliana Medina. liliana.medina@mancoltda.com.co Universidad de la Sabana; Universidad Javeriana. Colombia.

ABSTRACT
This paper presents empirical evidence about the impact of intentional (physical) infrastructure design to teach sustainability. The authors develop a case study through the use of linear analysis and action research covering the stages of design, implementation and operation of a new campus for a K-12 & High School in Colombia. This document develops on Medina (2015) work, defining learning (organisational) as a nonlinear and Complex Adaptive System phenomena. Within this context this document propose that when the - organisational - learning process is rationalised, validated and systemically embedded in and through the (physical) infrastructure of the organisation, it magnifies the learning dynamic and the development of effective learning environments with strong impact beyond the physical boundaries of the organisation.

1. INTRODUCTION

1.1. Sustainability and Educational Infrastructure

Since the introduction of the "*UN Decade of Education for Sustainability 2005 - 2014";* many educative institutions at all levels (K-12, High School/College, University) implemented initiatives towards greening their curriculums - in some occasions by following guidelines and adhering to international groups and initiatives (e.g. People and Planet). More committed organisations used this opportunity to introduce innovations in pedagogy and in some few cases as a consequence of this progressive involvement; some education institutions moved towards the development of green/sustainable infrastructure; sometimes aligned and with direct implications on the pedagogic model use

1. Dr. Pedro Pablo Cardoso Castro. Leeds Beckett University. Portland Crescent. The Rose Bowl - LS13HB. Leeds, UK. +44 0113 380 1380. p.p.cardoso-castro@leedsbeckett.ac.uk

by the institution. The balance and evaluation of the impact of this global effort to include sustainability in education was presented in the UN final report: "Shaping the future we want" (UNESCO, 2014) that comprehensively summarises the result of this initiative identifying new trends in education for sustainability, among them the emergence of whole -institution approaches; where educative institutions have progressively moved form the incorporation of sustainability in their operations and management, to changes in their academic activity (teaching, curriculum, research) and modifications in their infrastructure as well as the adoption of more participative forms of engagement with their shareholders - local communities.

The report also provides evidence of the impact in learning pedagogies were in over 9900 schools observed worldwide it was detected an increasing development and adoption of systems thinking - based learning (61%); multi-stakeholder social learning (66%); interdisciplinary learning (73%); discovery learning (76%); critical thinking - based learning (81%); problem-based learning (84%) and participative/collaborative learning (87%) when compared with the baseline. There results suggest a shift in the of conventional pedagogies and suggest more radical changes in the way of teaching for the next decade, implying challenges to the actual physical infrastructure for teaching to cope with and embrace the emerging and increasing new trends in pedagogy, particularly the ones that are student-centred with foundations in systems-thinking and complexity.

However, the report also highlight the need for further institutionalisation (deeper commitment in the education sector with the sustainability agenda; allocation of resources and changes in practice, praxis and physical infrastructure) and the need for the development of documentation, monitoring tools and quality and impact assessment of initiatives towards the incorporation of sustainability in the academic sector[2].

In response, an emergent body of literature emerged addressing the effect of infrastructure in sustainability. The OECD published a compendium of best practices on design for education (Kuhn et al, 2011). the document describes the evolution of infrastructure for education; provides some guidelines for the design of educational infrastructure to satisfy the challenges in education for the XXI century and analyse some case studies about the modification of existing infrastructure. In general, the document advocates for the adoption of open and flexible spaces and the use of out-of the classroom environments.

In this context, the concept of *design with intent* emerges with the hope that the physical infrastructure (the building) itself encourages behavioural change (learning experience); but such assumptions still need empirical study, particularly in the academic environment (Lockton et al 2008, 2010).

DW-L et al (2013); Brown et al (2009) and Brown et al (2010) state that despite sustainable buildings are becoming prevalent in the development of new infrastructure in education, very few studies analyse how the subjective user experience (learning) is enhanced when occupants move into green buildings. These studies raise questions for further research particularly in the areas of behavioural science, design, architecture, engineering and policy-makers as there is strong evidence suggesting that physical context can have a profound influence in learning and behaviour. More recent developments (Brittin et al 2015) provide some empirical evidence on the association between aspects of the academic infrastructure and students' activity. However, the literature lacks on the creation of a unified, practical, spatially - organised resource for campus/school designers and decision makers.

1.2. Infrastructure and Learning

Learning in the organisational context has evolved since the introduction of the concept by Burns and Burns and Stalker (1961) and Cyert and March (1963). Since then multiple definitions have been presented form many different approaches - e.g. group learning (Nonaka and Takeuchi, 1995); information acquisition and sharing (Argyris and Schon, 1996) and learning from failures (Ackerman, 2005), among many others. However, the development of this literature seems to ignore the effect of infrastructure even when some authors early recognise the role of the physical space as a powerful tool to enhance learning (Peters, 1992); a mean to induce relations proximity and essential conditions for learning (Amin and Roberts, 2008) and being described as part of a learning system that channel organisational enquiry and shape behaviour in organisations (Argyris and Schon, 1996).

Regardless the limited specific study of space and learning; is from the observation of organisational behaviour where this connection started to be documented; initially with the "Hawthorne studies" -

[2] This report collects information from 9900 secondary education; 2000 technical and vocational institutions and 747 Universities in regional clusters distributed worldwide.

criticised by the lack of scientific rigour (Carey, 1967). Later, empirical observations based on environmental psychology were added developing on the effect of space -proximity, density visibility - on organisational behaviour (Sutton and Rafaeli, 1987; Sundstrom, 1986). The introduction of "spacial turn" in social sciences (Soja, 1996) initiated a new wave of literature exploring the relationship between learning and infrastructure form different approaches like innovation (Penn at al, 1999); knowledge flow (Becker and Sims, 2001); creativity (Forster et al 2005); performance (Kampschroer et al, 2007) and collaboration (Wineman et al, 2009). However, despite of these advances, little is understood on how space affects learning as the results reported in the existing literature, in many cases are contradictory (e.g. open-plan and communications: Ives and Ferdinands, 1974 - vs - Clearwater, 1980). More contemporary research suggested that approaches integrating complexity should be used to to better understand the embedded relationships between space and the social realm, suggesting also that the rich diversity of definitions and concepts on (organisational) learning may be one of the causes of the limited understanding of the influence that physical space has on learning processes (Amin and Robers, 2008; Sailer, 2013).

The field of learning psychology provides more specific -yet anecdotal - evidence. Based on the maturing learning theory and with recent inputs from neuroscience (Schunk 2011, OECD, 2007) the evidence suggests links between building attributes and student absenteeism; physical and emotional health and wellbeing; school retention; vandalism; disruption in class; student/teacher relations; teaching strategies and engagement with local communities and businesses. The descriptive nature of this evidence corresponds to the difficulties of measure the building-learning relation with any degree of certainty. Although, conventional comfort indicators; aesthetic; thermal; acoustic; visual and air quality indicators; health and sanitation indicators; ergonomic indicators are important in learning environments as these properties can affect the health and well-being of students (Blyth, 2014; Kuhn, 2011).

The understanding of behavioural effects in building (for education) becomes evident in the OECD compendium of educational facilities where general design principles are considered to guide and evaluate the building performance and suitability for education. The report recognises the need to align the learning system - infrastructure included - with the demands of the XXI century context considering the inclusion of principles for effective learning AKA: self-motivation; personal interest; relational; holistic and experiential; complex and non-linear learning (Atkin 1994, 1996); as well as generic infrastructure characteristics such as flexibility, community needs, alternative financing, sustainability, safety and security. More recently, the effect of infrastructure in the organisational learning has been discussed from the ethnographic perspective (Leigh, 1999); and from an architectural and functionalist perspective; (Sailer, 2014) describing how architecture and space design affects organisational learning and behaviour and how this can be purposefully programmed since the stage of design in the development of infrastructure providing the foundations to the emergence for building design guidelines to enhance learning processes.

1.3. The education model

The education systems (infrastructure included) are facing the pressure to catch up with he needs of the post-industrial society and the social, technological environmental and economic changes of the XXI century. These challenges can be summarised as a series of new characteristics to what the educational system has to respond to provide meaningful and effective learning. The characteristic of such learning demand the understanding and use of societal trends such as recursive social structures; cross-sector coordination and integration; innovative learning environments; holism; integration to its environment and community; complexity and ecological and economical sustainability.

The dimension of the paradigm shift that education systems have to embrace can be visualised and the implications for change better understood if we compare the principal characteristics of how education and learning was defined over time (Table 1); from pre-industrial to post-industrial times.

The biggest changes are in the dimensions of time, location and sources and resources (when, where

LEARNING	Pre-industrial	Industrial	Post-industrial knowledge era
Style	Informal, personal	Formal, impersonal	Informal, formal AND personal
Place in community	Family, local community	School separate from community	Re-integration with community, integral part of community.
Location	Around the village pump	Confined, separate	Local- beyond local- global- virtual
Time	Anytime	Set times, set ages	Anytime throughout life
Form	Nature, environment, "apprenticeship", with people cross section of ages, in community	Mass production, uniform experience based on age bands, detached from community	Personalised in nature, learning in "apprenticeship", in community, single age and cross age
Source and resources	Experience, elders, life, people, family, community	Books, experts, teacher "who knows", 1:many	Anytime, anywhere, anyhow with anyone – both experts and fellow travellers
Context	Learning *through* life	Learning *about* life	Learning through AND about life through real life and virtual life

the learning occurs and from which sources).

Table 1. Characteristics of learning. Pre-industrial, industrial and Post-industrial era. OECD (2011).

The nature of the radical changes in these specific dimensions induces a sense of dynamism, omnipresence and continuity rather than assuming learning as a discrete and fix phenomena. Learning then, seems to occur as a choice that unfolds on a landscape of multiple paths rather than following a deterministic path. This emergent properties of learning in the knowledge era define the learning experience close to the nature of a systemic and complex adaptive phenomenon.

This wave of change has foundations in the cognitive learning theory. Early authors suggested that learning occurs when motivations exists, is experiential, life-cantered and self-directed (Linderman, 1926). Piaget (1957) suggest learning as a co-dependant event in which new information is connected to previous existing knowledge through (the learner) active participation in the learning environment. These principles are re-discovered and reframed later by Bruner (1966), Ausubel et al (1978) and Rogers (1951,1994); when suggesting that learners should be encouraged to learn through the exposition to appropriated tasks with links to previous learnt material - be anchored on what is already known - and be relevant to the learner. Gattnego (1970), developing on Rodgers (1951) defines the role of the teacher not as the provider of knowledge but as the facilitator of a learning experience leading through a sequence of sages that start with the introduction of new available material/knowledge to explore, ending with the internalisation, transfer and auto application o f a new skill; setting the foundations for student-centred learning.

Experiential learning theory emerges as experience is recognised as playing an important role in the learning process where knowledge is created and internalised (Vygotsky, 1978) through a transformational experience. Kolb (1984) and Boud et al (1993) describe the learning process a dynamic and cyclical were learners actively construct their own learning experiences through the configuration of educational webs; therefore suggesting that learning provision should adopt a holistic approach. Mahmoudi et al (2012) define the elements of holistic pedagogy as the focus on the interconnectedness of experience; use of reality (context); cross-disciplinary recognition and dynamic. The dynamic and holistic properties of learning suggests the need for a new form of learning delivery that should be non-linear and tuned with the natural experiential and structurally networked.

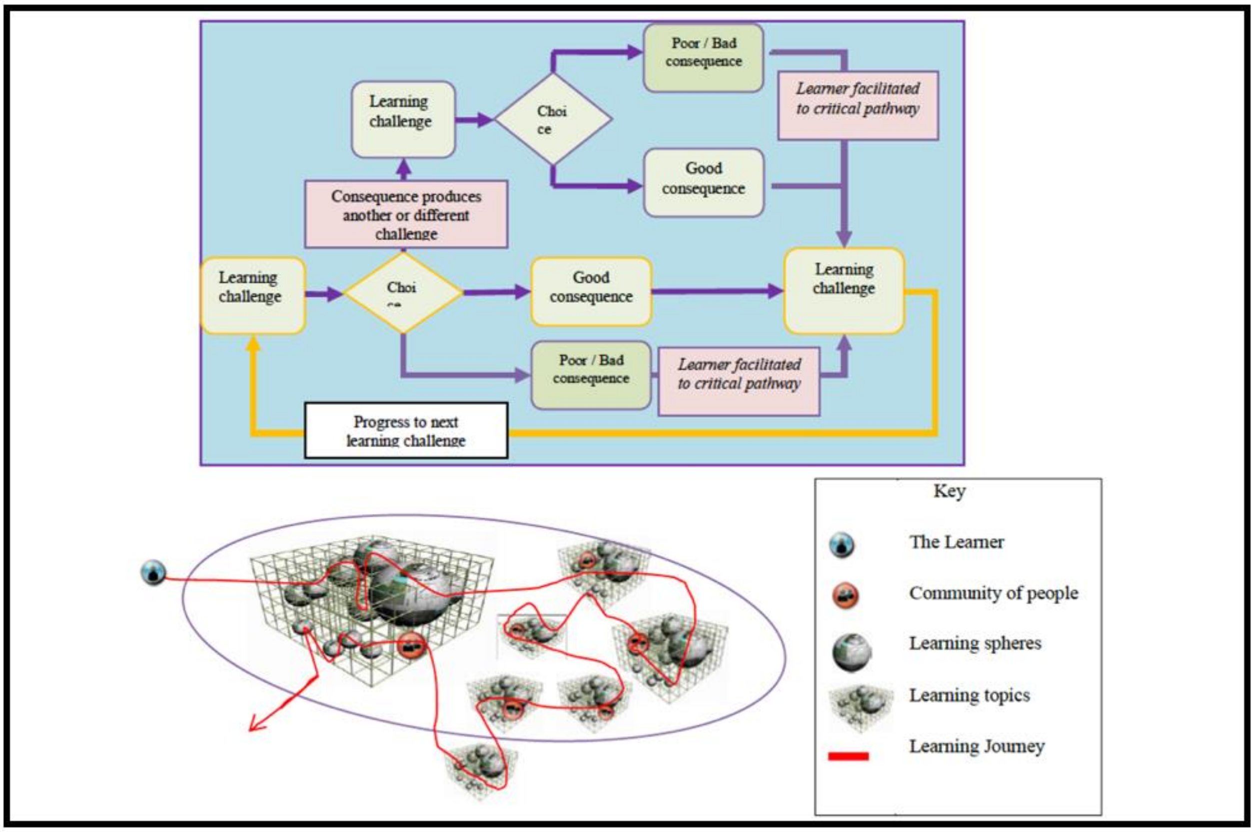
Carroll (2012) and Cleveland, et al (1997) describe learning as a "making connections" process between things we know and things we don't. In which learning is an experiential network construct that is generated when needed, subjective and individual (non-linear, student-centred); opposite to traditional education, following linear learning schemes and promoting fragmentation. These authors also suggest that non-linear learning presents some features linked to the properties of CAS as:

- The learners are provided with a rich variety of inputs
- Different learners follow different paths (landscape of learning options)
- The outcomes are emergent and cannot be foretold (unpredictability of learning)
- Learning is self-organised by the learner's activity in designing it
- Disciplines are integrated and roles are flexible
- There are rapid iterations between the parts & wholes (network dynamic activity)
- People co-evolve together in a learning community

Developing on these concepts, Kitchen (2003) and Felder (2005), propose that to develop a learner-centred pedagogy learning should be understood as self-directed; naturally related to a learning environment; based in reality; supported by systems thinking and complexity approaches; to be non-linear; not time bounded; allow outcomes to emerge freely (not to be foretold); to recognise that different learners will follow different learning paths; be experiential; promote self and peer reflection on the learning process; to be skilfully mentored and facilitated where learning/teaching roles are transitive and flexible in the learning community and facilitation is done by experienced and credible experts and affords the co-evolution of the networked learning community.

In this context, Glasser (1998) presents its Choice Theory as a learner-centred educational method based on the learner natural curiosity; pursuing its own learning targets allowing unique talents to be develop; providing freedom and assuming ethically own personal responsibility on their choices while sharing knowledge in transversal and cross disciplinary learning environments. Later developments provide structure to this of learner-centred method. The Multilevel Theory (Kozlowski, Chao and Nowakowski, 2009; Rootzen, 2007) suggest that the learner make choices on what and how to learn, based on the use of a discrete learning objects in a fragmented learning plan using various media that provide the student different levels of direction and selection in which the individuals coalesce, amplifying and crystallising individual learning, allowing collective learning the emerge as a multilevel phenomenon.

Kitchen (2003) lustrate this process in his multi-stage learning model where multiple choice checkpoints are provided where learning can start in anywhere whiten the learning environment and progression is self-determined and achieved by design through the exploration of different learning spheres and topics where support is obtained through interaction with the learning community (Figure



1).

Figure 1. Multi-Choice stages and multi-verse learning framework route (modified form Kitchen, 2003).

2. METHODOLOGY

Rochester School has been implementing Glasser's Choice Theory as its main philosophy in order to develop a green curriculum considering traversal educational projects since 1998. Following Glasser's pedagogic model the students (K-12) need to develop a "Quality Work" and finally a "Quality Product". Conceived by the student as a need-satisfying learning process, this learning route/product has to satisfy defined competences based on clear goals; individual preferences; continuous improvement and peer and self-evaluation; all exploiting the learning environment provided by the school (RocheStem, 2015).

The construction of a new campus where to grow and implement more efficiently this pedagogic model started in 2011 with the intention to develop the adequate infrastructure where where sustainability is core to the learning experience. During this process the authors intervened as part of a multidisciplinary consultancy team to provide advice to the board of directors in the participative design (involving academics and community members) of the new facilities - one of the authors participated as LEED (Leadership in Energy and Environmental Design) PA BD+C (LEED Accredited Professional Building Design and Construction) and expert consultant for the design of a green campus in alignment with the Colombian norm and LEED standards. During the construction the role was to monitor the implementation of the suggested design and the documentation of the building process; act as project manager in charge of the coordination of contractors following the LEED guidelines and in general during all the construction phase acting as the Sustainability Consultant for the Board of Directors providing expert advice on the definition of policies for the further operation and implementation of sustainability criteria and providing guidance to the academic staff in the design and integration of pedagogic strategies and greening the curriculum practices exporting the potential of the new facilities (for more detail see appendix 1).

The documentation of the intervention was done as an action research case where evidence from direct observation & participation was collected using principles of linear analysis, with emphasis on the documentation of the effect of the new infrastructure on the design and implementation of a green curriculum - ultimately in the learning experience.

3. RESULTS

The context provided by the ethos of the institution and the infrastructure development conduced to the achievement of LEEDS GOLD CERTIFICATION standards. The core variables considered in the design where also - via participative design with academics - used as core platforms to develop content related with sustainability (see table 2); to be experienced as a living textbook, core for the implementation of the green curriculum. Many of these guidelines are similar to he design specifications defined by the OECD such as open and flexible space; and comfort indicators such as acoustic, lighting, and ventilation.

Re-design Project	Main Goal
Architectural Design	To maximize daylighting and views, use of regional and low-VOC materials, open green areas, minimum parking based on local requirements, carpooling preferred parking, interconnected blocks, general and detailed drawings in CAD. Classrooms blocks considering Educational HUB concept, recommended by Ed Designs Consultants. Operational and Educational purposes.
Energy Efficiency – Energy Model	Energy savings based on design case no less than 2,082.3 kWh x 10 ³ (Baseline). Software Trace 700 recommended by LEED EAp2. Operational and Educational Purposes.
BioClimatic	Initial natural ventilation evaluation considering ASHRAE (62.1; 55) standards required by LEED IEQp1 Design Builder software use. Operational Purposes.
Mechanical Ventilation	Air renovation (No air conditioning) for classrooms, and air conditioning for data centre design based on ASHRAE (62.1 and 90.1) standards required by LEED IEQp1 and EAp2. Operational Purposes.
Acoustical	Design and measurement verification were required based on LEED IEQp3. Operational and Educational purposes.
Renewable Energy	Solar power for swimming pool heating and showers; photovoltaic arrangement supplying energy no less than 2% of total energy demand. Operational and Educational purposes.

Lighting	Maximum daylighting use, LED luminaries, external lighting to reduce lighting pollution, sensors and controls. ASHRAE 90.1, IESNA 9, IESNA RP-33 and RETILAP considered norms, DIALUX, AGI 32 and AutoCAD software refereed. Operational and Educational Purposes.
Hydraulic and Waste Water Treatment	Minimum water consumption savings in 20%; efficient water (low consumption) toilets, urinals, showers, and lavatories; tertiary water treatment system; treated water reused for sanitary discharges and landscape irrigation. Operational and Educational purposes
Landscape	Native species, low irrigation requirement. Operational and Educational purposes.

Table 2. LEED core areas of design and goals. Template for the design of learning activities.

During the construction phase of the project more specific opportunities to relate infrastructure with learning experiences based on the learner-centred parading where identified. The participative design facilitated the identification of key areas that respond to the local environment (e.g. urban agriculture, indoor air quality); beyond the standard variables of management for sustainability (e.g. Energy, Water, Waste Management) as described in Table 3.
In this sage of design details about the learning topics, infrastructure components and grades that will use such learning space was defined by the consultants and academics.

Learning Area	Environmental Topic	School Tool	Grade
Water	Water Footprint	Tertiary Waste Water System Water Efficiency	All grades
Energy	Ethical and sustainable use of Energy	PV and Sun panels; efficient lighting design.	All grades
Landscaping	Native species / biodiversity/ecology topics	Sustainable Landscape	All grades
Waste Recycling	Organic (compost and vermiculture) Non-organic (recyclables)	General food organic waste from cafeteria and snack bar. Recyclables	All grades
Urban Agriculture	Food Security	Composting and Orchards	All grades
Biodiversity and Conservation	Rochester School as Habitat	School as Natural Corridor	All grades
Indoor Environmental Quality	Air Quality and Health	Classrooms / IEQ implementation	9-12 grades

Table 3. Variables of sustainability. Relation between identified infrastructure features and curriculum development.

More advanced developments on the curriculum content, use of infrastructure, learning projects and learning goals where developed after the construction phase (table 4). In this new stage of the project the real interaction of academics and students with the new facilities occurs (2014). This stage provided more specific opportunities to develop green content, learning scenarios and experiences.

Since 2015, based on the permanent improvement of the Green - sustainable - Curriculum the Rochester School has been establishing agreements with external bodies as follows: a) a special alliance with the National Energy Regulation Unit - UPME to develop and implement a pilot project on energy conservancy curriculum for off-network areas; b) the Colombian Green Building Council for Green Schools Coalition to act as K-12 Sustainable Curriculum Leader; c) the National Park Unit – Chingaza Park to run a monitoring program K-12 educational Andean Bear (Spectacled Bear), installing trap cameras to identify and learn about the andean bear's activities; d) alliance with Universidad de La Sabana – Environmental Engineering and Education programs; to allow undergraduate students to develop final degrees projects.

In addition, created by final year students, the School generate literature (http://www.rochester.edu.co/publicaciones-2/) as the RocheSTEM, Sustainable Guideline, Rochester School Bird Fauna, Our Own Landscape (Rochester School Landscape Guideline) where the learning experience is consolidated as the result of evolving sustainable strategies defined since design phase - due to the intentional design - and conceived to be a living text book.

Strategies defined by design	Specific Implementation	Learning Area	Transversal Project	Learning Goals
Tertiary Waste Water System	Treatment system (Serial Batch Reactor, Filters, UV Lamps)	Water	Water Footprint	Water Chemical parameters, anaerobic processes
PV and Sun panels; efficient lighting design.	84 photovoltaic panels arrangement; LED luminaries controlled by presence and daylighting sensors, Pools heating by sun panels arrangement	Energy	Ethical and sustainable use of Energy	Energy physic, Energy Consumption, Renewable Energy Production In-Situ
Sustainable Landscape & School as Natural Corridor	Native species / biodiversity/ecology topics	Landscaping	Biodiversity and Conservation	Ecological requirements and behaviour
	Green areas, Artificial Reservoir, native species	Ecology	Rochester School as Habitat	Fauna migration, threatened species,
		Waste Recycling	Organic (compost and vermiculture)	Biodegradation

Waste Management Plan	Organic waste collectors and composting units.	Food Security & Urban Agriculture	Compost for orchards (vegetables)	Biological cycles
	Recycling collectors and Specific area for segregation	Waste Recycling	Recycle Program – Community Recycling Program	Segregation and recovering
Indoor Environmental Quality Sensors	Temperature, Relative Humidity and CO_2 Sensors installed based on Breathing Zone	Indoor Environmental Quality	Air Quality and Health	Air renovation rates, comfort

Table 4. Implemented learning strategies to enhance sustainable curriculum. transversal educational projects

To illustrate the use of infrastructure to teach sustainability in detail, the water topic can be used as example. With emphasis in water problems: water, energy, climate change and conservancy topics; the teachers facilitate the identification of a problem and the definition of the topic/learning objective/area where students will develop learnings (figure 2).

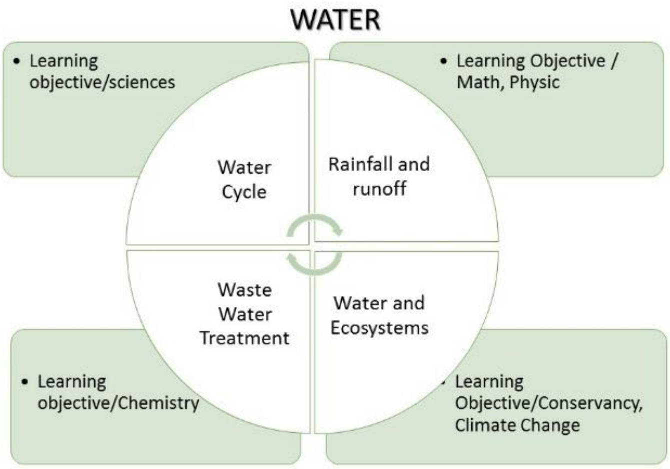


Figure 2. Rochester School Nonlinear learning scheme. Water topic example.

At beginning of school year the teachers develop and propose each learning unit. Students will need to identify the topics and define and achieve the learning objectives for each problem in 2 months. the Odyssey® platform is used in order to co-design curriculum objectives allowing teachers to identify and plan how students will reach learning goals. It also provides access to activities, data bases, publications, and other learning support materials. The students are organised in teams and they explore and define the problem they want to solve withe the guidance of teachers on how to find the best resources to solve questions and develop practical solutions considering learning unit's goals. In this stage they are encouraged to explore the facilities for both, topic problem identification, design and experimentation and implementation of practical solutions.

This method is used with students from year 1 of secondary school promoting the development of research, cooperative learning and problem solving skills.

All over the learning path the students are supported not only by teachers but staff -also trained in Choice Theory - who provide related information according to their own skills. A social-educational network is enhanced between students, teachers and staff in order to solve a common problem. A Sustainability Committee and Curricular Committee monitor the curriculum development and support teachers in order to identify and make connections between the campus and environmental-sustainable topics.

The effect of the implementation of this Sustainable Curriculum and nonlinear learning methodology can't be compared to other schools in Colombia, considering its condition as unique LEED School for now. Medina (2015). However, the internal reports indicate a sustained increment between 20-30% in the final grade projects where the main research problem is related to environmental (sustainable) and social topics (figure 3) where either the problem and/or the solution is explored and experimented with the use of the school facilities (e.g. solar park, agriculture areas, waste management areas).

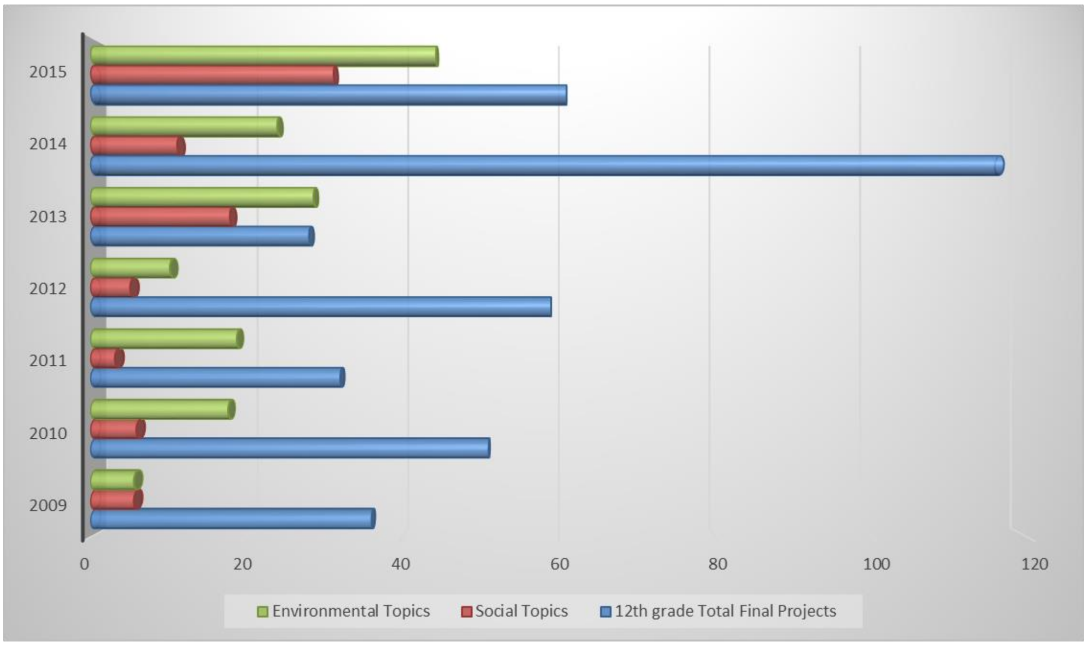


Figure 3. 12th grade Final Projects. Environmental and Social Topics Evolution. Medina (2015)

The external validation of this learning system has been made by external and independent recognitions such as: the Kimberly Clark Foundation – Ekco-Awards as an Exceptional Place to Work in 2013, BIBO-WWF in 2014 as "Academy – Best Environmental Practices", "Green Project Challenge - 2014" first place, BIBO-WWF in 2015 as "Academy – Best Environmental Practices". Since 2012 Rochester School is leading "Green Apple Day" in Colombia and "Our Choice", an integrative K-12 networking initiative based on sustainability educational strategies for schools since 2014 and LEED for Schools Gold Level since 2014 (first in Latin America). The school also generates several community projects in the town where is placed and is both, inspiration and operator of community based projects on local farming, organic agriculture and protection of the local bio-diversity.

4. CONCLUSIONS

This study contributes to validate the theory by providing evidence of the efficiency of such intentional design in the generation of learning process at different levels that transcend the limits of the organisation.

The literature review suggest a gap in the documentation of green infrastructure in high education and its effect in the students's learning experience; in particular within the context of the implementation of green curriculums. Similarly, it seems that the HE sector has been left behind in the adoption of learner-centred pedagogic systems (including infrastructure).

The design of infrastructure for education following the LEED guidelines is not substantially dissimilar to the general recommendations provided by the OECD in themes of the variables to consider, being the LEED principles more specific and process oriented as expected for an external validated certification.

The incidence of the green infrastructure design on the definition of a green curriculum in this case was positive and highly productive. The facilities provided a "living textbook" where real experience can be obtained through direct interactions with the multiple learning environments (AKA. Facilities for the sustainable management of the campus such as the solar park, water treatment plant, food production fields, etc) enhancing the learning experience and providing real life problems and interactions in a multi-level and diverse learning domains occurring almost simultaneously. However, such influence in the design of a sustainable curriculum in this case was volitive.
The impact of the design proves effective not just for the enhancement of the learning outcomes in relation to sustainability. It also provided opportunities for the development of an extended learning community including the local community and local business adding variety to the learning landscape and further development of learning scenarios - many of them specific to the study of sustainability. This work provides additional evidence to the impact of infrastructure and intentional design in education. It also offers empirical evidence of how infrastructure and intentional design -sustainable in this case - affects the development of content, didactics and incentives the development of a green curriculum - almost as a natural consequence derived form the characteristics of the infrastructure.

5. REFERENCES

Ackermann, M. (2005). *Systemisches Lernen: Individuelle und organizationale Lernprozesse in Kommunikationsarchitekturen [Systemic learning: Individual and organizational learning processes in communication architectures]*. Frankfurt am Main, Germany: Peter Lang Verlag.

Amin, A., & Roberts, J. (2008). Knowing in action: Beyond communities of practice. *Research Policy*. 37, 353–369.

Argyris, C., & Schön, D. A. (1996). *Organizational learning II: Theory, method, and practice*. Reading, MA: Addison-Wesley.

Atkins, J. (1994). *How students learn: A framework for effective teaching: Part two, Conditions that enhance and maximise learning*. Seminar Series No 34. IARTV. Melbourne.

Atkins, J. (1996). *From Values and Beliefs about learning to principles and practice*. Seminar Series No. 54. IARTV. Melbourne.

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). *Educational Psychology: A Cognitive View* (2nd ed.). New York: Holt, Rinehart and Winston.

Becker, F., & Sims, W. (2001). *Offices that work: Balancing communication, flexibility and cost* [Online]. Ithaca, NY: International Workplace Studies Program, Cornell University. Available: http://iwsp.human.cornell.edu/file_uploads/offices1_1238256905.pdf. [Accessed 10th January 2016].

Blythe, A. (2014). *What is a sustainable learning environment?*. [Online]. Available: http://alastair-blyth.com/ [Accessed10th December 2015].

Boud, D., Cohen, R., & Walker, D. (1993). *Using Experience for Learning*. Buckingham: SRHE & Open University Press.

Brown, Z., Dowlatabadi, H. and Cole, R. (2009). Feedback and adaptive behaviour in green buildings. *Intelligent Buildings International*. 1: 296-315.

Brown, Z., Cole, R. and Dowlatabadi, H. (2010). Evaluating user experience in green buildings in relation to workplace culture and context. *Facilities*. 28: 225-238.

Bruner, J. S. (1966). *Toward a Theory of Instruction.* Cambridge, Mass.: Belkapp Press.

Burns, T., & Stalker, G. M. (1961). *The management of innovation*. London: Tavistock Publications.

Carey, A. (1967). The Hawthorne studies: A radical criticism. *American Sociological Review*. 32,403–416.

Carroll, K., (2012). *Linear and non-linear learning* [Online]. Available: http://ken-carroll.com/2007/12/13/linear-and-non-linear-learning [Accessed12th October 2015].

Clearwater, Y. (1980). *User's assessment of a landscaped office*. Doctoral dissertation, University of California, Davis, CA.

Cleveland, J., Neuroth, J. and Marshal, S. (1997). *An Internet Dialog on Learning Organisations* [Online]. Available: http://www.learning-org.com97.07/0193.html [Accessed 24th September 2015].
Cyert, R. M., & March, J. G. (1963). *A behavioural theory of the firm*. Englewood Cliffs, NJ: Prentice-Hall.
DW-L, Wu., DiGiacomo, A. and Kingsstone, A. (2013). A sustainable Building Promotes Pro-Environmental Behaviour. An Observational Study on Food Disposal. *Los ONE*. 8(1): e53856.
Felder, R.M. (2005). *Navigating the bumpy road to student-centred instruction* [Online]. Available : http://www.ncsu.edu/felderpublic/ [Accessed 27th November 2015].
Förster, J., Friedman, R. S., Butterbach, E. B., & Sassenberg, K. (2005). Automatic effects of deviancy cues on creative cognition. *European Journal of Social Psychology*. 35, 345–359.
Ives, R. S., & Ferdinands, R. (1974). Working in a landscaped office. *Personnel Practice Bulletin*. 30, 126–141.
Gattnego, C. (1970). *What We Owe Children, The Subordination of Teaching to Learning* [Online]. Outerbridge and Diensfrey, New York. Available: http://www.slideshare.net/educationalsolutions/what-we-owe-children-web-book [Accessed 26th December 2015].
Glasser, W. (1998). *Choice Theory: A New Psychology of Personal Freedom.* HarperCollins,
Kampschroer, K., Heerwagen, J., & Powell, K. (2007). Creating and testing workplace strategy. *California Management Review*. 49(2), 119–137.
Kitchen, A. (2003). *Non-linear Learning Education for practitioner Social Entrepreneurs: Toward a new paradigm* [Online]. The social Learning Company. Available: http://www.thesociallearningcompany.co.uk/wp-content/uploads/2013/12/Non-Linear-Learning-Education-for-Practitioner-Social-Entrepreneurs-A-New-Paradigm-FINAL.pdf [Accessed 25th February 2016].
Kolb, D.A. (1984). *Experiential Learning: Experience as a Source of Learning and Development* [Online]. Upper Saddle River, NJ: Prentice-Hall, Inc. Available: http://academic.regis.edu/ed205/kolb.pdf [Accessed 15th December 2015].
Kozlowski, S., Chao, G. and Nowakowski, J. (2009). *Building an Infrastructure for Organisational Learning: A Multilevel Approach.* In: Kozlowski S. and Salas, E., Learning, training, and development in organisations. Routlege. Taylor and Francis Group. 27 Church Road Hove. East Sussex, UK.
Kuhn, C. (2011). *Learning environments for the XXI century. Designing for Education: Compendium of Exemplary Educational Facilities. OECD* [Online]. Available: http://www.keepeek.com/Digital-Asset-Management/oecd/education/designing-for-education_9789264112308-en#page20 [Accessed 15th February 2016].
Kuhn, C., Atkin, J. and Heitor, T. (2011). *Designing for Education. Compendium of Exemplary Educational Facilities*. OECD Centre for Effective Learning Environments.
Leigh, S. (1999). The Ethnography of Infrastructure. *American Behavioural Scientist*. 43 (3). pp. 377 - 391.
Lindeman, E. C. (1926). *The Meaning of Adult Education*.New Republic. New York.
Lockton, D., Harrison, D. and Stanton, N. (2008). Making the use more efficient: design for sustainable behaviour. *International Journal of Sustainable Engineering.* 1:3-8.
Lockton, D., Harrison, D. and Stanton, N. (2010). The design with intent method: A design tool for Influencing user behaviour. *Applied Ergonomics.* 41: 382-392.
Mahmoudi, S., Jafari, E., Nasrabadi, H.A. Liaghatdar M.J. (2012). Holistic Education: An Approach for 21 Century. *International Education Studies.* 5 (2); p 178- 186 [Online]. Available: http://ccsenet.org/journal/index.php/ies/article/download/17024/11514. [Accessed 7th December 2015].
OECD. (2007). *Understanding the brain: The birth of a learning science.* OECD publishing.
Penn, A., Desyllas, J., & Vaughan, L. (1999). The space of innovation: Interaction and communication in the work environment. Environment and Planning B. *Planning and Design.* 26, 193–218.
Peters, T. (1992). *Liberation management: Necessary disorganisation for the nanosecond nineties*. London: Macmillan.
Piaget, J. (1957). *Construction of reality in the child*. Routledge

Rogers, C.(1951). *Client-centered Therapy: Its Current Practice, Implications and Theory*. London: Constable
Rogers, C. & Freiberg, H. (1994). *Freedom to Learn*. 3rd Revised edition: Prentice Hall.
Rootzen, H. (2007). *Learning Statistics – in a web-based and non-linear way* [Online]. International Statistical Institute, 56th Session. Available: http://www.websm.org/db/12/12919/Bibliography/Learning%20Statistics%20%E2%80%93%20in%20a%20web-based%20and%20non-linear%20way%20/ [Accessed 26th September 2015].
Nonaka, I., & Takeuchi, H. (1995). *The knowledge-creating company: How Japanese companies create the dynamics of innovation.* New York/Oxford, UK: Oxford University Press.
Sailer, K. (2013). Organisational Learning and Physical Space—How Office Configurations Inform Organisational Behaviours. In: *Learning Organisations*. In: Berthoin, A., Meusburger, P. and Suarsana, L. Knowledge and Space. Vol 6. pp. 103-127. [Online]. Available: http://discovery.ucl.ac.uk/1426232/ [Accessesed 15th February 2016].
Medina, L. (2015). *Sustainable Educational Infrastructure in Colombia as transforming society tool: Rochester School Study Case*. SEEDS conference, Leeds Beckett University. UK.
Schunk, D. (2011). *Learning theories. An Educational Perspective*. Addison Wesley. NY.
Soja, E. W. (1996). *Thirdspace: Journeys to Los Angeles and other real-and-imagined places*. Malden, MA/Oxford, UK: Blackwell Publishing.
Sundstrom, E. (1986). *Work places: The psychology of the physical environment in offices and factories.* Cambridge, UK: Cambridge University Press.
Sutton, R. I., & Rafaeli, A. (1987). Characteristics of work stations as potential occupational stressors. *The Academy of Management Journal*. 30, 260–276.
UN *Decade of Education for sustainability* 2005-2014. [Online]. Available: http://unesdoc.unesco.org/images/0014/001416/141629e.pdf [Accessed 20th January 2016].
UNESCO (2014). *UN Decade of Education for Sustainable Development 2005 - 2014. Final report. Shaping the Future we want* [Online]. Available: https://www.bibb.de/dokumente/pdf/a33_un_decade_final_report_2014_230171e.pdf [Accessed on 20th January 2016]
Vygotsky, L.S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.
Wineman, J., Kabo, F., & Davis, G. F. (2009). Spatial and social networks in organisational innovation. *Environment and Behaviour*. 41, 427–442.

6. APPENDICES

6.1. Appendix 1. Summary of the researchers intervention activities and results.

LEED AP ADVISEMENT	IMPLEMENTATION	INTEGRATION TO EDUCATION CURRICULUM	RESULTS	TIME
DESIGN PHASE				
OPR (Owner Project Requirement) document validation	Sustainable strategies required by School Board evaluation based on local norm, available technology and suppliers in Colombia.	Evaluation how to integrate main selected strategies to “School as a teaching tool” LEED’s Innovation and Design credit.	A School Sciences teachers special sustainable team was integrated	1-2 months

BOD (Bases of Design) document validation	Minimum design requirements to Bidder's TOR (Term of References), based on LEED for school v3 pre-requisites were integrated	Evaluation how to integrate main selected strategies to "School as a teaching tool" LEED's Innovation and Design credit.	Sustainable team generated a comprehensive suggestions regarding how to enhance new infrastructure for operational and sustainable education.	2 months
Design Team LEED training - Designs development	Based on certification and local norm requirements, final designs were defined. Special teacher's team recommendations were integrated.	Design specification were considered as educational documents.	First reference technical documents as educational tool	3-5 months
CONSTRUCTION – START UP PHASE				
Special visit guidance to School teachers, administrative staff and parents	Site visit were promoted and guided by LEED AP and Special Team in order to explain how new infrastructure would be implemented. Comments and questions were considered in order to enhance operational (educational) phase.	Updates were considered to be integrated to "ID-School as a teaching tool" document	Visitor were our first "validation committee" regarding strategies in order to consider how to enhance educational strategies.	15 months
Special visit guidance to pre-graduate and post-graduate green building courses	Site visit were promoted and guided by LEED AP to universities in order to explain "Green Building" process.	Visit record was integrated as special educational goal to "ID-School as a teaching tool" document		
Sustainable strategies, LEED requirements and local norm full accomplish by contractors evaluation and validation.	Full validation. Technical information from materials, systems, devices, etc was compiled. in order to be consultancy educational documents.	Technical compiled documentation was considered as consultancy educational documents.	At present, full documents are available to teachers and students to learn how our school has a sustainable operational infrastructure.	15 months
Support Documents for GBCI development	Full documents required for LEED development and validation			6 months
School as a Teaching tool – Innovation & Design credit special document development	Special document was designed in order to support specific credit.	Special team integrated specific learning areas and transversal projects to a pilot sustainable curriculum	ID credit was awarded	4 months
OPERATIONAL PHASE				
School teachers training	Special training sessions with teachers in order to understand sustainable strategies and operational guidelines.	Teachers based on training were in charge to propose transversal projects using sustainable strategies	Sustainable curriculum committee was defined to evaluate pilot project evolution.	1 month
Sustainable curriculum initial implementation phase	Waste Recycling, Landscape and water educational areas were evaluated in own goals based on operational start up.	Enhanced learning activities were included as an integrated project: Green Apple Day of Service, first world event.	Rochester school leaded educational activities and community integration in order to solve an environmental problem to Chia Municipality	2 months
12 grade final projects special advisement	Students for final project were advised in sustainable topics	Students and teachers implemented sustainable topics and learning goals using implemented strategies	6 final projects were in sustainable topics	10 months

Sustainable curriculum first evaluation	A special evaluation session with Sustainability Curriculum Committee was in course.	Sustainable strategies, technical documentation and operational policies used by teachers for education were evaluated and faults considered.	First update to sustainable curriculum was done. Enhancement for next school year	1 month
School certified as LEED Gold School. First in Colombia and Latin America				
Sustainable curriculum 2nd year implementation phase	Waste Recycling, Landscape, water educational, energy, Urban Agriculture, Biodiversity and Conservation areas were evaluated in own goals based on first evaluation	New transversal projects were implemented	Rochester school leading sustainable education for students and community	10 months
12 grade final projects special advisement	Students for final project were advised in sustainable topics	Students and teachers implemented sustainable topics and learning goals using implemented strategies	8 final projects were in sustainable topics	10 months
Kimberly Clark Foundation – Ekco- Awards recognition for Exceptional Places to Work in 2013, BIBO-WWF in 2014 as "Academy – Best Environmental Practices", "Green Project Challenge - 2014" first place.				
Sustainable curriculum second evaluation	A special evaluation session with Sustainability Curriculum Committee was in course.	Sustainable strategies, technical documentation and operational policies used by teachers for education were evaluated and faults considered.	Second update to sustainable curriculum was done. Enhancement for next school year	1 month
Sustainable curriculum 3rd year implementation phase	Waste Recycling, Landscape, water educational, energy, Urban Agriculture, Biodiversity and Conservation areas were evaluated in own goals based on first evaluation	New transversal projects were implemented	Rochester school leading sustainable education for students and community	10 months
12 grade final projects special advisement	Students for final project were advised in sustainable topics	Students and teachers implemented sustainable topics and learning goals using implemented strategies	28 final projects were in sustainable topics	10 months
Sustainable School IBook contents (first version)	Based on LEED and Sustainable strategies an interactive IBook as educational tool was developed	Students, teachers, staff and parents use IBook as complementary educational tool		3 months
BIBO-WWF in 2015 as "Academy – Best Biodiversity and Conservation Practices"				
Sustainable curriculum third evaluation	A special evaluation session with Sustainability Curriculum Committee was in course.	Sustainable strategies, technical documentation and operational policies used by teachers for education were evaluated and faults considered.	Third update to sustainable curriculum was done. Enhancement for next school year	1 month