An instructional-learning model applying Problem-Based Learning enabled by ICTs

Vassilios Makrakis[1], Nelly Kostoulas-Makrakis[2]
makrakis@edc.uoc.gr, nkostoula@edc.uoc.gr
[1]Professor Dept. of Primary Education, University of Crete
UNESCO Chairholder ICT in Education for Sustainable Development
[2]Associate Professor Dept. of Primary Education, University of Crete

Abstract

The sustainability crisis that the world is facing needs a new paradigm in teaching, learning and curriculum contrasted to one dominated in the 20th Century. A critical and emancipatory perspective of problem-based learning (PBL) enabled by information and communication technologies may contribute to this shift. In this paper, we extend beyond the focus on the 4Cs to what we term 10Cs, which in turn drives our approach to a PBL model that can provide a mechansism for transforming teaching, learning and curriculum towards building a more sustainable society.

Key words: Problem-based learning, sustainability, ICT, 10Cs

The Challenge of PBL in the Era of Sustainability Crisis

We are increasingly confronted with complex, interconnected social, economic and environmental problems locally and globally. Humanity is living a crisis of sustainability that includes not only environmental issues such as climate change, ozone depletion, biodiversity loss, but also economic and social issues, such as poverty, social inequalities, violation of human rights, gender inequalities, loss of indigenous knowledge, etc (Makrakis & Kostoulas-Makrakis, 2013). The sustainability crisis is not just our biggest environmental, economic and social challenge; it is also a cultural challenge, a personal and moral one due to its anthropogenic cause. There is thus need for a shift of consciousness that alters: our way of being in the world (learning to be), our way for discovering others by discovering ourselves (learning to live together), our way of learning how to learn as well as appreciating all sorts of knowing (learning to know) and our way of putting knowledge into action (learning to do). It is above all learning to "transform problematic frames of references–sets of fixed assumptions and expectations (habits of mind, meaning perspectives, mindsets)–to make them more inclusive, open reflective and emotionally able to change" (Mezirow, 2003: 58).

Such a transformation can be significantly promoted through instructional and learning methods that focus on reflection and action to generate problem solutions, such as problem-based learning (PBL). Problem-Based Learning is not solely regarded as an instructional technique, but as an educational philosophy or approach for designing curricula that "empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem" (Savery, 2006: 12). Focusing on sustainability problems, PBL provides learners with opportunities to move beyond surface learning and content consumption and compartmentalised knowledge to critically and reflectively examine problems to generate change. PBL is confronting learners with problems of 'real-life'. The 'real-life' sustainability problems are often not bounded or

Π. Αναστασιάδης, Ν. Ζαράνης, Β. Οικονομίδης & Μ. Καλογιαννάκης, (Επιμ.), *Πρακτικά 9ου Πανελλήνιου Συνεδρίου με Διεθνή Συμμετοχή «Τεχνολογίες της Πληροφορίας & Επικοινωνιών στην Εκπαίδευση»*. Πανεπιστήμιο Κρήτης, Ρέθυμνο, 3-5 Οκτωβρίου 2014.

solvable within disciplinary frontiers; but by means of interdisciplinary approaches of knowledge construction. It, thus, puts emphasis on the interdisciplinarity and holistic perceptions of knowledge and problems, the empowerment of learners to consider multiple perspectives when examining a problem domain, the encouragement of learners to set goals for their learning and adopt a holistic view of the world. The epistemology of Problem Based Learning (PBL) is based on critical constructivism, a postmodern view of knowledge and learning, which has influenced teaching, learning and curriculum significantly in the past two decades. It is also based on transformative pedagogical processes that help to develop critical consciousness and knowledge construction that is purported to lead to individual and societal transformation.

PBL and the 10Cs enabled by ICTs

In the second half of the 20th Century, much of the discussion on skills needed was centred on the 3Rs - reading, writing, and arithmetic. In the las decade, there is a shift to what has been termed as the 4Cs for workforce readiness in the 21st century - critical thinking & problem solving, communication, collaboration & team building and creativity & innovation (AMA, 2010; Partnership for 21st C. Skills, 2011; AT21CS, 2012).

In a world of rapid change and expansion of human knowledge, along with sustainability crisis that threatens the very existence of humankind, education must extend beyond the focus on the 4Cs to what we term 10Cs, namely:

1. Critical thinking and problem solving
2. Communication
3. Collaboration
4. Creativity and innovation
5. Connectivity
6. Critical consciousness
7. Critical reflection
8. Cross/inter-cultural competence
9. Co-responsibility
10. Constructing knowledge

(Fig. 1)

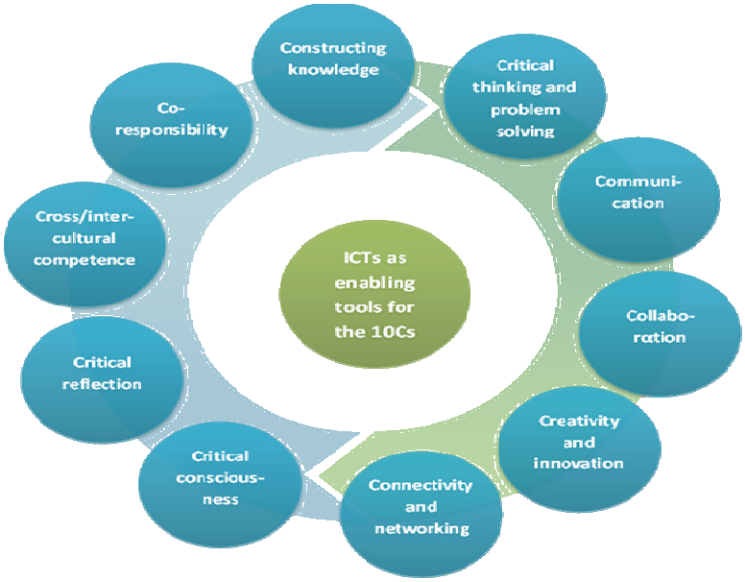

Figure 1. ICTS as enabling tools for the 10Cs

Students in the 21st century live in a technology and media rich environment where they have access to a plethora of ICTs that can function as enabling tools across all 10Cs (Scardamalia & Bereiter, 2006; Strampel & Oliver, 2007; Yang, S.-H., 2009; Makrakis, 2010; Mayo, 2012; Stanlick, 2014). Students, for example, can share a problem solution in the form of a digital story and video journal. Telling a story is a powerful way to communicate with others. It improves the creative skills of students and helps them explore the meaning of their own work and experience. Students can create their own digital stories with many available free tools, namely, Story Bird, PicLits, Slidestory. Wikis, such as Wikispaces, WikiQuESD (Makrakis, 2010; 2012), and the latest versions of Pixie, Frames and Share include collaboration options that allow multiple students to work on the same project at the same time. Blogging helps teachers and learners for communication in the classroom and in a global community. Blogs are a great way for the development of creative thinking (e.g. Edublogs, Blogger and WordPress). Mind-mapping and concept mapping tools can become a great collaborative way in reflecting, conceptualising, constructing and assessing knowledge (e.g. SpidrerScribe, Wise Mapping, ChartTool, Cmap, Creately). These tools boost learners creativity and provide them with different ways to interconnect their thoughts as well as to accomplish metacognitive reflection. Similarly, tools for creating infographics (e.g. Wordle, Tableau and Inkspace) engage students in actively discovering connections and develop creativity.

However, simply providing students with new powerful and interactive ICTs will not develop these skills and enhance their learning. What it matters is not how to use technology or even teaching with ICT tools, but more using ICTs as enabling tools to support communication, reflection and knowledge construction related to real-life problems.

Although there is some overlap among the 10Cs, each one has its own role in teaching and learning for problem solving. For example, critical thinking and problem solving refers

to the ability to make decisions, solve problems and take appropriate action, using learning processes such as conceptualizing, applying, analysing, synthesizing and/or evaluating information gathered by multiple means. Communication refers to the ability to synthesize and transmit ideas in both written, oral and virtual formats. Collaboration refers to the ability to work effectively with others, including those from diverse groups and with opposing points of view. Creativity and innovation refers to the ability to apply new ideas in developing innovative applications and solutions. Connectivity addresses the complexity of human to human interaction, society and nature. This is driven by the theory of connectivism- a response to a need to derive and express meaning, and gain and share knowledge, in an increasing networked global society (Siemens, 2004; 2006). These connections occur on neural, conceptual, and social levels (Siemens, 2008). Critical reflection refers to a complex process that strongly engages learners to critically reflect upon their reality, personal and social, and to transform it through action and reflection (Stanlick, 2014). Cross/inter-cultural competence requires that learners examine their own cultural backgrounds and identities to increase awareness of personal assumptions, values, and biases in order to work effectively in cross-cultural situations. Co-responsibility refers to a culture of sharing that necessitates shifting to less ego-centric principles and practices. Critical consciousness or concientization in Freire's (2000) terms denotes the process of developing a critical awareness of one's social reality through reflection and action. Constructing knowledge represents an attempt to shift from consuming information to constructing knowledge that merges with action.

21st Century Learning Pillars and PBL

In its 1996 report to UNESCO, Learning: The Treasure Within, the International Commission on Education for the 21st Century argued that education should be based on four fundamental pillars of learning- learning to know, learning to be, learning to do and learning to live together, which "provide maps of a complex world in constant turmoil" as well as "the compass that will enable people to find their way in it" (Delors et al.,1996: 85). At a later, stage, the 5th pillar of learning to transform oneself and society was added by UNESCO. We feel the need to add the 6th pillar of 'learning to give' in order to respond to the quest for merging volunteerism, social activism and learning (Fig.2).

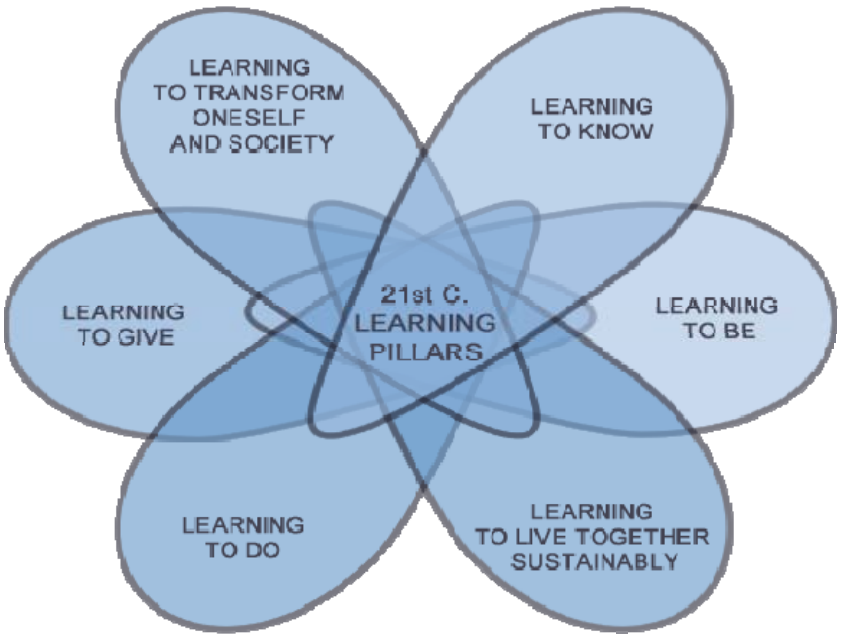

Figure 2. 21st Century Learning Pillars

Table 1. Definition of the 21st Century Learning Pillars

Learning to know	This type of learning concerns all the processes and practices that lead people to experience, construct and transform knowledge for making sustainability a mode of life and being.
Learning to be	This type of learning concerns all the processes and practices that lead to human self-actualisation, self-regulation and cultivating a sense of being versus having.
Learning to live together sustainably	This type of learning concerns all the processes and practices that lead to a peaceful and non-discriminatory society and human co-existence with the natural world.
Learning to do	This type of learning concerns all processes and practices that lead to merging knowledge with action for building a sustainable future.
Learning to transform oneself and society	This type of learning concerns all the processes and practices to transform their unsustainable values and behaviours and collectively engage to change society towards sustainability.
Learning to give	This type of learning promotes solidarity and caring attitudes to meet human needs as learners gain autonomy and purpose for their learning and civic engagement.

A conceptual framework of PBL based on the 10Cs and the 6 LPs

The proposed PBL framework consists of a number of key interacting processes (Fig. 3) which facilitate the theoretical and methodological clarification and understanding of the PBL as an instructional and curricular approach. Each interacting process integrates various skills drawn from the 10Cs (Fig. 4). Furthermore, it takes into consideration the contribution of the indented problem-solver and the potential impact that he/she brings to the outcome of problem solving process. It also gives primacy on a practical and critical reflective knowledge interest. The importance of the practical and critical reflective knowing is embedded in constructing knowledge and meaning merged with personal and social action. The processes represented into the two PBL models are re-conceptualised into a methodological framework depicted in Fig. 5. This framework functions as an organiser for designing, developing, applying and assessing a PBL approach contextualised in the area of education for sustainability. We expect that our approach provides a means towards building learning-based change that will ultimately contribute to building a more sustainable society.

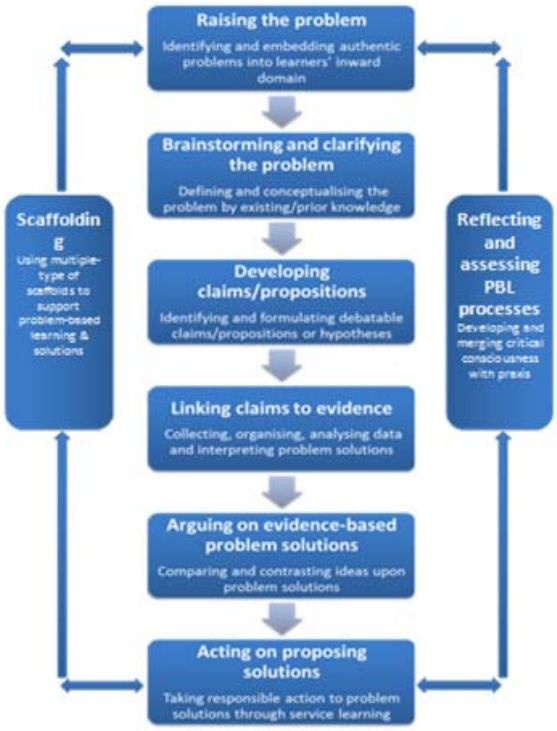

Figure 3. The key interacting processes of PBL

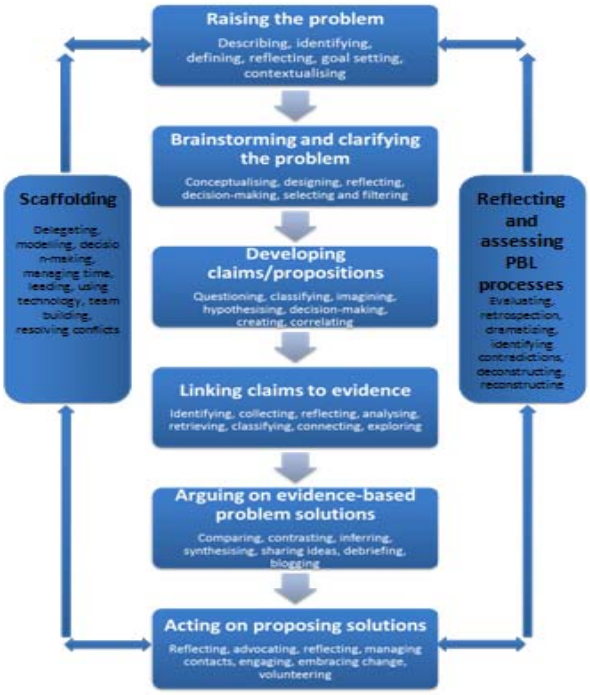

Figure 4. The key skills integrated into the PBL processes

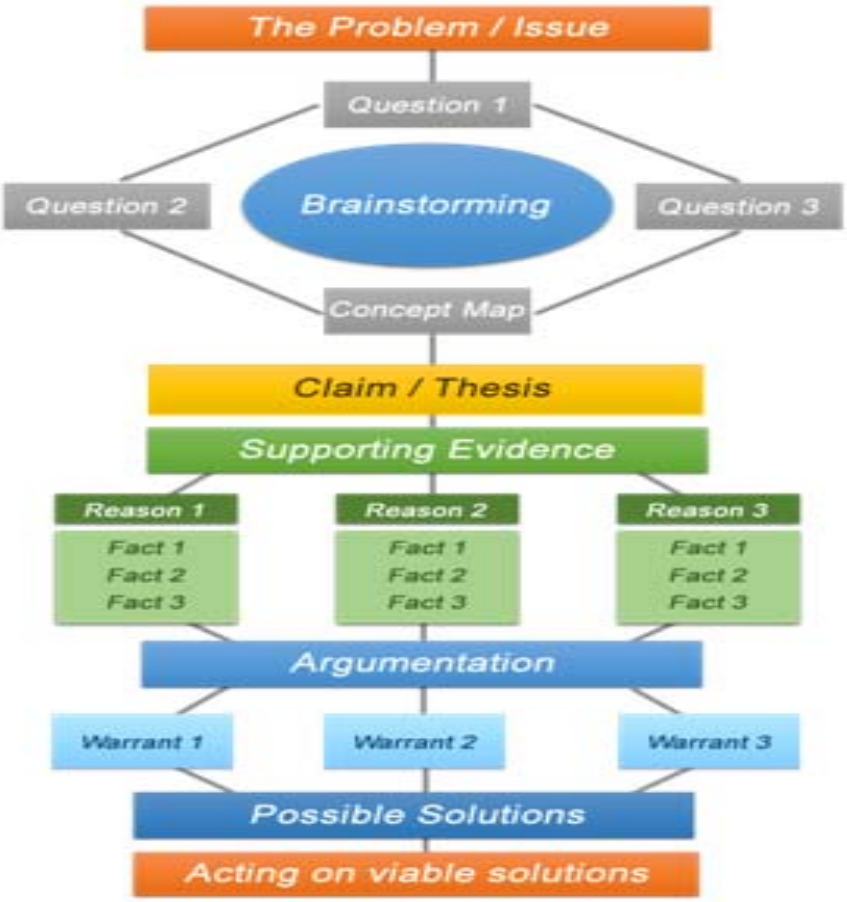

Figure 5. The PBL organising framework

Raising a problem

As the focus of the PBL process is on a problem containing motivating factors, the quality of the problem is of critical importance. Being able to raise good quality problems becomes a critical skill. A learning problem should not just be an objective issue that needs to be solved, but also an issue that is strongly embedded into learners' socio-pscyhological domain. The problem must be formulated in a way that motivates and challenges the learner to think and reflect as well as to provide opportunities to students to search and discover, build on their prior knowledge and promote transfer of what they have learned to other contexts.

Brainstorming about the problem issue

Brainstorming is a creative thinking process best used in groups and led by a teacher who acts as a facilitator to help learners generate ideas, access prior knowledge, construct and reconstruct knowledge and take action for tackling the problem studied. Through the brainstorming process, learners also start defining learning objectives by means of identifying what they actually know about the problem scenario and what they presumably need to know to formulate claims, link claims with evidence and develop effective argumentation on proposing solutions.

Developing claims/propositions

During this process, problem solvers elaborate the initial state of the problem and identify debatable claims. A claim or thesis/proposition is an expected opinion that conveys the problem solver's interpretations of or beliefs related to the problem. Claims are not facts but rather conclusions that the problem solver draws from facts. In other words, a claim is characterized by its controversiality and challenge. If a claim conveys something that is generally agreed upon or accepted as fact, then there is no reason to try to persuade people. This implies that a claim should be disputable and confront others, often, opposing points of view, which can be expressed as a counterclaim. In general, claims typically fall into one of four categories: 1) factual claims; 2) cause and effect claims**;** 3) value-laden claims and 4) policy claims (e.g. Weida & Stolley, 2014). The type of claim chosen will depend on the nature of the problem and its context, the learner's knowledge on the problem issue and his/her standpoint to the various interpretations related to the problem. The characteristics of the audience that problem solutions will be addressed to are also important to elicit. However, regardless of the type of claim chosen, it is of particular importance to identify the controversy or debate that is raised by those dealing with problem issue. This can be revealed through the different standpoints or positions adopted by the learners or raised by the learner alone, as a counterclaim to his/her own position.

Linking claims to evidence

As pointed earlier, claims challenge the beliefs or opinions of others, thus, they have to be linked to supportive evidence, which is consisted of objectified facts, but also beliefs, statements and assumptions that are socially constructed. In this process learners decide about what data and information is needed to support, modify or even reject their initial claims. The amount of evidence needed depends on the claim. Usually, there are two types of evidence based on the source: 1) primary source evidence and 2) secondary source evidence. The first type may include data collection techniques, such as: interviews, experiments, surveys, or personal experience, while the second type of data collection may include books, periodicals and websites.

Arguing on evidence-based problem solutions

It is not enough to link claims with facts, it is also essential to develop sound and persuasive argumentation on the claims grounded on evidence and supportive facts or conjectures (Jonassen, 1997). This is, in fact, the PBL process that synthesizes all the previous ones. In particular, it encourages learners to further explore and integrate knowledge and artifacts gathered through the previous problem-solving processes into their cognitive structures.

Evidence-based arguments are discussions that present and provide support for claims with evidence and premises (Eemeren & Grootendorst, 2004). Being able to produce convincing (i.e., logical and evidence-based) arguments is central to solving ill-structured problems (Cho & Jonassen, 2002). In the PBL argumentation process, learners can visualise how things should be and think of or what actions should be advanced and be committed to realize sustainable futures. This entails a futures dimension in the PBL process that is often neglected.

There are three major elements to persuasive argumentation: claims, evidence and warrants. Based on Toulmin model for analysing arguments (cited in Hitchcock & Verheij, 2006), warrant is the logical connection between a claim and a supporting fact. Sometimes, the logical connection, the way in which a fact logically supports a claim, might be obvious. However, more often, there is need to explain how and why a particular piece of evidence is good support for a specific claim. In this case a warrant is needed that will provide an underlying assumption that clarifies the evidence that supports the claim. Effective and persuasive argumentation emphasizes logic and reason, which provide a rational link between the evidence and the claim. However, there is often a place for emotion as well. Emotional appeals can use subjective or inter-subjective sources such as interviews and individual stories that could illuminate objectified evidence or provide a more legitimate picture of reality. For example, presenting a video that shows an individual story of a heavy smoker who died from lung cancer because of smoking may lead to a more persuasive argument than simply showing the percentage of deaths caused by smoking each year. Such examples could not only enrich persuasive argumentation, but possibly empower people towards direct action.

Acting on proposing solutions

As it has been pointed out in the introduction, one of the key attributes of PBL, that has been misunderstood or ignored, is action competence (cf. Mogensen & Schnack, 2010). This brings to the issue of turning problem solver's acquired and constructed knowledge, meaning, understandings and concerns into responsible action. There is thus need to merge knowledge with action and construct ways of thinking and acting that have an emancipatory knowledge interest. To this end, young learners should be encouraged to develop the capacity to envision sustainable futures, to think critically and reflectively of current unsustainable practices, to plan and evaluate alternative courses of actions, and to transform their attitudes, knowledge and concerns into individual and collective action for building a sustainable society. There is, thus, need to empower young learners to be seen as a resource in their communities with the potential to act as catalysts for and agents of change (Holden et al., 2004; Wallerstein et al., 2005).

Scaffolding

Scaffolding is generally regarded as support for learners while they are engaged in activities just beyond their own capabilities. As learners become more autonomous, scaffolding is gradually withdrawing. Scaffolds may take many forms to guide students through the PBL task. Saye and Brush (2002) identified two types of scaffolds to illustrate the important role of the teacher in guiding students to solve ill-structured problems: (a) hard scaffolds and (b) soft scaffolds. Hard scaffolds refers to "static supports that can be anticipated and planned in advance based on typical student difficulties with a task" (p. 81). This type of scaffolds could be referred to conceptual, metacognitive, or strategic hard scaffolds (Hannafin, Land,

& Oliver, 1999; Ge & Land 2004). Hard scaffolds (computer or paper-based cognitive tools) can serve the same scaffolding roles as soft scaffolds (Simons et al. 2004) and are meant to augment, not replace, soft scaffolding (Saye & Brush, 2002). Examples of hard scaffolds include expert modelling, question prompts, computer-based tools, concept mapping etc. In contrast, soft scaffolds include human beings, such as teachers, students or adults, who can provide dynamic and situational support. Vygotsky's (1978) notion of the "zone of proximal development" has been used traditionally to characterize scaffolding.

Reflecting and assessing PBL processes

Reflecting and assessing activities in authentic and ill-structured problem solving are important constituents of the PBL process. Giving students the opportunity to reflect on their own learning is a key element in PBL. Student reflections should be more than just commentary on what the students have done--they should used by students to highlight what they have learned, explain important decisions they have made, and articulate plans for incorporating feedback and moving forward. Traditional assessment techniques such as multiple-choice and true-false examinations do little to truly assess a student's understanding and far-transfer of the PBL learning experience. The PBL framework advanced here emphasizes that assessments should be a continuous and integral part of the learning process and not be viewed as a compartmentalized activity. Whatever assessment technique is used, it must be viewed by students as an active part of the learning process, not some ancillary activity. The learning principle emphasizes that assessments should continue the learning process and not be viewed as a disjoint activity.

Concluding remarks

As pointed in the introduction, there was need of an instructional design framework that helps teachers better understand the theory and methodology of PBL and enable them to adapt it as needed for their own teaching and learning environments. In such kind of learning environment, learners tackle authentic problems, develop debatable claims and linked them with supportive evidence, interacting with a wide variety of learning resources, and develop argument-based solutions to those problems. Further, they develop action competence as a means for engaging learners in problem solving and provide with a framework that enables learners to take individual or collective action to the proposed solutions.

Accordingly, PBL as a critical, reflective and transformative approach to teaching, learning and curriculum envisions learners as active participants both in the learning process and in the construction of social reality. Dealing with problems of environmental and social concern, the emphasis is placed on developing learners' action competence to participate actively in the PBL produced solutions. There is need to help learners realize that it is critical to their lives to be self-reflective and critical, be able to question their own and others' beliefs, the knowledge presented to them as an "objective reality", as well as societal structures and conditions. In other words, PBL entails developing young learners as critical thinkers and active citizens. Critical and reflective active citizenship is inextricably bounded to transformative learning and learning-based change in a non-prescribing and deterministic manner. On the one side, it points towards changes of the "inner" dimensions, such as unsustainable attitudes and values maintained by the person (personal level). On the other side, it points towards changes of the "outer" dimensions, such as existing social,

political and economic structures (societal level) that reproduce unsustainable attitudes and values. Both levels are necessary in order to turn constructed meaning and knowledge into meaningful action geared towards building more sustainable ways of thinking, behaving and living.

References

American Management Association. (2010). *Critical skills syrvey* Retrieved 13 April 2012 from http://www.amanet.org/organizations/2010-survey-critical-skills.aspx

AT21CS. (2012). *What are 21st-century skills?* Retrieved 8 November 2012, from http://atc21s.org/index.php/about/what-are-21st-century-skills/

Cho, K.-L. & Jonassen, D.H. (2002). The effects of argumentation scaffolds on argumentation and problem solving. *Educational Technology Research and Development* 50(3), 5–22.

Delors, J. et al. (1996). *Learning: The Treasure Within*. Paris: UNESCO.

Freire, P. (2000). *Pedagogy of the oppressed*. New York: Continuum International Publishing Group, Inc.

Ge, X. & Land, S.M. (2004). A conceptual framework for scaffolding ill-structured problem solving processes using question prompts and peer-interaction. *Educational Technology Research and Development*, 52 (2), 5-22.

Eemeren, F.H., von & Grootendorst, R. (2004). *A systematic theory of argumentation. The pragma-dialectic approach*. London: Cambridge University Press.

Hannafin, M., Land, S. & Oliver, K. (1999). Open learning environments: Foundations, methods, and models. In C. Reigeluth, (ed.), *Instructional Design Theories and Models*, (Vol. II pp. 115–140). Mahway, NJ: Erlbaum.

Hitchcock, D. and Verheij, B. (2006) (eds.) *Arguing on the Toulmin Model. New essays in argument analysis and evaluation*. Dordrecht: Springer.

Holden, D. J., Messeri, P., Evans, W. D., Crankshaw, E., & Ben-Davies, M. (2004).Conceptualizing youth empowerment within tobacco control. *Health Education & Behavior*, 31(5), 548-563.

Jonassen, D. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development*, 45(1), 65–94.

Makrakis, V. (2010). The Challenge of WikiQESD as an Environment for Constructing Knowledge in Teaching and Learning for Sustainable Development. *Discourse and Communication for Sustainable Education*, 1(1), 50-57.

Makrakis, V. (2012). Reorient Teacher Education to address Sustainable Development Issues through the WikiQuESD. In A. Jimoyiannis (ed.), *Research on e-Learning and ICT in Education* (pp. 83-94). London: Springer.

Makrakis, V. and Kostoulas-Makrakis, N. (2013) Sustainability in higher education: a comparative study between European Union and Middle Eastern universities. *International Journal of Sustainable Human Development*, 1(1), 31-38.

Mayo, J. (2012). Technology's role in constructing meaningful knowledge. *Pedagogy and the Human Sciences,* 1,(2), 8-21.

Mezirow, J. (2003) Transformative learning as a discourse. *Journal of Transformative Education* 1(1), 58–63.

Mogensen, F. & Schnack, K. (2010). The action competence approach and the 'new' discourses of education for sustainable development, competence and quality criteria. *Environmental Education Research*, 16 (1), 59-74.

Partnership for 21st Century Skills. (2012) Retrieved 13 April, 2012, from http://www.p21.org/index.php

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. Interdisciplinary *Journal of Problem-based Learning,* 1(1). Available at: http://dx.doi.org/10.7771/1541-5015.1002

Saye, J.W. & Brush, T. (2002). Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development* 50(3), 77–96.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York: Cambridge University Press.

Siemens, G. (2004). *Connectivism. A learning theory for the digital age*. Retrieved 4 July 2014 from http://www.elearnspace.org/Articles/connectivism.htm

Siemens, G. (2006). *Learning theory or pastime for the self-amused?* Retrieved 4 July 2014 from http://www.elearnspace.org/Articles/connectivism_self-amused.htm

Siemens, G. (2008). *What is the unique idea in connectivism*. Retrieved 4 July 2014 from http://www.connectivism.ca/?p=116

Simons, K. D., Klein, J. D. & Brush, T. R. (2004). Instructional strategies utilized during the implementation of a hypermedia, problem-based learning environment: A case study. *Journal of Interactive Learning Research*, 15, 213-233.

Stanlick, S. (2014). *"Leveraging technology for critical reflection and service learning"*. Retrieved 4 July 2014 from http://www.elon.edu/docs/eweb/org/nccc/Leveraging%20Technology.pdf

Strampel, K. & Oliver, R. (2007). Using technology to foster reflection in higher education. In *Proceedings ascilite Singapore 2007 "ICT: Providing choices for learners and learning"*. Retrieved 4 July 2014 from http://www.ascilite.org.au/conferences/singapore07/procs/strampel.pdf

Vygotsky, L.S. (1978). *Mind in Society*. Cambridge, MA: Harvard University Press.

Wallerstein, N., Duran, B., Minkler, M. & Foley, K. (2005). Developing and maintaining partnerships with communities. In B. Israel, E. Eng, A. Schulz, & E. Parker (eds.), *Methods in community based participatory research methods* (pp. 31-51). San Francisco: Jossey-Bass.

Weida, S.. & Stolley, K. (2014). "Developing strong thesis statements". Purdue OWL resources. Retrieved 4 July 2014 from https://owl.english.purdue.edu/owl/owlprint/588/

Yang, S.-H. (2009). Using blogs to enhance critical reflection and community of practice. *Educational Technology & Society*, 12 (2), 11–21