

Transdisciplinarity Action Research workshop for sustainable technology communities

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Abstract

The Research Institute for Sustainability Science and Technology under the Master degree in Sustainability Science and Technology organises the course Action Research Workshop on Science and Technology for Sustainability (5 ECTS). The authors have been coordinating the course during the academic years 13/14, 14/15 and 15/16. The purpose of the workshop is to put together civil society organisations, local administrations, students and educators to collaboratively undertake responsible research, using transdisciplinary Action-Research methodologies, to answer questions such as: Who are we researching for? Who profits from our research? What are the impacts of our research? Which methodologies and tools should be used? While dealing with socio-technological sustainability challenges.

Students work on real projects, related to local sustainability problems, represented by a community entity (Service learning and Campus Lab). Action research methodology is used with a two-cycle approach. In each real-life project, students, faculty and stakeholders are asked to follow the Action-Reflexion process of action research projects.

After three editions, we can conclude that: First, students realized the significance of framing an investigation under a research methodology that allows bringing research to the community, enhancing transdisciplinarity in any initiative or action. They set out the importance of some topics and the difficulty to hold them. Second, the formulation of the problem became one of the most arduous tasks in the process; difficulties were mainly related to the perception of the problem from distinct community group motivations. Third, interaction and communication with stakeholders and the recognition of their role was problematic because, usually, engineering students are not train to work in wicked problems and to work with stakeholders during the whole process. Finally, it is relevant to highlight that during the process students faced conflict and frustration situations, within their team and with stakeholders. To face that, an Emotional Intelligence module was introduced in the workshop and helped students to solve some paralyzing situations, which could have stopped the progress of the project. Hence, we suggest that engineering students need specific training in transdisciplinary research and conflict resolution, otherwise they could collapse in frustration when dealing with real transdisciplinary sustainability transitions.

1 Introduction

Sustainability issues are widely recognized as wicked problems (Yearworth, 2016), which should not be considered as problems to be solved, but as conditions to be governed. There is a general agreement on the need to reform scientific expertise, as it is required to deal with sustainability challenges, by developing new ways of knowledge production and decision-making. In that sense, Stephen Sterling

(2005) maintains that the nature of sustainability requires a fundamental change of epistemology, and therefore, of education. In relation to technological education, the Barcelona Declaration (2004) approved during the Engineering Education in Sustainable Development conference in 2004 declares the competences that engineers may have when graduating related to sustainability.

The Universitat Politècnica de Catalunya (UPC Barcelona Tech), aware of the new competences that engineers should have, offers a master degree in Sustainability Science and Technology. Within the Master, there is the course *Action Research Workshop on Sustainability Science and Technologies*. Next sections explain the learning environment and the challenges and lessons learnt when organizing such a course, as well as the learning results obtained by students.

2 Action Research Workshop on Sustainability Science and Technologies Course

The Action Research Workshop on Sustainability Science and Technologies is a course within the Master of Sustainability Science and Technology offered by Barcelona Tech University. It is a 5 ECTS (European Credit transfer System) course, which uses constructive and community oriented learning which has shown to be the most efficient way to train students in sustainability competences (Segalas, 2006; Segalas et al., 2010).

2.1 Goals and learning outcomes

The purpose of the workshop is to put together civil society organisations, local administrations, students and educators to collaboratively undertake responsible research, using transdisciplinary Action-Research methodologies, to answer questions such as: *Who are we researching for? Who profits from our research? What are the impacts of our research? Which methodologies and tools should be used?* While dealing with socio-technological sustainability challenges.

When finishing the course students should have the next competences.

- To know and understand the research paradigms (positivist, interpretive, critical theory and pragmatism) on which the research theories, methodology, and methods are based.
- To be able to choose the most suitable research paradigm to tackle a real sustainability challenge.
- To be able to work in transdisciplinary research settings.
- To know, understand and be able to apply the action research methodology and research tools (quantitative and qualitative) in real-life contexts.
- Understand how their work interacts with society and the environment, locally and globally, in order to identify potential challenges, risks and impacts
- To reflect in the results of the research process and the research process itself in order to understand the social dynamics that appear when applying action research in real sustainability challenges

2.2 Course organization

The course is organized around five areas (Fig. 1): Research paradigms, Action research methodologies, Dimensions of Action Research, Research tools and Reals projects.

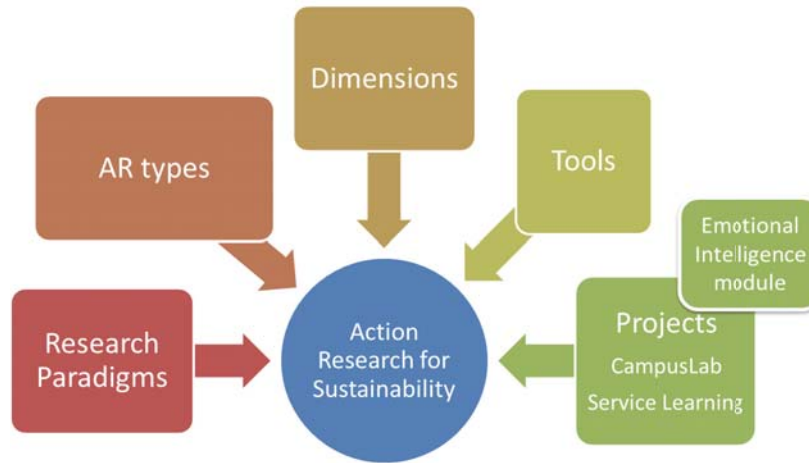


Figure 1: Workshop in Action Research structure

First students are faced with different research paradigms (Table 1) and its features in order to facilitate their reflection on the research that they should apply in their work as researchers. This is necessary because most of the students come from technological education holding a bachelor or master degree in engineering or architecture, and they usually only have been working with the positivist research paradigm which, when working with sustainability challenges with embedded social issues, is not usually the most appropriated (Martens, 2006).

Next, students are trained in Action Research methodologies. Starting with definitions (Wallace, 1987, Edwards & Talbot, 2014; Carr and Kemmis, 2009) and its main features (Whitehead & McNiff, 2002; Noffke, 2009) which can be sum up as:

- all the participants have something to contribute and to learn
- participants as co-researchers and co-learners, including the researcher
- knowledge and theory are inseparable from practice
- the main purpose is the improvement of a real situation or problem
- reflection and action are two core elements
- the whole learning-by-doing process is what counts

Once students are familiar with the main characteristics of action research, they learn about the main types of action research: i) Participatory action research (Baum et al., 2006); ii) Action learning (Revans, 2011; Kember, 2000); iii) Critical action research (Tripp, 1990) and iv) Collaborative inquiry (Coughlan and Coughlan, 2011). Students study their main features, pros and cons, methodological approaches and examples.

Table 1: Four scientific paradigms. (Sobh and Perry, 2005)

Element	Paradigm			
	Positivism	Constructivism	Critical theory	Realism
Ontology	Reality is real and apprehensible	Multiple local and specific “constructed” realities	“Virtual” reality shaped by social, economic, ethnic, political, cultural, and gender values, crystallised over time	Reality is “real” but only imperfectly and probabilistically apprehensible and so triangulation from many sources is required to try to know it
Epistemology	Findings true – researcher is objective by viewing reality through a “one-way mirror”	Crating finding – researcher is a “passionate participant” within the world being investigated	Value mediated findings – researcher is a “transformative intellectual” who changes the social world within which participants live	Findings probably true – researcher is value-aware and needs to triangulate any perceptions he or she is collecting
Common methodologies	Mostly concerns with a testing of theory. Thus mainly quantitative, methods such as: survey, experiments, and verification of hypotheses	In-depth unstructured interviews, participant observation, action research, and grounded theory research	Action research and participant observation	Mainly qualitative methods such as case studies and convergent interviews

Then, students are introduced to the three dimensions of action research (Noffke, 2009): Personal (practitioner as researcher and the process of self-reflection, planning and introducing changes to improve self-practice), professional (professional development purposes, to enhance profession) and political (generate democratic processes to empower groups lead to social change). These are overlapping and may be present in any action research study. These conceptualizations of action research allow students to position themselves as researchers when tackling a sustainability challenge in terms of research paradigm that may guide their inquiry, action research methodology that best fits the porpoise of their research and underlying assumptions on the dimensions of their research practice. Finally, students are trained in qualitative, quantitative and mixed research tools and methods typically used in action research: Conceptual maps, questionnaires, interviews, backcasting, complexity and network analysis, etc. At this point students are ready to apply the action research methodology (Fig. 2), following the action research loop of analysing-planning-acting-evaluating-reflecting in three cycles in order to frame the problem, intervene and evaluate the intervention.

They apply all their learning on Action Research in real sustainability projects under two active learning paradigms: Campus lab (Evans et al., 2015) and Service Learning (Sipos et al., 2008). Next section describes the projects that have been carried out during the three years of life of the course.

2.3 Three years of training

The course was born from convergence of two former courses: *Interdisciplinary workshop* and *Sustainable Technology Innovation (STI)* seminar, which used constructive and community oriented

learning. In the Interdisciplinary workshop, its relationship with "real-life projects" was identified as a very powerful aspect, but methodological basis was missing. Moreover, STI clearly showed its enormous potential to bring social needs to the world of ideas, beyond a learning space. STI had also a strong methodology aspect, appreciated by students. In this sense, both needs were clustered to perform a course that deepen into research methodologies, with a strong transdisciplinary approach, to work real-life projects, with a sustainability perspective.

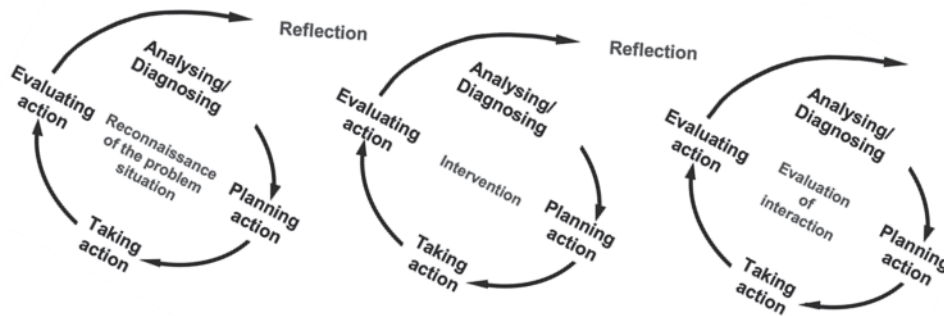


Figure 2: Action research cycles (Adapted from Coghlan and Brannick, 2014)

The course is organized around current sustainability relevant topics, broadly related to unsustainability aspects which are analysed in study real-life projects in local real situations, needs or challenges. Table 2 shows the topics for each course, organisations who lead their own real-life projects and the research question for each of them.

Organisations are called for collaboration and they bring their current demands to be developed jointly by teams of students, professionals, faculty and researchers. Participating organisations come from the UPC itself and from civil society and collaboration has been performed under Campus Lab and Service Learning respectively. The Campus Lab methodology is used because university as living labs can provide a potential holistic and iterative framework for the co-production of knowledge (Evans et al., 2015). Service learning is used as it is considered a strategy for action to achieve social transformation through education (Aramburuzabala, 2013). Real-life projects are constructed with the aim to both respond organisation requirements and enable students training and competence achievement.

Moreover, in order to increase transdisciplinary approaches we include in the course senior citizens through "Aprendre amb la Gent Gran (Learning with elderly)": a social program for the elderly, of the *Districte de Sarrià* (Barcelona). The aim of the program is to bring together and to establish linkages between all the stakeholders and seniors. During 6 to 8 sessions, the elderly worked together with students in the co-elaboration of academic works (surveys, reports, videos, diffusion pamphlets...). Students have learnt about personal strategies to address issues of awareness, (i.e. how to relate to groups that do have experiential knowledge, which may be far from a scientific-technical one); to listen at the experience of people and to have strategies to frame problems for people to understand, feel affected and own those "global" problems. Table 2 shows a characterization and the main features of the real-life projects. All the real-life projects has been guided by a research question, posed to pull the thread of the investigation and agreed by all the participants, which has been one of the most challenging stages in the Action Research process.

Table 2: Summary of the research projects process, research tools used and results

Topic	Stakeholder	Real-life projects	Research question	Research tools	Results
2014					
Sustainable clothing and slow fashion	Clean Clothes Campaign (SL)	Spanish fashion in Morocco	What a local clothing company can do to minimize labour exploitation risk, when pushed to find suppliers in Morocco?	Literature review, surveys	Backsting report
	Slow Fashion Spain (SL)	A local booming sustainable clothing market	What are the barriers and challenges faced by sustainable fashion initiatives in current markets?	Literature review, surveys	Backsting report
2015					
Energy poverty in Catalonia	Energy Bank Association (EB) - Municipalties	Detection of motivations to participate in the EB in Premià	What are the factors that influence the decision to join the driver group of EB?	Surveys, interview	Clusters analysis
	Premià/Sabadell (SL)	Phase 1 of implementation of the Energy Bank in Sabadell	What key factors that encouraged real participation in a local energy program can be used for EB?	Surveys,	Report on online poll
Energy inefficiency in public buildings-UPC	Office of Sustainability OGSIO- UPC Energy Optimisation Projects (EOP) (CLab)	Analysis of communication networks in the performance of EOPs structure	Does the current organizational structure of the EOPs, influence on the obtained results?	Surveys, interview	Report on Network Analysis
		Reporting server "orphan building" (*) energy consumption	What part of servers' consumption can be attributed to information management and which to use? How to reduce their energy consumption?	Surveys, interview	Report
2016					
Energy poverty in Catalonia	Energy Bank – Premià (SL)	Phase 2 of EB implementation in Premià: private sector	What affordable and sustainable offer could facilitate the private organizations involvement to the Energy Bank?	Focus groups	Strategy approach design
Gas Geopolitics	OdG- Debt Observatory in Globalization (SL)	MIDCAT, huge construction of a mega- pipeline for gas interconnection France-Spain	What is the capacity of this civil organized campaign facing to maximize transparency and public accountability?	Data analysis, surveys	Policy paper
		Gas imports of the Port of Barcelona	What is the city responsibility on the perpetuation of fuel energy model based on natural gas?	Data analysis, surveys	Policy paper
Communities for energy performance	UPC Energia 2020 (CLab)	Energy Hackathon design for developing sustainable energy projects at UPC	What kind of activity should be proposed to increase community participation in sustainable energy systems at campus?	Focus groups, interviews, pilot	Guide: 1 st UPC Energy Hackaton
UPC's water management teaching	EWB-Engineers Without Borders (SL)	What kind of water management is promoted at UPC?	Does UPC Water education and research respond to need of ensuring the human right to water?	Surveys, interview, network analysis	Mapping of relationships

(*) This "Orphan building" is where the UPC servers are located. High consumption of servers masks the efforts of energy saving, causing no one feels responsible for energy optimization

SL -Service Learning; CLab- Campus Lab

2.4 Course Assessment

The assessment in the course is design to evaluate, the learning of the students and the course itself.

At the end of the course, students have to deliver two reports. A first report where they analyse all the Action Research process that they have applied reflecting on: the research paradigms, Action Research types and its dimensions, research tools used, Action Research cycles applied and the results obtained. A second report is the result of their research to be delivered to the “client” (guide, policy paper, communication strategy, etc.). Those reports are shown in an oral defence to all the stakeholders and clients, student mates and faculty. Faculty assesses the Action Research report using a rubric (Craig, 2009), the rubric is also used by the students in the peer-assessment (Topping, 1998). Moreover stakeholders/clients evaluate the results provided by the students.

In order to evaluate the course, two explicit reflexive questions are asked to the students: *What have I learned in this course?* And, *What do I think about the course (structure, organization, timing, projects, etc.)?* The results of the students’ reflexions have been clustered in table 3.

Table 3: Reflections of students about their learning and the course

	Topic	Relevant comments from students
Learning	Research methodologies	<ul style="list-style-type: none"> • <i>Qualitative and Quantitative approaches are needed to see beyond the numbers.</i> • <i>I learned the relevance of qualitative aspects as we learned more from direct interaction with people than with quantitative data obtained by “R software”.</i> • <i>The management of relations with qualitative research, which is not usually taught in tech universities, have been very stimulating</i> • <i>Qualitative data from interviews is a very inspiring process</i>
	Stakeholders	<ul style="list-style-type: none"> • <i>I have learned the relevance of stakeholders and the role they play.</i> • <i>To realise that the different needs and concerns of stakeholders may shake the project process.</i>
	Transdisciplinarity	<ul style="list-style-type: none"> • <i>We learn to work with people from different disciplines and to improve our communication skills when working with professionals with different project management schemes</i> • <i>We learn to be more tolerant with our group mates that have different background and ways of working.</i> • <i>The most valuable point was the interaction with stakeholders from other disciplines, listening their points of view and experiences in the topic.</i>
Course	Real-life projects	<ul style="list-style-type: none"> • <i>To participate in a real project has been very interesting and being in touch with real stakeholders</i> • <i>I liked to work in real projects</i>
	Discussions in class	<ul style="list-style-type: none"> • <i>Which I liked the most was the organization and group work in class, allowing to listening and learning from each other</i>
	Low directedness	<ul style="list-style-type: none"> • <i>There were many expectations at the beginning from all stakeholders and we feel a bit lost</i> • <i>The goal of the research had to be defined between the stakeholders which delayed the project, and was time consuming</i> • <i>The planning was confused and it took time to our self-organization with the stakeholders</i> • <i>I think that this course give us too much freedom to make our choices, depending on the stakeholders and the goal were changing...</i>
	Comprehensive project	<ul style="list-style-type: none"> • <i>The course should be run at the first semester as a course that uses the knowledge of the other courses that we take simultaneously in a comprehensive real-live project.</i> • <i>It will be interesting to integrate more than one course in a project like this, so we will have more time to perform a better project.</i>

In relation to the learning process, most students appreciate: i. learning with mixed research methodologies and tools; ii. dealing with stakeholders' interest and their relevant role in sustainability challenges; iii. the need of Transdisciplinary approaches; and iv. teambuilding. In relation to the course, they appreciate: i. the real-life projects both Service learning and Campus Lab with real stakeholders/clients; ii. the group work sessions in the classroom with interesting discussions and reflexions on the project process. The main criticisms were related to the low degree of directedness at the beginning that for some was very frustrating, (the low directedness was deliberate in order to train students in dealing with stakeholders' different interests in real settings). Due to the frustration among students, the course coordinators introduced an emotional intelligence workshop in the course (see next section). Another issue for improvement is that students feel overwhelmed with project work as this course is run simultaneously with other 6 courses and most of them have project work. Students suggested that there should be a comprehensive project for the whole semester where each course can contribute from its theme. This suggestion is taken seriously by the master coordination unit and we are now redefining the master structure.

2.5 Emotional Intelligence module

As commented before students longed for some capacity to bring back the “energy of frustration” related to the project uncertainty and to be able to give a positive approach to obtain a final result, “having patience” to develop and obtain results. At the same time they claimed for strengthening the group's relationship as necessary to feel comfortable in a work dynamics which demands more participation, better communication and somehow to get out of the self comfort zone. Students realized that as professionals they should face situations in which have to: manage emotions; solve unexpected situations; solve frustrating situations in the workplace; and of course, manage teams. We decided to offer a different approach to their understanding, posing that many times this kind of situations may be approached by means of generating situations of empathy to ensure that participants can relax and create new common codes. The module aims to allow students obtaining some experiential knowledge related to emotional intelligence and what are the related competences. These interpersonal competences, related to emotional intelligence are rarely included in curricula, although they have been widely studied and claimed (previous works: Kunnanatt, 2004; Barth et al., 2014; Dlouha and Burandt, 2015). Regarding the structure of the module (session of 2,5h), it starts with a framing theoretical introduction about emotional intelligence (see Gardner, 2001; Bisquerra, 2007), multiple intelligences theory (Mayer & Salovey, 1997; Goleman, 1996) and related competences, always in the framework of sustainability (Lambrechts et al., 2013; Wiek, 2011). Then students experience some dynamics of therapeutic theatre. The module follows the thread of the 5 domains of emotional competence: *emotional awareness, emotional regulation, emotional autonomy, social competence, skills for life and well-being*, proposed by GROU¹. After an initial group distension dynamic, the module is conducted, through dramatized exercises.

Participants recognize in an experiential way what are the emotions involved in each of the domains of emotional intelligence, self-competence in all of them and, also, how emotions can be perceived, expressed, understood, regulated and facilitated. Furthermore, one of the students contributed as reflection that “*I considered as an great enjoyment not only to find out how a group dynamic is working, also to see himself acting as an individual integrated in a wider sense, but also to learn about its own consciousness and capacity of nonverbal communication and awareness*”.

¹ GROU: Psychopedagogical Counseling Research Group. MIDE, Faculty of Education. University of Barcelona. <http://www.ub.edu/grou/>

3 Conclusions

After the three editions, we can conclude that: First, students realized the significance of framing an investigation under a research methodology that allows bringing research to the community, enhancing transdisciplinarity in any initiative or action. They set out the importance of some topics and the difficulty to hold them. Second, the formulation of the problem became one of the most arduous tasks in the process; difficulties were mainly related to the perception of the problem from distinct community group motivations. Third, interaction and communication with stakeholders and the recognition of their role was problematic because, usually, engineering students are not trained to work in wicked problems and to work with stakeholders during the whole process. Finally, it is relevant to highlight that during the process students faced conflict and frustration situations, within their team and with stakeholders. To face that, an Emotional Intelligence module was introduced in the workshop and helped students to solve some paralyzing situations, which could have stopped the progress of the project. Therefore we suggest that engineering students need specific training in transdisciplinary research and conflict resolution, otherwise they could collapse in frustration when dealing with real transdisciplinary sustainability transitions.

The participation of the senior learning program *Aprender amb la Gent Gran*, has provided a perspective of intergenerational and interpersonal skills, and the relationship with the elderly has provided values and communication and interpersonal skills to students.

References

- Aramburuzabala, P. (2013). Aprendizaje-Servicio: Una herramienta para educar desde y para la justicia social. *Revista Internacional de Educación para la Justicia Social (RIEJS)*, 2(2), 5-11.
- Barcelona Declaration. (2004). Engineering education in Sustainable Development Conference Barcelona.
- Barth, M., Adomßent, M., Fischer, D., Richter, S., & Rieckmann, M. (2014). Learning to change universities from within: A service-learning perspective on promoting sustainable consumption in higher education. *Journal of Cleaner Production*, 62, 72–81.
- Baum, F., MacDougall, C., & Smith, D. (2006). Participatory action research. *Journal of epidemiology and community health*, 60(10), 854-857.
- Bisquerra, R., y Pérez, N. (2007). Las competencias emocionales. *Educación XXI*, 10, 61-82
- Carr, W., & Kemmis, S. (2009). Educational action research: A critical approach. *The Sage handbook of educational action research*, 74-84.
- Coghlan, D., & Brannick, T. (2014). *Doing action research in your own organization*. Sage.
- Coughlan, P., & Coghlan, D. (2011). *Collaborative strategic improvement through network action learning: The path to sustainability*. Edward Elgar Publishing.
- Craig, D. V. (2009). *Action research essentials (Vol. 11)*. John Wiley & Sons
- Dlouhá, J., Burandt, S. (2014). Design and evaluation of learning processes in an international sustainability oriented study programme. In search of a new educational quality and assessment method. *Journal of Cleaner Production*, 106, 247-258

- Edwards, A., & Talbot, R. (2014). *The hard-pressed researcher: a research handbook for the caring professions*. Routledge.
- Evans, J., Jones, R., Karvonen, A., Millard, L., & Wendler, J. (2015). Living labs and co-production: university campuses as platforms for sustainability science. *Current Opinion in Environmental Sustainability*, 16, 1-6.
- Gardner, H. (2001): *La inteligencia reformulada*. Barcelona, Paidós.
- Goleman, D. (1996): *Inteligencia emocional*. Barcelona, Kairós.
- Kember, D. (2000). *Action learning and action research: Improving the quality of teaching and learning*. Psychology Press.
- Kemmis, S. (1985). Action Research and the politics of reflection. *Reflection: Turning experience into learning*, 139-163.
- Kunnanatt, J. T. (2004). Emotional intelligence: The new science of interpersonal effectiveness. *human resource development quarterly*, 15(4), 489-495.
- Lambrechts, W., Mulà, I., Ceulemans, K., Molderez, I., & Gaeremynck, V. (2012). The integration of competences for sustainable development in higher education: an analysis of bachelor programs in management. *Journal of Cleaner Production*, 48(6), 65-73.
- Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., et al. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science*, 7(S1), 25-43.
- Martens, P. (2006). Sustainability: science or fiction? *Science, Practice, & Policy*. 2(1), 36-41.
- Mayer, J. D. & Salovey, P. (1997). What is emotional intelligence? In P. Salovey & D. Sluyter (Eds). *Emotional development and emotional intelligence: Implications for educators* (3-31). New York: Basic Books.
- Noffke, S. E., & Somekh, B. (Eds.). (2009). *The Sage handbook of educational action research*. Sage.
- Noffke, S.E. (2009). Revisiting the Professional, Personal, and Political Dimensions of Action Research. In Noffke, S. E., & Somekh, B. (Eds.). *The Sage handbook of educational action research*. Sage, 6-30.
- Revans, R. W. (2011). *ABC of action learning*. Gower Publishing, Ltd..
- Segalas, J.; Mulder, K.; Ferrer-Balas, D. (2006). Embedding sustainability in engineering education. Experiences from Dutch and Spanish Technological universities. Conference: *Higher Education for Sustainable Development: New Challenges from a Global Perspective*. Luneburg.
- Segalas, J.; Mulder, K.F.; Ferrer-Balas, D. (2010). What do engineering students learn in sustainability courses? The effect of the pedagogical approach. *Journal of Cleaner Production*, 18(3), 275-284
- Sipos, Y., Battisti, B., & Grimm, K. (2008). Achieving transformative sustainability learning: engaging head, hands and heart. *International Journal of Sustainability in Higher Education*, 9(1), 68-86.

Sobh, R.; Perry, C. (2005). Research Design and data analysis in realism research. *European Journal of Marketing*, 40(11/12), 1194-1209.

Sterling, S. (2005). "Higher education, sustainability, and the role of systemic learning", in Corcoran, P.B., Wals, A.E.J. (Eds), *Higher Education and the Challenge of Sustainability: Problematics, Promise and Practice*, Kluwer, Boston, MA, 49-70.

The WorldWatch Institute (2012). *State of the world 2012. Moving Toward Sustainable Prosperity*.

Topping, K. (1998). Peer assessment between students in colleges and universities. *Review of educational Research*, 68(3), 249-276

Tripp, D. H. (1990). Socially critical action research. *Theory into practice*, 29(3), 158-166.

Wallace, M. (1987). A historical review of action research: some implications for the education of teachers in their managerial role. *Journal of Education for Teaching*, 13(2), 97-115.

Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustainability Science*, 6(2), 203–218.

Whitehead, J., & McNiff, J. (2002). *Action research. Principles and Practice*. London: Routledge Falmer. McNiff, Jean. &

Yearworth, M. (2016). Sustainability as a ‘super-wicked’ problem; opportunities and limits for engineering methodology. *Intelligent Buildings International*, 8(1), 37-47.