# Chapter 29
# Problem-Based and Project-Based Learning for Sustainable Development

**Ron Cörvers, Arnim Wiek, Joop de Kraker, Daniel J. Lang, and Pim Martens**

**Abstract** Universities hold a crucial responsibility and role to contribute to sustainable development, also in their education task. The concept of competencies for sustainable development and the idea of using real-world sustainability issues in education are promising approaches to transform sustainability programmes at universities into student-centred learning environments. Especially the educational formats of problem-based learning and project-based learning foster such a process of educational innovation towards student-centred learning. Moreover, hybrid forms of problem-based and project-based learning offer added value, but challenges for PPBL courses in sustainability remain salient.

**Keywords** Competencies • Real-world problems • Student-centred learning • Problem-based and project-based learning

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## 1 Introduction

Given the educational and research capacity, the external partnerships, and the position of higher education as an influential voice in society, there is ample opportunity for universities to help shift societal norms, practices, products, and services towards sustainability (Cortese 2003; Rowe 2007). Universities therefore hold a crucial responsibility and role to contribute to sustainable development within their scope of Community engagement, Operations, Research, and Education; the so-called CORE activities (Jenssen 2012). However, in practice only few universities excel in meeting this challenge as most universities lack a systematic approach to implement sustainability in their CORE activities (Ferrer-Balas et al. 2008; Jenssen 2012; Lang and Wiek 2012). Right now, sustainability is treated by many as an add-on, as another item on an already full plate.

In this chapter we focus on the *education* task of universities. In particular, we discuss the concept of competencies for sustainable development and the idea of using real-world sustainability issues to transform sustainability study programmes at universities into student-centred learning environments. The educational formats of problem-based learning and project-based learning foster such a process of educational innovation by viewing learning as a student-centred, experiential, interactive, situated, and social process, instead of a unilateral process in which the teacher imparts knowledge on the students.

## 2 Competencies in Sustainability

Given the challenges of sustainable development and the need for policy and behavioural change, Rowe (2007) and others argue that universities need to reconsider the competencies students are expected to acquire. The emphasis needs to shift from descriptive-analytical knowledge, logical reasoning, and critical thinking alone to the inclusion of normative competence and effective change-agent skills. This implies a re-emphasis on the role of universities in not only educating academics and professionals, but in educating responsible citizens and decision makers. And even the profile of academics needs to get revisited and revised. For moving forward to a sustainable world, Martens and Rotmans (2012) argue that it is time for many (more) scientists to become 'scientivists' (scientists-activists): individuals and groups that are engaged in systematic knowledge acquisition and generation (the scientist part), as well as in promoting and directing societal change (the activist part). See Box 29.1 on the roles of sustainability experts (academics and professionals).

- *Task*: Give pros and cons for the statement that sustainability scientists should be 'scientivists'. In your answer you should also reflect on the variety of roles sustainability experts can fulfil in modern society amidst other actors such as representatives from the government, business community, non-governmental organisations, and citizens.

**Box 29.1: Roles of Sustainability Experts**

Sustainability experts (academics and professionals) work at the interface between science, policy, and society when helping to solve problems of sustainable development. However, the roles they perform differ depending on the nature of the problem and the type of knowledge needed to solve it, as well as on the institutional setting of their work and their personal and professional values. The latter implies that, to some extent, it is up to the individual professional to choose a role. Despite the variety of roles, certain patterns can be distinguished. Here we present five different roles of sustainability experts:

1. The pure scientist, who restricts himself to explaining the state of affairs. The pure scientist delivers the facts, but does not interpret them in the light of a policy question.
2. The arbiter, who tries to provide the best available knowledge to answer policy questions, with the aim to inform, not to advise. Arbiters typically communicate their expertise in the form of 'if-then' statements.
3. The advocate, who uses knowledge to argue for a specific course of action. The advocate goes a step further than the arbiter and adopts a normative position.
4. The broker, who attempts to open up decision-making processes by exploring multiple perspectives and alternatives and by integrating stakeholders' concerns with available knowledge. However, the broker takes the primacy of scientific knowledge over other types of knowledge for granted and maintains a distinction between knowledge and action.
5. The participatory expert, who engages in participatory knowledge production in which the distinction between knowledge and action and between scientific and lay knowledge is blurred.

In principle, each of these roles can contribute effectively to addressing sustainability issues, depending on the factors mentioned above.

Source: Broekhans and Turnhout (2012) and Pielke (2007)

The majority of graduates will not work as academics, but will be employed in government, business, or civil society and will have to deal with diverse challenges in pursuit of sustainable development. If universities want to prepare students to contribute to sustainable development in their working life, the key question is: What competencies are critical to acquire for the upcoming sustainability professionals?

There is a growing body of literature on *competencies* for sustainable development, but most proposals are lists of isolated competencies, instead of integrated frameworks (Wiek et al. 2011a). To overcome this gap, Wiek et al. (2011a) reviewed the literature and synthesised a framework of key competences in sustainability (Fig. 29.1). Competence is defined as 'a functionally linked complex of knowledge,

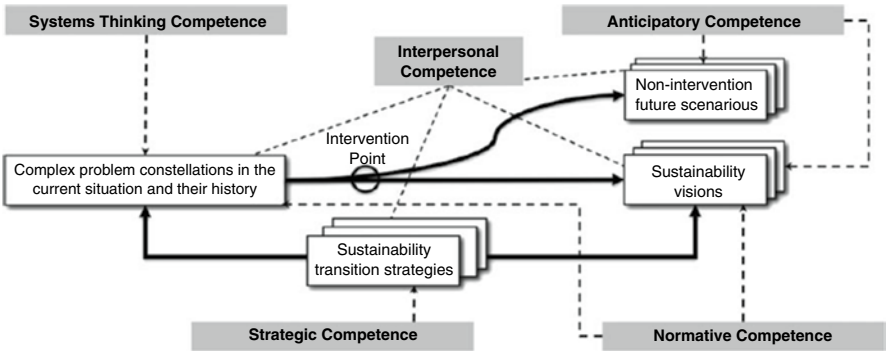


**Fig. 29.1** The interplay of five key competencies for sustainability research and problem-solving (Wiek et al. 2011a)

skills, and attitudes that enable successful task performance and problem solving' (p. 204). The overarching sustainability competence is being able *to mitigate and solve sustainability problems* (*through transformational research or professional practices*). Five key competencies are required to get integrated:

- *Systems-thinking competence*: being able to understand structure and dynamics of complex system
- *Anticipatory competence*: being able to anticipate possible and/or sustainable futures
- *Normative competence*: being able to differentiate, justify, and apply values and goals for sustainability
- *Strategic competence*: being able to create transition and intervention strategies to enact change
- *Interpersonal competence*: having communicative and collaborative skills

The interplay of the five key competencies in sustainability enables graduates and professionals to mitigate and solve sustainability problems (in research and professional practices).

Other studies largely align or support the concept proposed by Wiek et al. (2011a). The International Society of Sustainability Professionals (ISSP) surveyed about 400 sustainability professionals (mainly sustainability consultants and managers working for or in corporations) to find out what they believe are important competencies for their jobs (Willard et al. 2010). The results indicate that sustainability professionals mainly promote the value of sustainability concepts and deal with climate change and energy issues. Top skills were considered to have good skills for communicating with internal and external stakeholders and to be able to inspire and motivate others (interpersonal competence). Additional skills considered important are strategic planning, systems thinking, and project management. A study by the Institute of Environmental Management & Assessment (IEMA) suggests that *leadership (for change)* is a key competence for working in environmental or sustainability professions (IEMA 2011).

In summary, we see emerging agreement on key competencies of sustainability that bridges the often existing gap between sustainability education and professional practice. A key factor is that mitigating and solving complex sustainability problems becomes the common goal across the community of sustainability academics, students, and professionals.

- *Task*: In the discussion on competencies for sustainable development, interpersonal competence plays an important role (e.g. leadership, good communication, strong teamwork, effective networking). To what extent do you think that this competence can be acquired through formal training, and how much is 'natural talent'? Justify and illustrate your answer.

## 3 Problems and Projects: Learning through Real-World Sustainability Issues

As indicated in the previous section, the complexity of sustainability challenges asks for experts (academics and professionals) who are able to 'cross borders': to work with colleagues from different backgrounds, to judge the value of different types of knowledge, to participate in multi-stakeholder processes, to analyse a problem from a systemic perspective, to envision sustainable future states, and to generate evidence-based solution options (De Kraker et al. 2007; Wiek et al. 2011b). The development of such competencies requires learning environments that combine actual practice ('learning by doing') and explicit reflection on what and how to learn from that practice ('learning by reflection').

To meet these challenges De Kraker et al. (2007), Rowe (2007), Brundiers et al. (2010), and others propose to address *real-world sustainability issues* in different educational settings. In this way, it might be possible to develop and renew sustainability education at universities in a fundamental way, 'from the outside in'.

Recent literature suggests that a *student-centred learning* strategy is a powerful setting to building students' competencies and that it should be based on four learning principles (Dolmans and Schmidt 2010):

– *Constructive learning*: students should learn constructing their knowledge base by connecting new information with existing knowledge (e.g. through discussion).
– *Collaborative learning*: students should learn collaborating with each other in order to maximise learning effects through peer-to-peer teaching (sharing knowledge, challenging, negotiating, etc. in small-group work).
– *Contextual learning*: students should learn to consider relevant context of cases and problems in order to be able to transfer and apply insights and knowledge to different cases (e.g. through real-world problems).

– *Self-directed learning*: students should learn to regulate their learning by playing an active role in planning, monitoring, and evaluating their learning process (e.g. through elaborations on subject matters of own interest).

The educational models of *problem-based* and *project-based learning* incorporate these four learning principles and have been further developed in direct response to the calls for innovation and transformation in sustainability education. Accordingly, sustainability programmes around the world have begun to offer problem-based and project-based learning courses (Lang and Wiek 2012; Brundiers and Wiek 2011; Brundiers et al. 2013; Wiek et al. 2014). In these settings, student learning shifts from passive (course instructors deliver, students receive) to active (students deliver, course instructors provide feedback), and students work on real-world problems by engaging in small-group work (ideally in interdisciplinary teams) and often collaborating with stakeholders on developing solution options to the identified problems (Brundiers and Wiek 2013). Both educational models have many features in common, but display also some differences (Fig. 29.2).

- *Task*: What are the key differences between the educational model of problem-based learning and project-based learning? Justify and illustrate your answer.

Brundiers and Wiek (2013) argue that in education for sustainability hybrid forms of problem-based and project-based learning – *PPBL courses* – offer added value. First, a hybrid PPBL course adopts the problem inquiry as in problem-based learning and, in order to develop solution options, the product orientation from project-based learning. Second, a hybrid PPBL course expands the engagement structure of problem-based learning, wherein stakeholders are mostly not actively

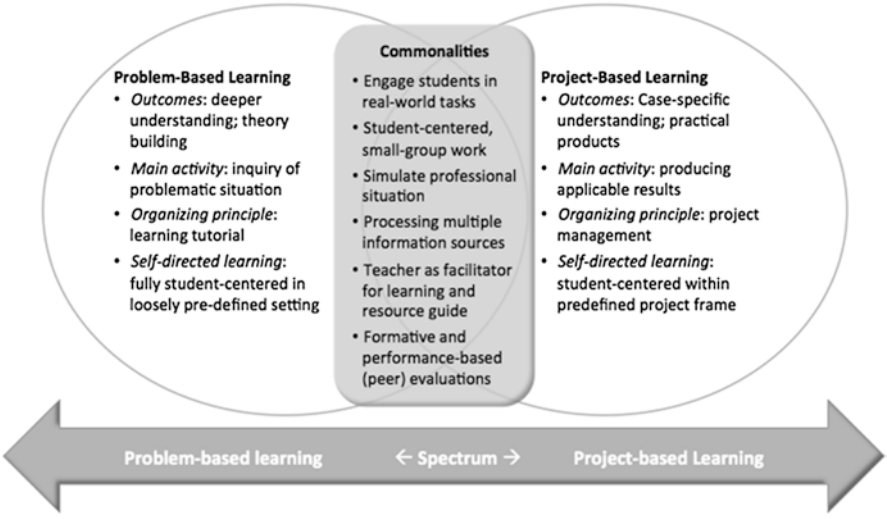


**Fig. 29.2** Commonalities and differences between problem-based learning and project-based learning (Brundiers and Wiek 2013)

involved, to a collaborative process of knowledge generation and critical reflection with stakeholders, which is much more common in project-based learning (Brundiers and Wiek 2013). See Box 29.2 for two examples of problem-based learning and project-based learning courses.

**Box 29.2**
**European Virtual Seminar on Sustainable Development**

In this course, students from 12 universities in Europe work together in international, multidisciplinary teams. The learning objectives are (1) that students gain an understanding of the concept of sustainable development and apply it to a case study in a European context and (2) that students learn to collaborate with students from other disciplines, countries, and cultures, using internet technology. The topics of the case studies range from sustainable urban waste management to sustainable regional tourism and sustainability communication. The ultimate goal of the case study is to come up with evidence-based recommendations on the topic. The challenge is to fully utilise the international and multidisciplinary diversity in the group in terms of different perspectives and expertise among the group members. The case study groups are responsible for their learning process: keeping the learning and research process going and delivering integrated group products on time. Each group is coached by a tutor, who oversees the process, and an expert, with in-depth knowledge of the case study. Students work in 'virtual teams' – a recent trend in global sustainability education (Wiek et al. 2013). The majority of team members do not meet each other in person. Yet, supported by Web-based communication tools, such as discussion forums, chat, and tools for joint document writing, most case study groups develop into well-functioning teams. Such learning environments offer a diversity of interacting perspectives that is often difficult to achieve in face-to-face settings (Cörvers and De Kraker 2009).

**Sustainability Assessment Project at Maastricht University**

Problem-based learning has been at the core of all study programmes at Maastricht University since it was founded in 1974. Also the Master of Science programme in Sustainability Science and Policy (which started in 2011) fully embraces this educational model, while its Sustainability Assessment Project is a hybrid form of problem-based and project-based learning. In this course students work together in small groups on real-world sustainability problems (case studies) commissioned by different stakeholders such as local and regional governments, small and medium-sized enterprises, multinational corporations, research institutes, and non-governmental organisations. The course builds on previous courses in the Master of Science programme and acquired skills are applied to the case. Research is carried out by student project teams that are coached and assessed by faculty members, the external client, and, if appropriate, other stakeholders. The project results,

(continued)

**Box 29.2** (continued)
including policy recommendations, are presented live and in project reports. Examples of sustainability problems examined in 2013 are sustainable car use and parking in Maastricht (commissioned by Q-Park, an international parking organisation), a strategy for an energy-neutral Maastricht in 2030 (commissioned by the city of Maastricht), waste management at Maastricht University (commissioned by Green Office, a student-driven department of the university), conflict mineral-free products at Philips (commissioned by the sustainability department of Philips), and sustainable management of the Rijn river (commissioned by Deltares, an independent research institute).

From a comparative study of six PPBL courses in sustainability programmes at universities in Europe, North America, and Australia, Brundiers and Wiek (2013) conclude that three challenges for PPBL courses in sustainability remain salient:

– Define learning objectives that directly and comprehensively aim at the acquisition of sustainability competencies.
– Design strong transacademic settings that allow meaningful and continuous collaboration between students and stakeholders.
– Fully account for key principles such as self-directed learning, advanced team working, and solution-oriented research with real-world impacts (Brundiers and Wiek 2013).

Problem-based and project-based learning both foster student-centred learning, and hybrid PPBL courses can combine the best of both worlds for acquiring competencies in sustainability. The idea of using real-world sustainability issues in university programmes is innovative and powerful for building competencies that are applicable in professional settings; yet, in practice, it is not always easy to comply with all guiding principles of problem-based and project-based learning.

- *Task*: Why is it difficult to design and implement problem-based and project-based learning that fully embrace all guiding principles discussed? Think about critical factors such as the prevailing educational model at the university, the diversity in prior knowledge of students, a potential tension between theory and practice in the offered content, and the role of course instructors, students, and stakeholders in the learning process. Justify and illustrate your answer.

## 4 Conclusions

We summarised competencies in sustainability and offered a brief insight into real-world learning settings in sustainability programmes at universities in Europe, North America, and Australia. The educational models of problem-based and project-based learning, and their hybrid forms, can support universities in changing towards

student-centred learning and realising a strong sustainability mandate to educate the next generation of sustainability experts (academics and professionals).

Three issues require further attention:

– An integrated framework of key competencies in sustainability finds more and more acceptance in academia and professional circles; it can act as a focal point for education and professional development. There is still more effort required to fully disseminate and incorporate this framework in academic programmes and professional settings (Wiek et al. 2011b).
– Sustainability professionals should be competent in the key competencies outlined above. There is still more structured and shared experience to be gained in order to fully understand how these competencies (individually and collectively) can be acquired through formal training and learning-on-the-job and for designing sustainability education accordingly.
– There is wide agreement that problem-based and project-based learning are powerful settings for sustainability education. Yet, there are still various institutional inertia and obstacles to fully incorporate these settings in sustainability programmes around the world; innovative coping strategies have been developed, but more efforts are needed to fully utilise this potential.

## Further Reading

Roorda N (2010) Sailing on the winds of change. The Odyssey to sustainability of the universities of applied sciences in the Netherlands. PhD thesis Maastricht University, Universitaire Pers Maastricht

Wiek A, Withycombe L, Redman CL (2011) Key competencies in sustainability: a reference framework for academic program development. Sustain Sci 6:203–218

## Weblinks

Centre for PBL & Sustainability. http://www.pbl-sus.plan.aau.dk/

European virtual seminar on sustainable development. http://www.openuniversiteit.nl/eCache/DEF/90/085.html

MSc Sustainability Science and Policy, Maastricht University. http://www.maastrichtuniversity.nl/masterssp

UNESCO programme Teaching and Learning for a Sustainable Future. http://www.unesco.org/education/tlsf/index.html

## References

Broekhans B, Turnhout E (2012) Roles of environmental experts in practice. In: Tuinstra W et al (eds) Environmental problems: crossing boundaries between science, policy and society. Open University, Heerlen, pp 89–105

Brundiers K, Wiek A (2011) Educating students in real-world sustainability research – vision and implementation. Innov High Educ 36:107–124
Brundiers K, Wiek A (2013) Do we teach what we preach? An international comparison of problem- and project-based learning courses in sustainability. Sustainability 5:1725–1746
Brundiers K, Wiek A, Redman CL (2010) Real-world learning opportunities in sustainability – from classroom into the real world. Int J Sustain High Educ 11:308–324
Cortese AD (2003) The critical role of higher education in creating a sustainable future. Plan High Educ 31(3):15–22
Cörvers RJM, De Kraker J (2009) Virtual campus development on the basis of subsidiarity: the EVS approach. In: Stansfield M, Connoloy T (eds) Institutional transformation through best practices in virtual campus development: advancing e-learning policies, Information science reference. IGI Global, Hershey/New York, pp 179–197
De Kraker J, Lansu A, Van Dam-Mieras MC (2007) Competences and competence-based learning for sustainable development. In: de Kraker J, Lansu A, van Dam-Mieras MC (eds) Crossing boundaries. Innovative learning for sustainable development in higher education. Verlag für Akademische Schriften, Frankfurt am Main, pp 103–114
Dolmans D, Schmidt H (2010) The problem-based learning process. In: Van Berkel H, Scherpbier A, Hillen H, van der Vleuten C (eds) Lessons from problem-based learning. Oxford University Press, Oxford
Ferrer-Balas D, Adachi J, Banas S, Davidson CJ, Hoshikoshi A, Mishra A, Motodoa Y, Onga M, Ostwald M (2008) An international comparative analysis of sustainability transformation across seven universities. Int J Sustain Higher Educ 9(3):295–316
Institute of Environmental Management & Assessment (IEMA) (2011) Environmental skills map. IEMA, Lincoln. http://www.iema.net/skills
Jenssen S (2012) Sustainability at universities. An explorative research on assessment methods and tools for sustainability implementation at universities. Master thesis, Maastricht University
Lang DJ, Wiek A (2012) The role of universities in fostering urban and regional sustainability. In: Mieg HA, Töpfer K (eds) Institutional and social innovation for sustainable urban development. Earthscan, London, pp 393–411
Martens P, Rotmans J (2012) Scientivists urgently needed. Blog http://ideas4sustainability.wordpress.com/2012/09/20/scientivists-urgently-needed/
Pielke RA (2007) The honest broker. Making sense of science in policy and politics. Cambridge University Press, Cambridge
Rowe D (2007) Education for a sustainable future. Science 317(5836):323–324. doi:10.1126/science.1143552
Wiek A, Withycombe L, Redman CL (2011a) Key competencies in sustainability: a reference framework for academic program development. Sustain Sci 6:203–218
Wiek A, Withycombe L, Redman CL, Banas Mills S (2011b) Moving forward on competence in sustainability research and problem solving. Environ Sci Policy Sustain Dev 53(2):3–12
Wiek A, Bernstein M, Laubichler M, Caniglia G, Minteer B, Lang DJ (2013) A global classroom for international sustainability education. Creat Educ 4(4A):19–28
Wiek A, Xiong A, Brundiers K, van der Leeuw S (2014) Integrating problem- and project-based learning into sustainability programs – a case study on the School of Sustainability at Arizona State University. Int J Sustain High Educ 15(4):431–449
Willard M, Wiedmeyer C, Flint RW, Weedon JS, Woodward R, Feldman I, Edwards M (2010) The sustainability professional: 2010 competency survey report. Environ Qual Manage 20(1):49–73