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HOW TO ASSESS KEY COMPETENCIES FOR SUSTAINABILITY IN ENGINEERING EDUCATION

Lena Gumaelius, Anders Rosén & Marc de Vries

ABSTRACT

The consideration and implementation of competencies in educational systems has been an integral part of the shift from input-oriented knowledge-based teaching to outcome-oriented competence-based learning, driven by the Bologna process, the CDIO initiative, and similar activities around the world. Such a shift builds on the idea that education should not only provide knowledge in itself, but also foster the development of competencies as interplays between knowledge, skills, and attitudes among the learners.

KEYWORDS: Competence, assessment, key competences, engineering education, sustainable development

TYPE OF CONTRIBUTION: Practice-based abstract

PRESENTATION FORMAT: Roundtable discussion

FULL ABSTRACT

The term key competencies is sometimes used to distinguish competencies of particular importance. Within Education for Sustainable Development (ESD) the so-called key competencies for sustainability are considered necessary for all learners to cope with the increasingly diverse and interconnected world and to enable them to contribute to the urgently needed transformations towards a sustainable society (e.g. de Haan 2010; Wiek et al. 2011; Rieckmann 2012). There is no general consensus on a specific set of key competencies for sustainability and the concept is still under development and debate (e.g. Shephard et al 2018). Some sort of convergence can however be seen, where key competencies for sustainability are generally considered to be cross-cutting, multifunctional, context- and domain-independent. UNESCO (2017) outlines the following eight key competencies for sustainability based on a compilation from the research literature: systems thinking competency, critical thinking competency, collaboration competency, anticipatory competency, normative competency, strategic competency, self-awareness competency, and integrated problem-solving competency.

Only a few examples of the consideration of key competencies for sustainability in engineering educations are found in the research literature. Some of these are mainly focusing on intended learning outcomes (e.g. Segalàs et al 2009, Rosén et al 2019). Others are focusing on teaching-learning practices which typically are learner-centred action-oriented learning approaches such as challenge-driven education, problem-based



learning, and case-based collaborative learning (e.g. Guerra 2017, Goncalves Quelhas et al 2019, and Högfeldt et al 2019). Thürer et al (2018) states that there is a need for more research and development on how to assess the learning of key competencies for sustainability, and that is the scope of the here presented study with a particular focus on engineering education (EE).

Our first research question was formulated as, ***RQ1: 'What approaches are used for assessing key competencies for sustainability in EE?'***. We started out by turning to the literature, conducting an initial literature review using the database Web of Science core collection (WoS). This database was selected as it is a broad database including the journals of interest both within EE and ESD. A first trial resulted in 7 articles, where none was relevant for giving any further information on approaches for assessment of key competencies. This result lead us to the conclusion that not much research has been conducted in this field. A second research question was therefore formulated as ***RQ2: 'What approaches are used for assessing key competencies in other disciplines?'***. A broader literature review was therefore conducted, still by using the same database, WoS. Since our interest lies in how to assess the learning of competencies in project- and problem-based and challenge-driven courses, the study was expanded to also include project- and problem-based learning. In order to limit the search, six of the eight key competencies for sustainability were included. The search criteria were formulated as follows: 1) only journal papers published between year 2000 to 2020 were considered; 2) problem based learn*, project based learn*, competence*, PBL as well as assess*, measure* or evaluate* was present in the title; 3) system think*, collaborate*, critical think*, problem solve*, interpersonal or ethic* was mentioned in the abstract; 4) teach*, learn* or educate* as well as higher education*, college, university, post-secondary OR engineer* was mentioned in the abstract.

In this search, 193 articles were found. However, among these only four articles were identified that particularly focused on assessment of key competencies for sustainability within education, whereas the others considered the here targeted competencies either in more generic or subject specific terms. Still, out of the 193 articles, 147 were found to be relevant for this investigation. Those articles were divided into two fields: educational studies and other. The first field was further divided into three sub fields, one representing education in health care, one engineering education and the third one education in all other areas. Health care education was selected to be a sub field as the majority of articles represented this field, engineering was the second largest sub field and among the other education areas no one was represented by more than ten articles. A summary of this analysis is presented in table 1.

A priori analysis found that the number of publications each year, in the area of interest, increases over the years, and articles are seen to be most prevalent in journals representing education or health care.



Table 1. Summary of analysis

Fields	Sub fields	Number of relevant articles
Education	Health care education	61
	Engineering education	22
	Other education areas (teacher education, higher education, etc.)	46
Other	(Social work, health, psychology, veterinary, food related areas etc.)	18
Total number of relevant articles out of 193		147

A first reflection on the overall results is that the fields differed when comparing which competencies the articles considered. In health care education, there was a somewhat greater focus on collaborative skills as well as other different interpersonal skills than for the other fields, whereas in EE a focus was placed especially on problem solving. In all fields, critical thinking and ethics were found to the same extent. Many different approaches to assessment were used across all fields, questionnaires and surveys being most common. Other methods described were interviews, expert observations, online simulation of real cases and the use of certified tools, most often described as self-evaluation scales.

Somewhat surprisingly, the analysis does not say that the problem-based learning community has focused on examining assessment of competences, as only ten articles are about PBL and assessment of possible competencies. This observation is further strengthened by a review article, which is one of the 10 PBL articles in this study, which points out that studies which include theoretical frameworks or other rationales for how PBL constructs were assessed are lacking (Selland, 2009).

Even though there are quite a few articles in the subject area of EE, there is almost no examples of studies where established methodology for EE have been used. Out of the eight articles describing a specific tool for assessment, seven are about development/testing a new tool.

Health care education, especially nursing education, stands out as a field with significantly higher number of articles than the other fields. Perhaps even more interesting is that, for this field, a different pattern can be discerned when comparing the content of these articles with the articles representing other sub fields of education. When examining the articles that handle tools for assessment, the majority of the articles are about applying an already developed tool. Out of 27 articles dealing with tools for assessment 20 describes implementation, evaluation, or validation of the tools and only seven discuss the development of new tools.

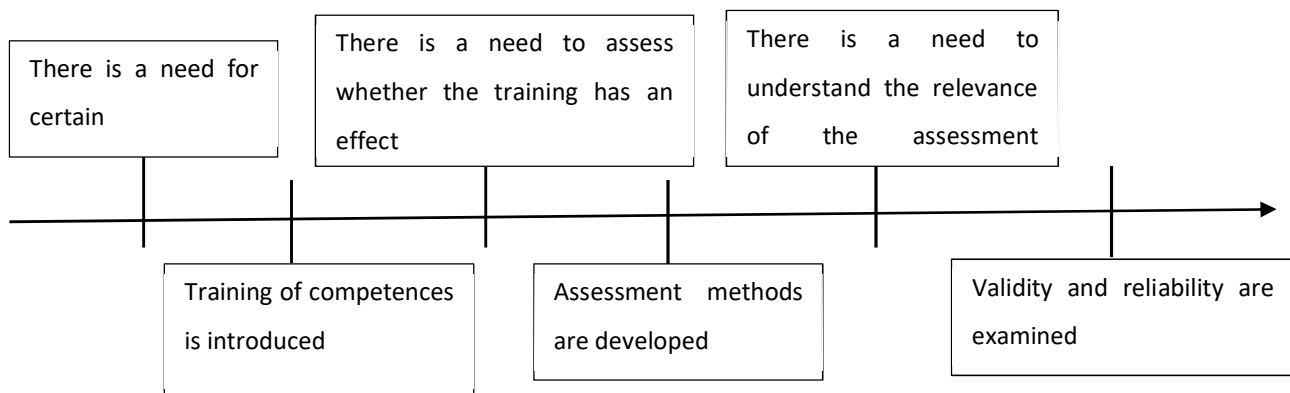
It should be noted that, due to the limitation of only using one database in this literature search, we are fully aware of the possibility that there are more fields that might have a well-developed understanding on assessment of competencies. Interesting fields we have not looked into are, for example, innovation and business studies as well as political science. To get an overall picture, it would be necessary to expand this



study to include more journals and conference proceedings, both in the areas we have studied, but also in completely different areas where the ability to act in a sustainable way is important.

The result further lead to the reflection on how the field of Engineering Education for Sustainable Development (EESD) can learn from other fields? Is it possible to transform any of the tools used in other education fields/areas? Can EE learn from how other areas work on assessment of competencies? Based on these reflections a third research question was formulated as, ***RQ 3: 'What research and development needs to be conducted in order to achieve a better consensus when it comes to assessing competencies?'***

Figure 1. Suggested development line for implementing competence learning in a specific subject area.



The third research question is up for discussion at a round-table discussion about strategies for developing assessment approaches for key competencies in different problem-, and project-based and other active learning settings in EESD. As a result of the analysis, the authors claim that it is possible to see a line of development for how competencies are implemented in education and other operations. The articles in this review reflect the different phases of this line of development (see Figure 1). It is primarily in healthcare education that the articles reflect the final development phase, ie where the relevance of the assessment methods used is discussed in a scientific manner (see figure 1.) To answer research question number three, we want to use this round table discussion to discuss how the results from this review article can be used to understand what progress should be made when moving towards a better consensus on how to assess different key competencies. The results presented in Table 1 together with the development line (Figure 1) will serve as a basis for this conference discussion.

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