

Integrating threshold concepts into set-theoretic frameworks

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Currently, part of the research on threshold concepts as suggested by Meyer and Land (2003, 2005) is focusing on questions of how to teach, assess, and to identify them (e.g. Davies, 2006; Land, Cousin, Meyer & Davies, 2005). We address these issues by proposing several approaches to integrate threshold concepts into three set-theoretic frameworks: the *knowledge space theory* (KST; Doignon & Falmagne, 1985; 1999) and two of its extensions, the *competence-based knowledge space theory* (CbKST; Albert & Lukas, 1999; Heller, Steiner, Hockemeyer & Albert, 2006) and the *misconceptions approach* (Lukas, 1997).

The KST defines a knowledge domain by a set of problems (e.g. questions in an exam). The number of problems a person is capable to solve is the person's *knowledge state*. Because of *prerequisite relations* between problems, not all potential knowledge states are feasible. The set of feasible knowledge states is called a *knowledge structure*, which enables adaptive and efficient knowledge assessment. The CbKST extends the knowledge structure by a competence structure which involves sets of underlying skills and competences, necessary for mastering the domain's problems (e.g. Korossy, 1999). The *competence structure* provides suggestions about different adaptive and personalized learning paths. Finally, the misconception approach additionally takes misconceptions into account and thus provides a framework for identifying the reason for student's problem solution patterns including systematically wrong solutions. For example, a false solution can be the result of missing competences or the presence of misconceptions; however, a correct solution can result even if a misconception is present. This latter case seems similar to what Meyer and Land (2005) called *mimicry*.

Threshold concepts can be integrated into these three set-theoretic frameworks in several ways, depending on if they are modelled as problems (or family of problems) or as underlying competences (e.g. understanding opportunity costs). In both cases at least some of the threshold concepts main characteristics (transformative, integrative, irreversible, bounded and troublesome) would be represented within the knowledge and/or competence structure. For example, a concept is integrative if it has several prerequisites. Let us consider for example the work of Davies and Mangan (2007) on threshold concepts in economics: the threshold concept of opportunity costs has prerequisites in form of some basic concepts like the differentiation between price and costs or between investment and saving. Furthermore, it seems plausible, that knowledge and/or competence structures will change after a threshold concept has been grasped. This would reflect the *transformative nature* of these concepts.

To sum up, the purpose of the integration between threshold concepts and these three set-theoretic frameworks is twofold: First, it can enable teachers and lecturers to assess the student's knowledge state in an adaptive way and it enables the creation of adaptive learning paths in order to support learners to grasp *the jewels in the curriculum* (Cousin, 2006). Second, it can support researchers to identify threshold concepts by observing its characteristics within knowledge and/or competence structures, their changes after threshold concepts have been grasped as well as by the assessment of student's misconceptions.

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