Competence Development Through Inquiry-Based Learning

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One basic principle of inquiry-based learning that hitherto has received too little reflection is its potential to allow for a focus on competence goals rather than on discipline- or course-specific educational contents (e.g. disciplinary knowledge). Although a broad potential for fostering a wide array of competences is attributed to inquiry-based learning, this has yet to be systematically researched and demonstrated. This chapter outlines which competences can be fostered by inquiry-based learning and how these competences are to be understood. So far, the competence goals of inquiry-based learning have only been abstractly specified. This is insufficient for competence-oriented teaching, since it remains unclear which particular competences are to be fostered and how these may be actively promoted. Drawing on concepts and findings from current research projects, this chapter will operationalize these abstract competence goals and discuss ways to address these during higher education teaching.

6.1 Competence Goals

In looking at the module catalogs or course descriptions for inquiry-based learning (Rueß et al. 2016), educators primarily associate significant discipline- and even topic-specific goals with these formats. Inquiry-based learning in these cases is employed to help students deepen and develop their knowledge of topics independently. Such topic-related goals necessarily need to be differentiated for each individual purpose of inquiry-based learning and cannot be examined from a cross-curricular perspective at this point. Instead,

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H. A. Mieg (ed.), *Inquiry-Based Learning – Undergraduate Research*,
https://doi.org/10.1007/978-3-030-14223-0_6

the focus of this chapter will be on overarching, supra-disciplinary competence goals. These fall within three principal categories: the promotion of research competence, the development of a researcher's mindset and the promotion of what are known as metacognitive competences.

- The most frequent references in the literature credit inquiry-based learning with the promotion of students' *research competence*. The German Science Council (Wissenschaftsrat 2006) recommends inquiry-based learning so that students can learn how to develop questions, solve problems, acquire insights methodically and reflect critically on questions of principle.
- Secondly, inquiry-based learning is associated with the goal of teaching students a *researcher's mindset.* Such mindset should not only make it possible for them to utilize largely theoretical knowledge acquired during their studies in order to analyze the professional field, but will also support them in their own professional activity in a critical reflexive manner that fosters development through inquiry. This goal is formulated for teacher training especially often (Fichten 2013; Wildt 2009; Wissenschaftsrat 2001).
- Finally, inquiry-based learning should foster *metacognitive competences* (Huber 2004). This includes those processes and experiences that deal with knowledge and the control of students' own cognitive functions (Flavell 1979). The metacognitive competences are considered higher-level competences that are acquired throughout the course of study, but not in individual courses.

This quick look at competence goals summarizes the literature on inquiry-based learning. Descriptions of competence goals, however, comprise scarcely more than mere naming of goals. Such general goal formulations are suitable neither for empirical analysis nor for designing teaching in a competence-oriented manner. Simply specifying goals leaves unresolved the question of how these competencies are to be understood. In the following, we therefore attempt to further differentiate the first two goals, namely the acquisition of research competence (Sect. 6.2) and the acquisition of a researcher's mindset (Sect. 6.3), and thus make these applicable to both research and teaching. Figure 6.1 specifies the different components of the first two competence goals, which we will explain below.

6.2 Research Competence

The description of research competence draws on the results of current research projects, including, inter alia, from the German scientific transfer project "Modeling and Measuring Competencies in Higher Education – Validation and Methodological Innovations" ("Kompetenzmodellierung und Kompetenzerfassung im Hochschulsektor"), which has coordinated national and international research projects in this area since 2011. Based on the concept of competence developed by Koeppen et al. (2008), this projects understands

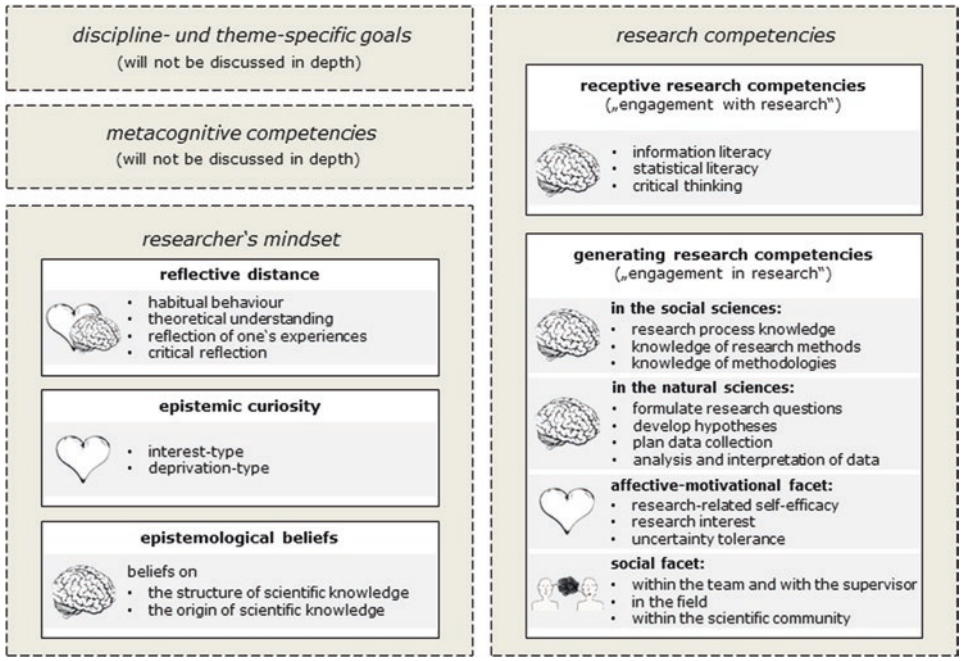

Fig. 6.1 Overview of the potential competence goals in inquiry-based learning. (Source: author's representation)

competences as context-specific cognitive dispositions relating to performance; the emphasis is therefore largely placed on cognition (Blömeke et al. 2013).

In addition, a distinction must be made between two approaches to modelling research competence: *receptive research competence* and *actively generating research competence*. The difference between the two approaches lies in how they understand research competence. First, receptive research competence refers to the understanding and application of existing research results. Borg (2010) describes this as "*engagement with research.*" Second, the term "actively generating research competence" may refer to the *active generation* of research findings, which – in contrast to the reception of research findings – can be understood as "*engagement in research*" (Borg 2010). This second understanding of research competence tends to originate in teaching practice and is conveyed by the goals formulated in study regulations: Students should be enabled to conduct independent research.

6.2.1 Cognitive Facets of the Receptive Research Competence

An exemplary approach to the operationalization of research competence in understanding "engagement with research" can be found in the project "Learning the Science of

Education" (Groß Ophoff et al. 2015), where research competence in educational science is conceptualized by an emphasis on working with the scientific literature. Accordingly, students must first be able to ask suitable questions, and then to find and assess specific information regarding this question, usually research literature. This requires information competence ("information literacy"). The subsequent interpretation of this information requires the competent handling of data ("statistical literacy"). Finally, the evidence that is identified must be assessed and conclusions must be drawn from the interpreted information. This, according to the conceptual framework, requires critical thinking. According to this model, competence-oriented inquiry-based learning would mean conducting less empirical work oneself and instead working on an application-oriented research question with the available literature.

6.2.2 Cognitive Facets of the Generating Research Competence

In understanding research competence as referring to "engagement in research," it cannot be understood to be a generic or supra-disciplinary construct. Due differing research methodologies between disciplines, it must be assumed that the required tendencies relating to performance differ between the larger disciplinary traditions. Accordingly, discipline-specific models for social and natural sciences are available for the operationalization of this competence.

6.2.2.1 Social Sciences

An empirically sound model for research competence exists for disciplines employing research methods from the social sciences (Gess et al. 2017). The model was developed on the basis of interviews and surveys with experts (namely professors). It consists of linking three *competence dimensions* and three *research activities*. According to the model, competence dimensions include: (1) research process knowledge; (2) knowledge of research methods; and (3) knowledge of methodologies, which includes an awareness of the basic methodological concepts and principles. Research activities include: (a) identification of a research problem, (b) planning a research project and (c) analyzing and interpreting data. According to this model, competency-oriented inquiry-based learning would mean that students conduct an empirical study that involves acquiring and applying knowledge of research methods. This corresponds to a type of inquiry-based learning in which students proceed through the entire research process (Rueß et al. 2016).

6.2.2.2 Natural Sciences

Research competence in the natural sciences was examined in the German cross-university project "Competence Modeling and Assessment regarding the Understanding of Science with regard to Natural-Science-Related Methods of Working and Thinking in Teaching-Students in the Three Disciplines Biology, Chemistry and Physics". Based on Mayer (2007), the competence model makes distinctions between the sub-competences

"formulating a research question," "developing hypotheses," "planning studies" and "analyzing and interpreting data" (Hartmann et al. 2015). Competency-oriented inquiry-based learning pursuant to this model would mean that students would conduct open-ended experiments and reflect on the inquiry process. This corresponds to the type of inquiry-based learning in which research questions are pursued for the purposes of learning research methods (Rueß et al. 2016).

6.2.3 Affective-Motivational Facets of the Generating Research Competence

The models of research competence that have hitherto been presented all limit themselves to the cognitive facet. This is generally the case for most of the current projects in competence measurement and is, among other things, based on the priorities of the research funding programs. Other facets, such as the affective-motivational, are often not taken into account due to pragmatic issues of conducting research (Fleischer et al. 2013). Even when these facets are considered, efforts to define and model them lag far behind those of the cognitive facet. Based on Kunter et al. (2013) who looked at the professional competence of instructors, the following sections will examine: (1) research-related expectations of self-efficacy, (2) intrinsic motivation or research interest and (3) the tolerance of uncertainty in the research process.

6.2.3.1 Research-Related Self-Efficacy

Expectations of self-efficacy are a person's subjective belief in their own ability to successfully perform certain tasks, even under difficult circumstances (Bandura 1977). Research-related expectations of self-efficacy thus refer to challenging research tasks. This disposition has already been studied a number of times and is often operationalized pertaining to the steps in the research process (Forester et al. 2004; Gess et al. in review). Based on Forester et al. (2004), four areas of self-efficacy can be identified: self-efficacy in data collection, self-efficacy in data analysis, self-efficacy in the analysis of the state of research and in merging findings with the state of research and self-efficacy in the creation of a written research report. According to theory, self-efficacy expectations can be fostered when people have a sense of achievement, can learn by example, are encouraged verbally or experience an emotional response (Bandura 1977).

6.2.3.2 Research Interest

A distinction can be made between two types of research interest: thematic research interests, which relate to concrete objects or discipline-related topics, and activity-related research interests, which relate to classes of activity. The *thematic* research interest is often the impetus for especially ambitious student research projects. However, the practical benefit of promoting thematic research interest is questionable, since a thematic interest is unlikely to be transferable to other topics. Therefore, for practical purposes, it appears that

activity-related research interest is better suited to such investigation. Here, the research interest is operationalized via the interest in the steps of the research process (Bishop & Bieschke 1994; Gess et al. 2014). Individuals who are interested in research will conduct research because they enjoy the activity itself and regard this as subjectively important. Empirically, two factors of activity-related research interests emerge: firstly, working with literature and the communication of results, and secondly, interest in collecting and evaluating data (Gess et al., in review). The more research steps students take in exploratory learning, the more intensely interest is fostered (Gess et al. 2014).

6.2.3.3 Tolerance of Uncertainty in the Research Process

The research process, which is per se open, frequently leads to contradictory or complicated results or situations for which there is no "right" or "wrong" decision. This can be daunting and demotivating if students are not able to deal positively with these uncertainties. Accordingly, the *tolerance of uncertainty* in the research process should play a significant role (Wessels et al. 2018). It refers to a person's tendency to view unclear decision-making situations and contradictory findings in the research process as a positive challenge and thus the ability to successfully handle these situations. Intolerance of uncertainty would be expressed as anxiety or discomfort. In our interviews, experienced educators in particular mentioned students' anxieties about making decisions in critical research situations, which frequently result in students failing to make necessary decisions or else avoiding these situations.

6.2.4 Social Facets of the Generating Research Competence

Like affective-motivational facets, social facets of competences are rarely examined. For this reason, it is only possible to provide an initial, preliminary list of social subcompetences associated with research competence based on the literature and our interviews with experienced educators (Wessels et al. 2018). In so doing, the focus is on students' communication skills, which can be examined from three perspectives, concerning students': (1) capacity for internal communication, i.e. with their research team and supervisor, (2) ability to adequately communicate externally, in the field of research, and (3) ability to comunicate with the scientifically engaged public.

6.2.4.1 Communication in the Research Team and with Supervising Instructors

Inquiry-based learning is often conducted in teams. Students need to acquire skills such as setting common goals, sharing tasks among themselves and providing feedback. This falls within the capacity for internal communication. In addition, there is communication with the supervisor. Students should acquire both the ability to seek help and to accept assistance and criticism, as well as to convince supervising instructors of the merit of their own ideas. In order to align inquiry-based learning with this competence goal, these

communication processes should be explicitly addressed. For instance, supervising faculty could provide suggestions for improving communication that go beyond the technical feedback.

6.2.4.2 Communication in the Field of Research

Communication in the field of research is particularly necessary in the case of qualitative social research since this accounts for a large proportion of a researcher's time. In the natural sciences, communication with others in the research lab, e.g. with technical assistants, is necessary. Communication in the field itself could be made the subject matter of the research, in order to implement inquiry-based learning pertaining to this competence goal. Conversation partners could be asked for feedback regarding communication in interviews or students could reflect on communication in the field in research journals. Even in laboratory situations, contact with colleagues and technical personnel can be recorded and reflected upon.

6.2.4.3 Communication with the Scientific Public

In communication with the scientific public, it is important that students are able to empathize with the recipient's perspective so that they can describe their research projects and results appropriately. Experienced educators emphasize that this ability is also needed in conversation with other researchers so that common interests and opportunities for collaboration can be identified. In order to align inquiry-based learning with this competence goal, exchange with outside collaborators should be integrated into the course. This typically takes the form of final poster presentations.

6.3 Researcher's Mindset

Especially in the case of students aiming to achieve teaching certification, the goal is often formulated as promoting an "attitude of inquiry-based learning" (Wissenschaftsrat 2001), a "researching stance" (Fichten 2010) or an "investigative habitus" (Reitinger 2013) through inquiry-based learning. This often refers to a reflective approach to one's own professional practice. In professions other than teaching, such an attitude is also required, as one's own practice must be reflected upon in nearly every field. In the following, we will postulate that the constructs of (1) reflective distance, (2) epistemic curiosity and (3) epistemological beliefs are components of a researcher's mindset.

6.3.1 Reflective Distance

An objective, unbiased attitude towards practice is the basis for improving practice. Taking a reflective distance enables critical questioning and an empirically based change to one's own professional practice. In the literature, this ideal of the critical-reflective professional

is referred to as a "reflective practitioner" (Schön 1983) and "reflective thinking" is looked at empirically (Kember et al. 2000). Inquiry-based learning aiming to foster a reflective distance would mean to primarily pursue practice-relevant research topics. Practical problems that students identify while observing their future occupational field of activity would be especially suitable. The reflective distance can then be tested by consciously checking the students' own presuppositions and beliefs and then questioning them during seminars.

6.3.2 Epistemic Curiosity

In addition to a distance from the professional field, curiosity that motivates students to find out more about an issue is also important—termed epistemic curiosity in the literature. A distinction is made between two dimensions of curiosity (Litman and Mussel 2013): firstly, there is a search for knowledge that is driven by interest or enjoyment ("I-type"), and secondly, there is a search for information that is driven by a sense that knowledge is missing ("D-type"). As yet, little is known about how epistemic curiosity can be fostered. Inquiry-based learning that aims to promote I-type epistemic curiosity should probably involve an extended phase, to allow students to identify their own topics and research questions. In order to promote D-type curiosity, educators could point out the consequences of a lack of knowledge for the research process, but at the same time be available as counselors to fill in any knowledge gaps when asked for information.

6.3.3 Epistemological Beliefs

Epistemological beliefs are beliefs regarding the structure and formation of scientific knowledge in a domain (Stahl and Bromme 2007). It is to be assumed that individuals who regard knowledge as flexible, changeable and useful in practice would be more likely than others to wish to generate new knowledge or change the practice. In inquiry-based learning, students can gain experience with the formation of knowledge and thus receive an impetus that could lead to a change in their own beliefs. Epistemological beliefs can be fostered in a course of academic study by explicitly addressing them and having students reflect upon them (Elby 2001), by discussing the various methods of arriving at the construction of knowledge and the quality of scientific findings (Lahtinen and Pehkonen 2012) and by confronting students with controversially discussed scientific topics, in which conflicting studies trigger epistemic doubt (Ferguson et al. 2012).

6.4 Outlook

There are various competence goals associated with inquiry-based learning. In addition to imparting disciplinary knowledge, competence goals can be classified according to three levels: the promotion of research competence, conveying a researcher's mindset and the development of general metacognitive competences. While general metacognitive competences have already been defined in detail elsewhere and are only partially suitable as competence goals of individual courses due to their breadth, research competence and a researcher's mindset must be comprehensively operationalized in order to be usable for competence-oriented courses and competence-oriented teaching evaluation.

Educators can refer to these competence goals when designing their courses. It is thereby essential to consciously choose from the competence goals presented here, since it is not possible to address all goals in a single course. Depending on the competence goal, different priorities should be set: For example, if the goal is to foster the receptive research competence and reflective distance among students, then students should pursue practice-relevant research questions about which they already have emotionally charged assumptions (for example, regarding homework assignments in teacher training). If, on the other hand, the goal is to develop the *generating* research competence, then the course will have to be designed differently from the ground up. The focus should then be on the research process, which the students should go through as completely as possible and upon which they should repeatedly reflect.

For the design of degree programs, this implies the use of multiple forms of inquiry-based learning within the course of studies, either in order to leave students free to decide which competences they would like to acquire, or in order to allow development of a broad range of competences in the course of study. Naturally, these goals would have to be combined with discipline-specific and topic-specific competence goals, which were not discussed in detail in this chapter.

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