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Modelling Undergraduate Research and Inquiry-Based Learning – Why Enculturation Matters

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Abstract

In the beginning of the 21st century, models have emerged to describe and develop undergraduate research and inquiry-based learning. This article discusses four examples of modelling didactical issues around this topic. The aim of the first part is to scrutinize the epistemological and didactical purposes of these four models. As essential dimensions of undergraduate research and inquiry-based learning are neglected, two alternative models are developed in the second part. The first of these puts the coordination of theory and evidence at the centre and determines three different horizons of significance in the field of science. In relation to these horizons, the second new model highlights the broader societal context of scientific practices. The role of research and science in society is recognized here, on the one hand as an affirmative process of institutionalization of approved knowledge, and on the other, as practices of criticizing and breaking away from established forms of knowing, testing, evaluating, and approving. Concomitantly, the education ('Bildung') of students through and within scientific practices of research and inquiry-based learning (Humboldt's 'Bildung durch Wissenschaft') is interpreted against the backdrop of two opposing trajectories, which influence students' ambitions to engage with problems of science. In relation to this, higher education didactics need to distinguish between long-term and short-term goals. It is argued that the latter concretizes the former. This understanding of teaching is corroborated against the backdrop of the concept of learning as 'enculturation' in science. The argumentation refers back to insights by Lev S. Vygotsky, Ludwik Fleck and Michael Polanyi.

***Keywords**:* Undergraduate research, inquiry-based learning, enculturation, gestalt theory, didactics, scientification, perezhevanie

Introduction

Does higher education research and practice need models? The question may come as a surprise, as models are inseparable constituent parts of scientific and professional practice. In architecture, models serve as illustrations of building plans; economics employs them to reconstruct (and, if possible, also predict) complex economic developments, while physics uses models to explain specific laws, especially in those cases where observations are no longer feasible (for instance at an atomic level). More generally speaking, do models bring us closer to what is remote, utopian, or exists outside of our space of immediate sensual experience, and sometimes even outside of our imagination (like anti-matter)? Models are necessary for making relevant epistemic experiences. They structure and scaffold our perception and imagination. The materiality of models is often not (or not only) a miniature version of something too big to comprehend, or an enlargement of something too small to handle. Other models tend to become symbolic and abstract. The intention of modelling is often not to completely represent something real, but to discern what is essential from an epistemological point of view. Therefore, models often reduce complexity and turn to formalism. Models are thus never true or false (in a realistic sense), but powerful, or limited, or sometimes even unsuitable for the intended purpose (in a rationalistic or logical sense). Another criterion for models is substantiality or triviality (in a practical sense). These distinctions are ultimately relevant for (but not identical with) deontological reasoning, i.e. with arguments and reflections of what should be done.

Against this backdrop, the use of models in higher education didactics for developing undergraduate research and inquiry-based learning shall be scrutinized. What is their power and what is the scope of their aims? Do they serve for illustration, reconstruction, or even for (causal) explanation of teaching and learning in university courses? In what follows, their epistemological context in research and teaching practice is explored. Moreover, their design is investigated for the ways it might help to guide and foster undergraduate research and inquiry-based learning (cf. Griffiths, 2004; Brew, 2013).

The paper scrutinizes four models: one by Healey and Jenkins (Fig. 1), one by Levy and Petrulis (Fig. 2), one by Brew (Fig. 3) and one by Reinmann (Fig. 4). These examples are currently widely recognized by practitioners in higher education didactics and therefore seem to convey relevant insights. They are discussed in the first two sections with respect to their epistemological and practical purposes. It is found that although a practical purpose seems to exist, essential dimensions of undergraduate research and inquiry-based learning are ignored, which is indicative not only of theoretical problems but also of deficiencies in didactical practices. These deficiencies become obvious when abstractions about university teaching and learning made in the modelling are revealed.

Two new models are developed in the final sections. The first alternative model (fig. 5) puts the coordination of theory and evidence at the centre and considers three different "horizons of significance" in undergraduate research and inquiry-based learning to theorize levels of students' engagement. "Horizons of significance" are, according to Taylor, ethical and value-related dimensions of human practice (Taylor, 1991). Here, 'significance' indicates that the person makes a stance clear and engages with aspects in the world while experiencing herself as significant and authentic against the background of "issues of importance" (p. 39). Taylor also highlights the intelligibility of feelings for this interrelation:

> Your feeling a certain way can never be sufficient grounds for respecting your position, because your feeling can't *determine* what is significant. […] Things take on importance against a background of intelligibility. Let us call this a horizon. It follows that one of the things we can't do, if we are to define ourselves significantly, is suppress or deny the horizons against which things take on significance for us. (p. 37)

Horizons of significance can be interpreted in a similar way. Lev S. Vygotsky explained the concept of experience (*perezhevanie*) as a unity of emotional and intellectual self-consciousness regarding an aspect of reality:

> There exists a dynamic meaningful system that constitutes *a unity of affective and intellectual processes.* Every idea contains some remnant of the individual's affective relationship to that aspect of reality which it represents.

Following Vygotsky, insights into personal experience or self-consciousness will methodologically depend on modelling the unity of affective and intellectual processes as concrete activity:

> In this way, analysis into units makes it possible to see the relationship between the individual's needs or inclinations and his thinking. It also allows us to see the opposite relationship, the relationship that links his thoughts to the dynamics of behavior, to the concrete activity of the personality. (Vygotsky, 1987, pp. 50–51)

With respect to this self-consciousness, this paper draws attention to how ethics and values in students' undergraduate research and inquiry-based learning come into play while they discover significance in learning and in solving scientific problems.

In that sense, the use of models implies a double meaning – one is (meta-)cognitive, and the other is ethical. A didactical model is (meta-)cognitive insofar as it may guide collaboration and interaction between teachers and students; and it is ethical as it may convey judgments about finding this way of doing it right or wrong. With this distinction, the use of models, whether didactical or scientific, simultaneously generates resonance in ways of thinking and feeling, *which is why certain skills for research and inquiry are not* *simply passed on from teachers to students, and not only appropriated by the students as 'learning content'*.

A guideline for this paper is therefore to see the acquisition of ethics and values as part of students' learning and enculturation in science.

In combination with the first new model (fig. 5), a second alternative didactical model (fig. 6) therefore highlights the broader societal context of research and teaching practices at universities, with their ethical and value-related horizons of significance. The role of research and scientific practices in society is recognized here, on the one hand as an affirmative process of institutionalization of approved scientific knowledge, and on the other, as a matter of criticizing and breaking away from established forms of knowing, testing, evaluating, and approving. Tensions, as they might revolve around affirmation versus critique, or more indirectly between values (or ethics) are assumed to be relevant for students' learning and engagement.

The analysis follows the insight that university teaching and learning in their concrete forms encompass, (1) the particular relationships of collaboration between teachers and learners, (2) the learners' relationship with the scientific object of learning, and (3) the learners' relationship to him-/herself while changing his/her perception, thought and competence throughout the learning process, thereby contributing to new horizons of significance (Langemeyer, 2006). These dimensions are acknowledged as parts of a whole, that is, they are only understandable as (inter-)related aspects and not as self-reliant elements. In what follows, the task is to question the four established models (figs. 1 to 4). This questioning is not exhaustive but rather exemplary for modelling higher education didactics, and aims to find solutions for overcoming simplifications or false abstractions.

Describe or Explain? The Use of Modelling

Polarizing Axes

The first example of modelling is the model of undergraduate research and inquiry by Healey and Jenkins (2009), which is the most cited of the four examples. To understand its logic, its construction shall be explained. It polarizes along two orthogonal axes (fig. 1); on the one hand, between the active-participative vs. the more receptive roles of students and, on the other, between the research process vs. the research outcome as matters of learning. This model is based on earlier concepts by Griffiths (2004) which, according to reports by those authors, were developed as a sideline in a project about the relations of research and teaching. Thus, the model displays different types of undergraduate research and inquiry in four sections.

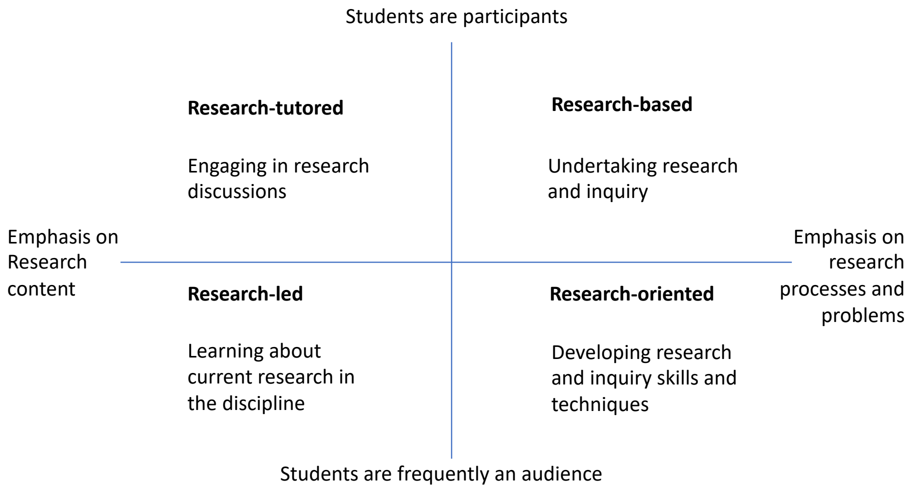

Fig. 1.: The nature of undergraduate research and inquiry, quoted from Healey and Jenkins (2009)

Levy and Petrulis (2012) (fig. 2) modify Healey and Jenkins' model and highlight further aspects of undergraduate research and inquiry. First, they take into account the difference between constructing knowledge from an individual or from a collective perspective. Their main concern is that knowledge can be new to the individual student but not necessarily new to the scientific community to which they start to belong (cf. Levy, 2009). This distinction is illuminated in the horizontal axis. The new model (fig. 2) therefore depicts four types of concrete learning actions – "producing, authoring, identifying, and pursuing". The first two actions refer to inquiry for knowledge-building and discovery; this implies that *new* knowledge is built by students' learning activities. Identifying and pursuing are types of inquiry for learning or exploring *existing* knowledge; this can be new to the individual learners only. Subsequently, Levy and Petrulis (2012) modified the model again to illuminate the differences between more and less support from the teachers.

So far, the construction of these models (figs. 1 and 2) mainly operates with binary distinctions with regard to (a) the roles of students and teachers, (b) teaching activities, (c) learning activities, and (d) the epistemic relation to knowledge (old/new; individual/ collective gain of knowledge). But what dimensions do these models leave out, and in what ways is this relevant to their power to explain higher education didactics and bring closer what is otherwise not feasible?

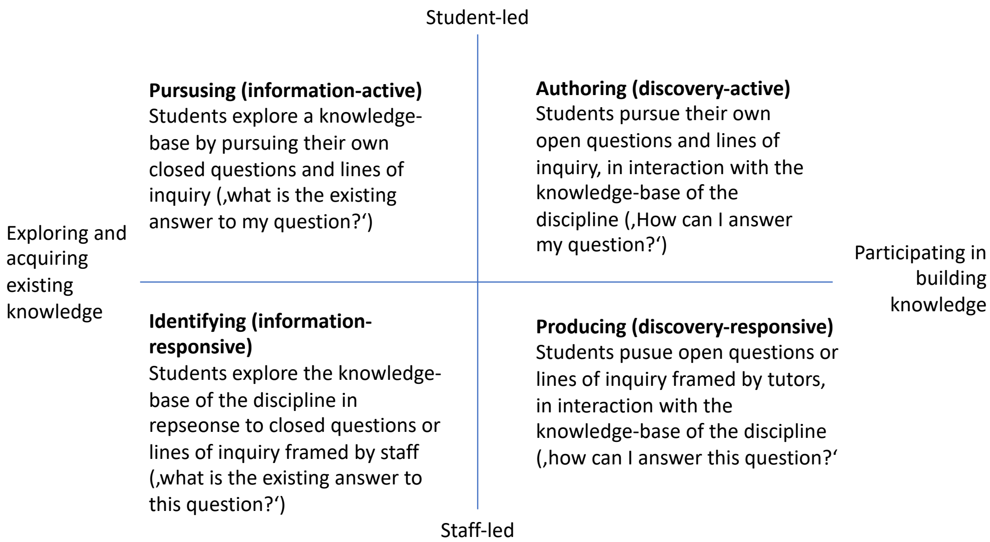

Fig. 2: Quoted from Healey and Jenkins (2009) based on Levy and Petrulis (2007, p. 3)

The opposites symbolized by the axes abstract from many of the concrete phenomena in the many facets of teaching and learning in science. As explained in the introduction, this is not problematic as such. The question is whether relevant issues are ignored such that particular insights or imaginations for higher education didactics are impaired. To discover aspects not recognized in the models and their implications, one has to look for the abstractions which have been made: Which concrete dimensions of teaching and learning are no longer addressed and no longer visible?

Facets neglected include, those about the concrete learning activities when students engage with research and inquiry: (1) Is the relationship between the teacher and the learners really a collaborative and insightful one – if yes, in what ways when, and why is there perhaps a lack of collaboration and understanding? To explain this lack, the second dimension, the learning matter, is important: (2) What are the main characteristics of the research object and how complex is it? Is it accessible by concrete-sensual experiences such as a stone falling into the water or people's conversation? Is it a phenomenon with a distinct shape (like a table) and with a clear beginning and end (e.g. a course in Geography)? In other words, can the phenomenon be observed completely by a researcher's/learner's sensual perception in a particular situation? And, if not, how does this affect the teaching-learning-situation? Given that the subject of teaching is mainly a theoretical object such as 'society' or 'identity', which scientists think of as existing in reality but without evident boundaries, how can teaching support students to make relevant theoretical experiences with such objects?

All these questions are salient with respect to the third dimension, the relationship of learners towards themselves: (3) Is (and in what ways) the learning challenge related to the comprehension of scientific theories and research? Is it necessary for the learner to discover a particular "horizon of significance" (Taylor, 1991) as relevant for him-/herself? Learning in science as well as research practices requires capacities of (precise) perceiving, skimming, measuring, interpreting, questioning, evaluating etc. All of this is not devoid of ethical and value-related dimensions. 'Doing science' is therefore both (meta-)cognitive and ethical. Students' experience in undergraduate research and inquiry-based learning needs recognition in these terms. In what ways do they feel challenged, or even overstrained as newcomers, since they are not used to radically questioning familiar beliefs?

The students' "horizons of significance" as they develop in a particular scientific domain are often neglected didactically, or at least considered as subordinate to the "content" or the "subject matter". However, teachers' awareness of students' worldviews and of their emotional-intellectual way of experiencing is essential to acting purposefully and meaningfully in educational practices. If students, for example, are to acquire an understanding of why propositions like '*Modern society is yellow*' or '*Mary's identity is bigger than Paul's*' are scientifically nonsense, they are dealing with a particular horizon of scientific thinking. Understanding the quality of judgments, their particular relevance, and what is sense or nonsense is often unclear to students (and probably not as self-evident as in these examples). To understand them, students would need to make experiences in their respective fields, using concepts and their logic in theory.

Concomitantly, they would need to learn not only the definition of concepts like "society", "identity" or "evolution", but also their significance and their epistemological status within scientific reasoning. Their learning would also have to be about transforming and developing their worldview (cf. Vianna, Hougaard & Stetsenko, 2014) as a reflected and coherent framework, in which e.g. they cannot deny that the "evolution of species" occurred simply because no one has ever directly experienced the process of evolution. Capacities of scientific reasoning require a certain type of experience concerning the history and genesis of scientific concepts, methods and beliefs, and thus scientific reasoning develops with the consciousness of different epistemic cultures (Knorr Cetina & Reichmann, 2015). As a rule, capacities of scientific reasoning also build on contradicting everyday-life experience. For example, "matter" in the physics of Einstein is not the same as what a child thinks about it. This implies that learning in the context of research occurs also as a rupture with regard to common sense beliefs and paradigms (cf. Bachelard, 1984). Didactically, all of this needs to be recognized as core features of undergraduate research and inquiry-based learning.

Yet these considerations are not indicated by the binary construction of axes in the models discussed (figs. 1 and 2). If a model for undergraduate research and inquiry-based learning were to create a basis for a reflection of this issue, it would need to incorporate insights from the philosophy of science and relate these to apparent features of activities within undergraduate research and inquiry-based learning. However, the models provided by Healey and Jenkins, and Levy and Petrulis, with their polarizing axes, show some deficits in this respect. Research processes cannot be conducted without reflecting upon the available stores of knowledge. But both models' polarizing axes separate these aspects. And vice versa, research findings cannot be interpreted without any reference to the research process. Similarly, reception does not exclude active participation in research or, conversely, active participation in research does not exclude receptive learning. The two models presented primarily satisfy the need for a systematic approach to formats of teaching and learning practices rather than explaining or developing them.

To corroborate this argument, further problems consist in the fact that university teachers are not provided with a framework to decide how and when scientific research can be turned over to in- or less experienced students, or to reflect about didactics raising, e.g., the sense of responsibility for critical thinking, and students' aspirations to independent scientific research at a methodical, theoretical and philosophical level. In addition, teaching/education in a research- and inquiry-based manner implies more than just reflecting these decisions or answers. Teaching is ultimately an interaction with concrete students conducted through in situ relationships of collaboration.

Another important argument here is that the two models using polarizing axes (fig. 1 and 2) do not make a clear distinction between teaching and learning activities. We do not know whether the models illustrate the students as they are seen *by the teacher* as an observer rather than an active participant, or whether they represent *students* genuinely complying with one or the other role. One might argue that these models idealize the effects of social interaction, and that if teachers address students as an audience, then they will act as alert listeners. But why is it then that students do not always comply with the roles teachers allocate to them? These models could help to explore and explain these issues. But given the polarizing axes, neither of the models meet this claim, because they do not deal with events that would be hidden, or at least not directly observable. To sum up, the general problem seems to lie in the construction of polarizing axes and the resulting abstractions.

Wheel Models

There are several different issues with regard to the model introduced by Brew (fig. 3). Brew (2013) criticizes the model by Healey and Jenkins as well as its advancement and modification by Levy and Petrulis. Brew's critique is similar to mine in the previous section, although she acknowledges the practicability of the models:

> It is clear that these frameworks are helpful for academics in thinking through aspects of research and/or inquiry-based learning, but they have some limitations. For example, it is difficult to see how students can be developing research and inquiry skills when they are an audience for research as suggested by the Healey and Jenkins model. Further, in that model, there is no space given to where students are engaging in debates about the history, sociology and philosophy of research. The Levy and Petrulis model lacks clarity, for example, about what is meant by 'more support' and 'less support'. (Brew, 2013, p. 608)

In her own model, Brew (2013) turns to circles and divisions similar to a 'wheel', instead of polarizing axes, and pays attention to decision responsibilities, e.g. whether teachers or students choose a topic, or whether they negotiate this, and whether the student or teacher is responsible for assessing the outcome. Brew's model should thus help to understand the 'complex decision'-making in higher education on 'different levels' (Brew 2013, pp. 604-5). In particular, Brew distinguishes between 'curricular and pedagogical decisions' (p. 606), and argues that from 'a curriculum perspective, […] questions arise about the overall structure of the course' (p. 608), whereas 'from a pedagogical point of view', 'questions arise about […] the integration of the different elements' of the relationship between teachers and students (ibid.).

From the pedagogical perspective, Brew emphasises a 'student-centred way of thinking' (p. 609), and independent of this, from the institutional perspective she stresses 'that universities should progressively become scholarly knowledge-building communities where academics and students work together to learn and to solve problems of the world' (ibid.). Against this backdrop, she discerns the challenge to understand the 'complex interaction between curricular intentions and research intentions' (p. 610). Thus, Brew's model (fig. 3) is meant as a holistic conception of a student-centred form of higher education where different 'levels of autonomy' as well as different 'aspects of inquiry' can systematically be reflected in their dynamics (p. 614).

Brew's intention to support teachers' thorough reflection on the students' and the institution's perspectives, corresponds with the presentation of many more facets of the teaching-learning process compared to Healey and Jenkins' or Levy and Petrulis' models with their polarizing axes. However, if we look closely, the possible dynamics of learning processes are not explained or depicted here. Brew's model also abstracts from concrete issues of experiencing.

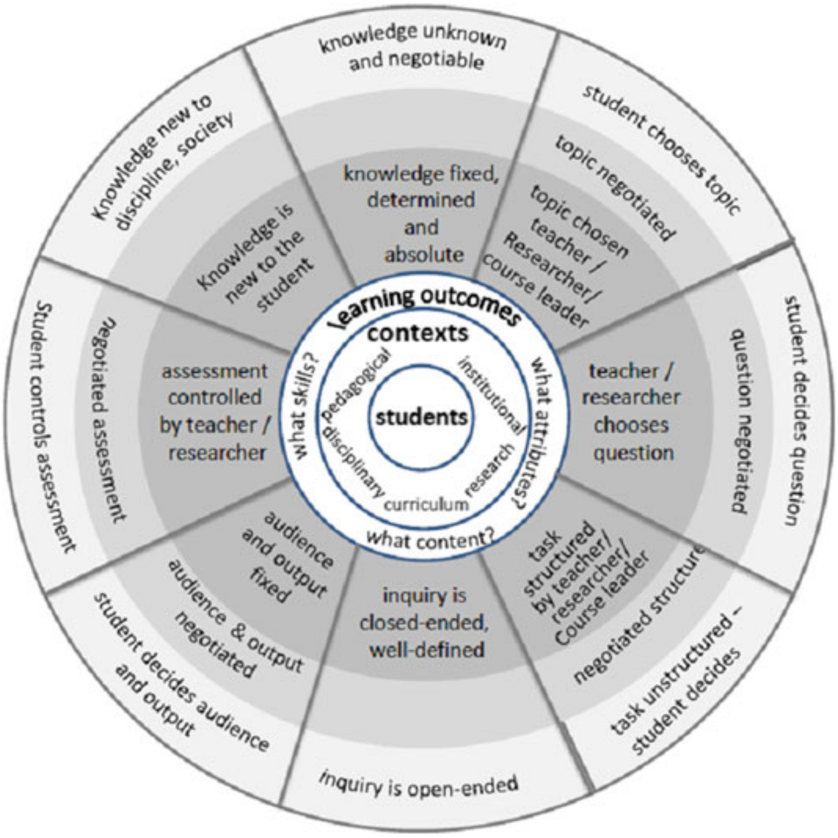

Fig. 3. A holistic Model for Research-based Learning Decision-Making, Brew (2013, p. 613)

The change from learning through a structured task to learning with an unstructured task, for example, is likely to result in uncertainty as it shifts the learning to a higher level. This could (unfavourably) be seen as trivial in the sense that it is merely a teacher's decision to either embrace uncertainty or to mitigate it by scaffolding activities and the like. The triviality of this decision-making could be overcome by reflecting on the consequences for both teachers and students. However, Brew leaves this unclear.

Another example of modelling university teaching for undergraduate research and inquiry-based learning in a holistic way is by Reinmann (2016) (fig. 4). Her wheel-figure highlights three types of learning activities: (i) 'Learning about research' means that the relationship of the student towards research matters requires reception, to become informed, to listen, to watch or to read about scientific inquiry; (ii) 'Learning through research' is the relationship of the student towards research matters, which implies production and exploration, i.e. to discover something, to find a research question, to try to answer it with scientific means and methods etc.; and (iii) finally, 'learning for research' stands for the relationship of the student towards research matters, which mediates between the first two.

Therefore this learning is about methods and metacognitions which are not necessarily new to the scientific community, but which open up a potential to discover something new.

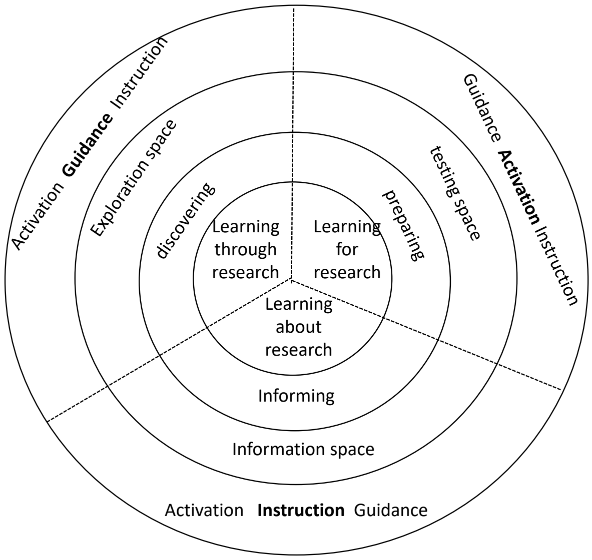

Fig. 4: Model for Academic Teaching, Reinmann, 2016, p. 236 (my translation)

For Reinmann, all three forms of learning are interdependent in university teaching and cannot exist without one other. Given Reinmann's divisions, the model (fig. 4) shows that didactical planning needs to consider three different spaces of learning: (i) an 'information space', (ii) an 'exploration space', and (iii) a 'testing space'. In all these spaces teaching fulfils the tasks of instruction (knowledge transmission), and guiding or supporting as well as activating students, however the focus on these tasks varies: Learning about research mainly refers to instruction, learning through research refers to guidance or support, and learning for research refers to activation. Yet, questions like 'How and when should teachers proceed from one didactical setting to another?', or 'Is it important to provide an exhaustive information space before exploring a particular matter?' have no guidance through the model.

To compare the models presented in this section: New aspects raised by Brew are student autonomy and the openness of the research process, which university teachers should take into account. Her model also tries to address the many facets of teachers' decisions about the learning process in a manner that should support student-centred forms of learning. It is for this purpose that she presents a wheel figure (fig. 3) instead of polarizing axes, and promotes a holistic view. Reinmann's model (fig. 4) preserves this holistic view but reduces the variety of aspects to three facets. These facets are presented in a more interconnected way than in Brew's model. However, Reinmann's model moves slightly away from a strong commitment to student-centred forms of teaching towards indicating that more traditional forms of teaching are also meaningful if they are realized in an interrelated manner. Overall, according to Reinmann, the purpose of academic teaching should be subordinated to the ideal of empowering students for scientific reasoning and research.

However, neglected aspects remain with regard to (1) the relationship between teachers and learners: What kind of relation is necessary and why? In what ways is it sound to shift from instruction to guidance and from here to activation? And since these qualities are not exhaustive, how do they interact with e.g. fear, resistance or critique? Teachers' feedback to students' particular engagement with scientific problems is undeniably relevant for (2) the individual learner's relation to the subject matter. The two wheel models, however, do not display this dimension sufficiently. If teachers look for guidance in reflecting their feedback to students, they will find hardly any support in these four models (figs. 1 to 4). None of them depicts how students' horizons of significance (their meaningful self-relation (3) shift as they are influenced by learning, nor considers how learners might be blocked or hindered by themselves from achieving a scientific and relevant goal.

Long-term and Short-term Goals in Didactics

In what follows, two new, alternative models for university teaching are introduced to develop an epistemologically and ethically deepened understanding of the scientific practices to which undergraduate research and inquiry belong. The first model (fig. 5), the *coordination model*, captures three levels of research practice and experience conceptualized as the coordination of theory and evidence. Its perspective is simultaneously one of a student-learner as well as a researcher-learner, but not the university teacher. In the second model (fig. 6), the *enculturation model*, university teaching is addressed from the standpoint of the teacher-subject by means of *long-term* and *short-term goals*, insofar as university teachers evaluate their actions not only in the light of a concrete situation in lectures or seminars and their immediate outcomes, but also as an ethical intervention into students' life-worlds and worldviews, with long-term consequences. In this sense, the enculturation process of students is addressed.

Enculturation is often understood as an *adaptation to* or *assimilation by* a *given* culture. In science, this can be the epistemic culture of a certain discipline (Knorr Cetina & Reichmann, 2015). The community-of-practice-research relates enculturation also to changes of identity, proficiency and expertise, and interprets research-driven learning as a form of apprenticeship (cf. Feldman et al., 2013). In what follows, the argument goes further, to see theoretical experience, knowledge acquisition, and scientific discovery itself as deeply rooted in processes of enculturation.

The coordination of theory and evidence is considered as the essence of research-related proficiency and thus of research-driven learning. It is determined, according to Deanna Kuhn, as the core competence of scientists:

> The scientist (a) is able to consciously articulate a theory that he or she accepts, (b) knows what evidence does and could support it and what evidence does or would contradict it, and (c) is able to justify why the coordination of available theories and evidence has led him or her to accept that theory and reject others purporting to account for the same phenomena. Although they do not encompass all aspects of scientific thinking, these skills in coordinating theories and evidence arguably are the most central, essential, and general skills that define scientific thinking. (Deanna Kuhn, 1989, p. 674)

This definition is relevant to acknowledge not only skills, but the entire change in students' internal behaviour, including their worldviews and fundamental ethical and epistemic beliefs. In what follows, this will be addressed as an important aspect of the *scientification* of intellectual behaviour on an individual level (Langemeyer, 2015a, 2015b). 'Scientification' describes the quality of the production of knowledge, both individually as well as societally, as it contributes to more and more exact, valid, profound and relevant forms of knowledge. The university plays an important role in the long-term societal process of scientification, which changes the mode of production and the entire societal exchange. Thus, scientification is (a) a material process to institutionalize certain scientific practices, affirming certain pieces of approved knowledge as achievements towards objective truth, certainty, and a common acknowledgement of expectations. In sum, this means that these stores of knowledge become societally relevant, and usable for different purposes. Institutionalizing scientific results is not only important within the societal organization to further scientific research. It also contributes to stability and efficacy in society, to the development of forces of production, and reciprocally to the reputation of scientific institutions, titles, proficiency and expertise. In other words, this institutionalization is simultaneously about forming societal practice through scientific expertise *and* about building up prestige for science as such. Therefore, the process of institutionalization can be recognized as a contribution to a field of power structures in society. These power structures are not necessarily scientific themselves, but they support the relevance of universities as well as research institutions. Scientists who belong to this power structure participate in organizing the disposal of resources as well as opportunities to influence people's opinions and the formation of their worldviews.

However, the process of scientification must be understood also as (b) a process of radical doubting and criticizing, and thus even as an effort to break away from established forms of scientific societal practice, technologies, ethics, worldviews, and paradigms, and of reorganizing science and the field of power structures (Langemeyer, 2015a, ch. 4; Langemeyer, 2017). These two counter-movements can be depicted as levels of reflection and critique, along with a reworking of the particular theories, methods and hypotheses. The coordination model (fig. 5) highlights a number of situations of decision-making in research and inquiry: Similarly to professional researchers, students may be confronted at first with some obvious mismatches between the theory (displayed by their research question or hypotheses) and the data or research material provided. This can be a starting point for further research-related activities and decisions: Students may start to test in what ways the data is insufficient or irrelevant to the question of evidence, and these activities may guide their reflections. In addition, they may explore how better data can be collected, and so they need to anticipate new possibilities for relevant insights. Next, again similarly to researchers, students might move on to criticize the quality of either the hypotheses or the data (which often requires reflection of broad knowledge), or the way they are related to each other. Thus, they start to collect new data and/or modify the theory. Depending on the intensity of inquiry, this research may lead to philosophical reflections on the paradigm to which the theory belongs. Concomitantly, students need to anticipate how a paradigm shift could open up new possibilities to coordinate theory and evidence with respect to a certain research problem. Theoretical experience with the limits and shortcomings of a system of thought and belief, or of a 'thinking style' (which will be explained later), thus become paramount.

The two sides of the scientification process as both critique and affirmative institutionalization, have great influence on the spaces of experiencing for both researchers/teachers and students/learners. The process of criticizing and breaking away determines an experience of disconformity. Consequently, this space (or horizon of significance) is more likely characterized by insecurity, uncertainty, isolation and a lack of recognition and support.

In contradistinction, the process of establishing a scientific discipline, paradigm or scientific approach usually determines a space of experience of conformity with a centre of power, with plenty of possibilities to attain certainty, security, membership and recognition. The role model here implies respect of authorities, and acceptance of a given order.

For both teachers and students, the two dimensions of scientification are linked to different forms of existence, i.e. different ways of life and different models of being an intellectual in society. Although the trajectories of these roles point in opposite directions, I assume that in universities, scientists and teachers as well as students are challenged to compromise and balance between them. All of this influences teachers' and students' aspirations to engage with science (a particular scientific discipline) in general, as well as with concrete situations and tasks of research and inquiry.

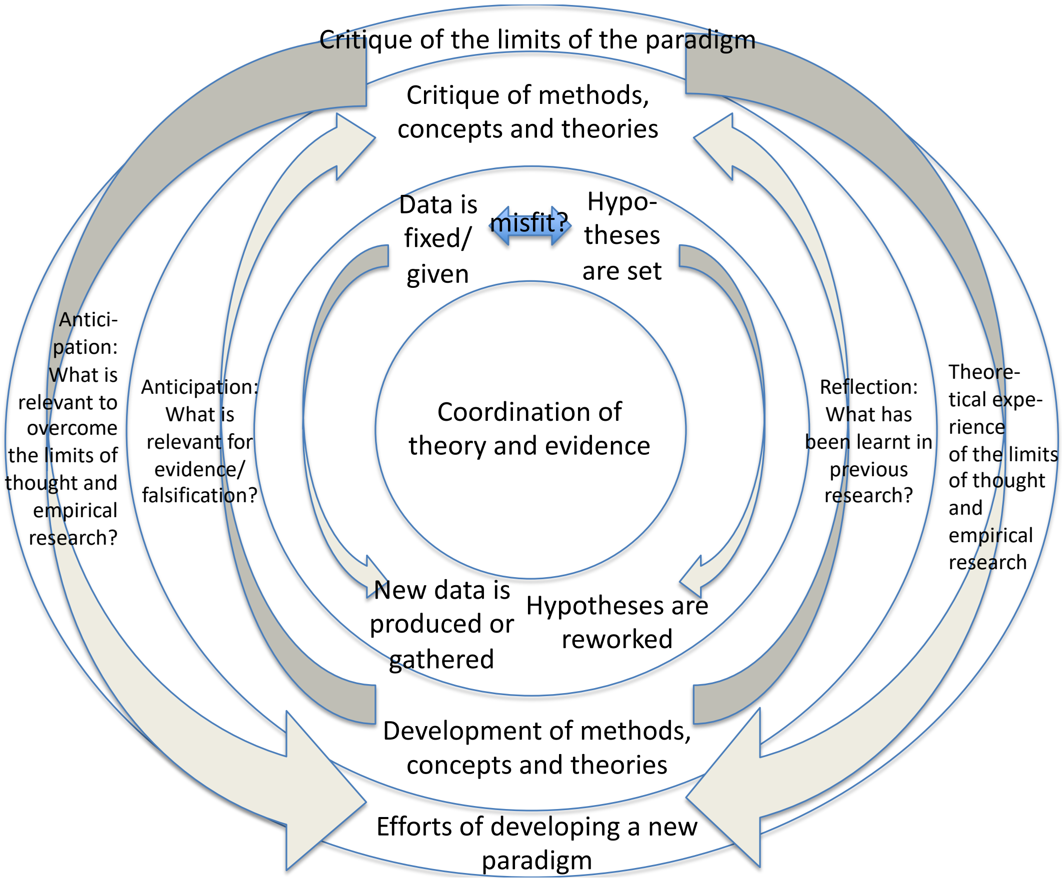

Fig. 5: Three Levels of Experience Gained in Research and Inquiry-Based Learning through the Coordination of Theory and Evidence.

Against this backdrop, I return to the idea of distinguishing between the short-term and long-term goals of teaching – referring to the enculturation model (fig. 6). Short-term goals can change in a teaching situation, although the long-term goal may remain in place; every short-term goal lends a more concrete shape to the long-term goal. The analytical assessment thus involves reflections of students' level of research experience and competence, the level of universities' curricula and research programs as institutions, as well as the level of sciences and universities as life-worlds as particular material forms of existence. By distinguishing these levels, it is possible to reconsider the horizon of significance as to how and why students engage with research and inquiry. In particular, it is possible to reflect how they are or become involved with the two aspects of scientification: the institutionalization process (as affirmation) and the critique of knowledge.

Teaching and learning are thus not only interactions which are often initiated or guided by the teacher in relation to particular students. Intentionally or not, teachers serve as role models with which students identify, or sometimes disidentify, thus embracing or rejecting different ways of life and different worldviews. Experiences of this kind are constitutive on an inter- and intrapersonal level. At the same time, the three levels of experience in research and inquiry (fig. 5) become relevant to the students, for they ask themselves why it is important to get involved in certain research problems rather than others. Students are always on the look out to find authenticity and significance for themselves in the broader context of science as a societal dimension, and its societal functions as an epistemic but also a world-changing practice, as an institution with authority and prestige, as a legitimation and prerequisite to obtain certain positions and occupancies, and to exercise certain competences in society. Teachers should become aware of these horizons of significance as students perceive them, and therefore they need to reflect on their teaching activities in the light of long-term goals (fig. 6).

Thus, for undergraduate research and inquiry, in pursuing his or her long-term goal the teacher tries to achieve a process of enculturation of students. The choice between modes of learning is determined by contextual circumstances and constraints, but is not as essential as the idea of the enculturation process. Beyond identification with its goals and institutional roles, this encompasses familiarization with the different nature of scientific types of thinking, dissemination of a specific scientific ethos, and strictness of a specific discipline. Other explanations follow below.

It is important at this point to emphasize that the teacher's *short-term goals* under the long-term goal of "enculturation" may vary, as they are put into concrete terms under different premises, which may change. Structural patterns of teaching do not correspond to a mere either-or decision between recipient and active (in the role of students), and result vs. process (for the objective of learning), respectively. Teaching and learning always exist in a dynamic situation in which the relations of long-term and short-term goals need to be analysed as either harmonic or dissonant, depending on the horizons of significance of the whole scientific field. Figure 6 therefore illuminates trajectories of the personal relationships between teachers and learners in science.

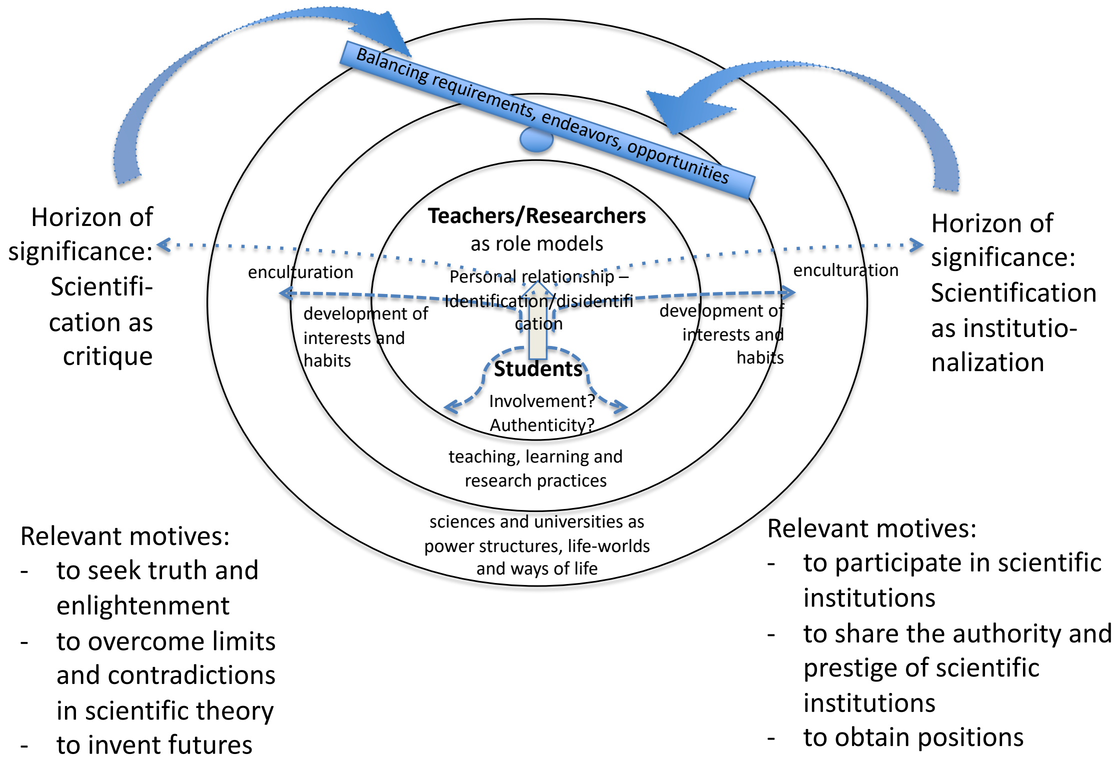

Fig. 6: Enculturation in Science through Undergraduate Research and Inquiry as a Long-Term Goal

Enculturation as a Leading Principle

The concept of "enculturation" in my theoretical framework stems from several sources. It is based in *gestalt* psychology and its reception by the philosopher Michael Polanyi, and then on the biologist and science theoretician Ludwik Fleck and thirdly, in the psychology of Lev S. Vygotsky. Their frameworks intersect in many ways, but these authors did not work in a common socio-historical context.

The assumption of a long-term goal called "enculturation" is imperative because research processes are open (at least in part) to something problematic, something unforeseeable, which has not yet been recognized or happens at random (cf. Langemeyer, 2015a, ch. 4). Therefore, teaching needs to arouse in the mind of the learner an attitude of querying and investigating (Huber 2009, p. 9). Developing expertise in science is a prolonged process of involvement and self-education, which cannot ever be completed. But each time it poses anew the challenge to pursue goals authentic to oneself. In this sense, it is assumed that teaching undergraduate research and inquiry serves to demonstrate different ways of being an expert researcher to students. Simultaneously, undergraduate research and inquiry-based learning allows students to solve problems in a more or less independent way, and thereby deepen their knowledge and understanding of a scientific area. In this way, subjectively meaningful relations between teachers and students may emerge and may also establish significant relations between individual learning and the processes of scientification.

Consequently, individual learning moves up to ‘higher levels’ in the sense that it gets closer to the general questions of science. Students are thus also meant to experience science itself as a horizon of significance. In a participatory way, university teachers may therefore demonstrate scientific approaches only as possible modes of thinking, and illustrate the differences between one way of producing a theory and others. The demonstration of specific and exemplary problem solutions is supposed to make students capable of deciding between one methodological approach and others, and to actively handle research issues through joint discussions. The long-term goal of “enculturation” in this way *accompanies* a systematic and didactic treatment of the subject matter. The long-term goal does not disappear in this way, nor does it compete, but it is interwoven into the intentions of short-term goals. Research-driven teaching in this way encompasses several short-term goals pursued partly simultaneously. However, there is one guiding principle in which students are to be advanced beyond a given thinking horizon to allow them to transcend what they previously recognized and understood, and continue to think independently with regard to general problems.

The horizon opened up by teaching undergraduate research and inquiry-based learning depends on the discipline involved and how the compromise between the two sides of scientification can be resolved. The broadening of the cognitive horizon does not necessarily (and probably only rarely) coincide with the objective that after a session of undergraduate research and inquiry-based learning, students will obtain the competence of researching (cf. Langemeyer, 2013; 2015a). Instead, this capacity requires taking a stance towards both scientification as affirmative institutionalization, as well as critique. Consequently, the imagination and anticipation involved in science is also especially established when working on scientifically unsolved problems.

Theoretical Foundations of the Enculturation Concept

These assumptions will be underlined further below, with Polanyi, Fleck, and Vygotsky. These authors were strongly influenced by gestalt psychology, whose holistic core concept implies that objects of perception are entities meaning more than the sum of their parts.

In what follows, enculturation refers to the entirety of psychic activity involved in perceiving, thinking, reasoning, imagining and learning, *as it connects the individual to the societal horizons of significance*. In these processes, as gestalt psychology conveys, elements are arranged as a shape (or gestalt) when they are moved into the foreground together, thus making their self-reliant elements part of the background. Recognizing a face, for instance, means making its elements (mainly the eyes, nose and mouth) become an entity. The face as a whole is seen “through” these elements. Polanyi uses the term ‘subsidiary,’ i.e. a provisional awareness for what remains recognizable in the background, as something on which one relies in order to comprehend.

> Being aware of something in a subsidiary way means that we do not realize it in itself but as a point of reference or tool pointing beyond itself. (Polanyi, 1959, p. 44, as quoted in Neuweg 1999, p. 189).

In research, the same principle can be found: ‘To diagnose a disease,’ for example, ‘is to grasp the joint meaning of its symptoms, many of which we could not specify; so we know these particulars only by relying on them as clues.’ (Polanyi 1961; p. 243). Like this form of knowing, researching also implies accepting uncertainties:

> Many of the clues of perception cannot be known in themselves at all; others can be traced only by acute scientific analysis; but all of them can serve the purpose of seeing what is in front of us only if we make no attempt at looking at them or attend to them in themselves. They must be left to abide in the role of unspecifiable particulars of the spectacle perceived by our eyes if we are to see anything at all. (Ibid., p. 242)

Thinking (and not only for scientific inquiry) implies in principle a movement from a *proximal* to a *distal* term (cf. ibid. Polanyi 1985, p. 19). In mental action the *integration* between the proximal and the distal terms is experienced both actively and passively. ‘On the one hand, it is caused but, on the other hand, it is actively experienced by the subject’ (Neuweg 1999, p. 206), as can be explained by the example of a scientific discovery: ‘We *make* it, and yet it *surprises* us’ (ibid.). This, being the actor of that integration and simultaneously the recipient of its results, also makes up the character, sometimes difficult to grasp, of learning and research processes. Nevertheless, it is useful to pay attention to this. Discovery often arouses enthusiasm and motivation in the person engaged with learning and researching. And in science, the nature of this experience is often simultaneously a transgression of individual limits. Therefore, the socio-cultural dimension of activities like thinking, perceiving, researching, diagnosing etc. needs to be explained.

Referring to Fleck, certain forms of perception or thinking are organized and cultivated in collectives such as scientific communities. When developing (or advancing) theories, these communities contain cultural powers to reinforce certain thinking styles. In addition, I suggest that they provide a ‘horizon of significance’. However, communities are also powerful when it comes to a critique and dissolution of specific systems of perception in order to deliberately establish a changed relation of elements with regard to a new *gestalt*. This new relation can be guided by a specific new *theoretical* organization of seeing and thinking. As everyday theories lend structure to perceptions, mostly unknown to people in their everyday lives, students must first of all learn how to reflect on the premises of their thinking. However, any re-organization of thinking guided by scientific principles builds on theoretical experiences from earlier generations and scientific communities constituting a certain paradigm. The difficulty of questioning and changing forms of perception is exemplified in Vygotsky's comment on the findings about the rotation of the earth about the sun, and the vision of ants:

> How much critical work on our perceptions and, thus, on the concepts linked with them, how much direct study of these concepts—visibility, invisibility, apparent movement—how much creation of new concepts, of new links between concepts, how much modifications of the very concepts of vision, light, movement etc. was needed to establish these facts! (Vygotsky, 1997, p. 251).

Similarly, Fleck argues that the specific paradigm of scientific theories questioning concepts and types of perception is not only a learning process for an atomized individual. It must be seen within the horizon of worldviews that are passed on, not only by scientific communities but also by other communities in society. As different worldviews compete with one other, scientific critique remains essential, and plays an important role in the enculturation process of students. Otherwise, they would miss what Vygotsky explains as the essence of science:

> After all, if concepts, as tools, were set aside for particular facts of experience in advance, all science would be superfluous; then a thousand administrator-registrators or statistician-counters could not down the universe on cards, graphs, columns. Scientific knowledge differs from the registration of a fact in that it selects the concept needed, i.e., it analyses both fact and concept. (Ibid.)

The process of *developing* a fact is seen by Fleck as an outcome of the work of *thinking collectives*. For only groups would be able to muster the energy to transform the unorganized elements of all real relations into an ordered system of knowledge (Thomas S. Kuhn calls this the generation of a paradigm, cf. Babich, 2003). Fleck underlines the power in this collective work in the following image:

> Interposed between the subject and the object is a third element, community. It is creative like the subject, stubborn like the object, and dangerous like an elementary force. (Fleck 2001 [1960], p. 470).

The cultural framework within which "facts" are seen and interpreted arises historically in relation to the common way of life and constitutes the background to the way of inquiring and investigating. It determines, for instance, the 'mood of the scientist' which decides 'whether the new *gestalt* appeared to him as a symbolic bright vision or as a weak prospect of opposition slowing down the free, almost arbitrary choice among the alternating images' (Fleck 2011 [1935], p. 232).

This confronts researchers and students in science with the challenge of giving up many types of everyday thinking which they have learned culturally in their milieu. They need to undergo a different enculturation process in order to be able to understand the many scientific experiences of earlier generations and scientific communities.

Fleck's approach and his use of the concept of collective styles of thinking shows what happens when people want to conduct scientific research but were *not encultured* in a specific discipline and its patterns of thought and perception. The insight into this necessity arises from the foundation of activities observed specifically in several bacteriological laboratories. To Fleck one experience turned out to be decisive.

When Fleck (2011 [1945], pp. 492-3; 2011 [1948], pp. 538-40) came as a prisoner to the Buchenwald concentration camp in 1943 he was to work there as a specialist in vaccines against epidemic typhus. Indirectly, he contributed to a useless vaccine being delivered to SS soldiers (ibid.). The background to the production of an ineffective vaccine can be used to explain the importance of enculturation. A group of prisoners had been charged with developing the vaccine. Fleck recognized the uselessness of the vaccine they produced, but kept this finding to himself to protect the group from the violence of the SS. For nearly two years, Fleck thus had the possibility to 'observe the scientific efforts of a group made up exclusively of laymen' (1983 [1935], pp. 135-6). The group was commissioned to solve complicated problems in the field of epidemic typhus, with fully equipped laboratories, laboratory animals, and a library of literature for their work. However, the head of the group, who was a physician but a layman in bacteriology, merely supplied materials and drove people on to work. One key problem was to study whether epidemic typhus pathogens (*Rickettsia prowazekii*) in the lungs of mice and rabbits infected through the nose could be found by a certain method. As the staff had never seen Rickettsia and were not familiar with the usual bacteriological flora of the lungs and bronchi, nor with the cellular elements of these organs, they had to use, 'descriptions and illustrations to learn to see these elementary things, i.e. somehow go the opposite way relative to normal processes of detection.' (Ibid.) As a consequence the group, 'exactly in correspondence with the rules in the books' and 'with high accuracy,' had found 'all stages of the development cycle of Rickettsia and their required sequence' although 'they did not really have these pathogens in their material at that time.' (Ibid.) 'The motor of this imaginary synthesis,' according to Fleck, was 'mutual reinforcement,' the 'build-up of a high level of expectancy to see specific effects,' the 'desire to be appreciated,' 'competition,' and the 'wish to satisfy their head, who badly wanted to see results'. Fleck comments on this situation (ibid.):

> The elements of the mood in principle were identical to those normally encountered. I observed such a situation – the birth of discovery.

What was 'discovered' by these lay researchers, according to Fleck, were eosin granules originating from the leucocytes of rabbits; the group believed, however, that they had just found the *Rickettsia* for which they had been looking.

> Then the entire cycle grew step by step. Things that did not agree were ascribed to permissible discrepancies among opinions in the field. […] The unavoidable "biological inaccuracy" became the guiding principle invented by the doctor of law and philosophy mentioned in the list of members of the group, who was the highest critical authority in the group. (Ibid.)

Against this backdrop, Fleck concludes that 'the social mechanism of the generation of a mistake [was] identical to the mechanism of generation of true knowledge' (Fleck, 1983 [1946], p. 140).

Fleck's enculturation concept allows us to show several central aspects of learning processes in undergraduate research and inquiry. It becomes obvious that a scientific course of studies in one discipline means more than just knowledge of scientific and technical literature and access to research equipment and methods. In particular, the indispensable process of independently experiencing research, inquiry and the requirements to be met in scientific aspects will fail in the absence of the need to have been part of a thinking collective. Only participation in scientific groups and their work allows them to make meaningful and adequate uses of the possibilities of thinking and action available. Only against the background of being a participant of a thinking collective can both the continuation of a particular scientific approach and its critique and correction become possible.

At best, the enculturation process gives rise to important experiences in a particular reference system of a discipline through theoretical interpretation of research issues or 'facts.' As in Polanyi's concept of background knowledge, participation in a collective style of thinking leads to empirical experience and theoretical insight being arranged in a specific way. The concept determines how something can become an object of research, which objects can or must be objects of empirical research, and which ones are not eligible. For instance, up until the 16th century people:

> [...] had been able to find bones close to graveyards and study them, but the Middle Ages simply had no intellectual need for such observations; when it looked at a bone, it was able to see only what could be found also in books without any need to look (Fleck, 2011 [1935], p. 229).

The enculturation process is therefore more than just an experience by which newcomers are adapted to a given culture. It also includes active participation in and engagements with a community's practices and beliefs. In scientific research practices, this encloses the tensions of scientification as both affirmative institutionalizations and critique.

What Is the Consequence?

Against the backdrop of the concept of enculturation, undergraduate research and inquiry-based learning implies both involvement and a change in being. Students' involvement in the scientific field means understanding historically why former generations learnt to see the world differently, to reflect on one's own worldviews, and to learn to engage oneself in scientific problems of contemporary relevance. Furthermore, it means that students become aware of discrepancies between their personal experience and the experience made on the basis of scientific methods, concepts, and theories (cf. Hinchliffe, 2011). They start to develop a deeper knowledge of the reasons why a given set of data fits or does not fit with the evidence, and why they sometimes need to collect new data with a different quality, or to modify or change their theoretical point of view. Sometimes this even includes a critique of the paradigm in which the theory can be considered as plausible and relevant.

As has been shown, the "enculturation" concept is relevant for a profound understand of didactics for undergraduate research and inquiry-based learning. It becomes evident as a concretization of this process through personal relationships with teachers and their teaching, according to short-term goals (and not goals as such). Comprehending the process exceeds the need for a systematic classification of types of teaching format or modes of interaction as we perceive or observe them immediately. This is what the four models discussed in the first parts of this paper neglect. The key question for teachers, i.e. what currently is most important to students, is ultimately to be decided in the light of contextual circumstances, and the two aspects of the scientification process as affirmative institutionalization and critique in the field of a particular discipline or practice. Didactically, undergraduate research and inquiry-based learning can only be developed through orientation by the long-term goal of "enculturation", because it implies becoming an expert researcher-subject within a research field – although this development may only be partially realized by students.

Nevertheless, in the absence of this long-term perspective to advance (certain) research fields in an affirmative but also a critical way, undergraduate research and inquiry-based learning would have to be declared impossible. Given the limits of short-term goals, students would not become aware of their responsibility, and thus teaching would fail to contribute to the development of research capacities with regard to unsolved societal issues and competences for building new futures.

If the objectives of enhancements in the didactics of undergraduate research and inquiry-based learning are to be achieved, the responsible players need to obtain more profound insights into the complexity of the learning situation as a moment within an ambiguous enculturation and scientification process. The modelling introduced here is more than a means to some systematic understanding. It should also be taken as a basis to detect the concrete potentials and impairments of the particular development of becoming a researcher. It is societally and individually important that this becoming is not one-dimensional (a mere form of functioning in the organisation). The countless learning processes of becoming a researcher are ultimately the ways in which the different sciences are reproduced. And this responsibility should not be reduced to the use of models for some practical guidance.

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