The regulated teaching cycle in biology lessons

Der geregelte Unterrichtskreislauf im Biologieunterricht

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Abstract

The regulated teaching cycle is based on the main parameters of modern biology lessons. Due to the teaching cycle it is possible to structure biology lessons in a scientific way. The teaching cycle consists of five phases which are "Problem" – "Purpose" – "Planning" – "Acting" – "Reflecting" (fig. 1.). Drawing on the example of the "Lotus effect" the article explores the teaching cycle and how it can be used to structure biology lessons. The lessons benefit from the use of the teaching cycle in several ways. (1) The teaching follows a certain structure, (2) The learners acquire and internalize hypothetic-deductive working skills, which is vital for dealing with scientific issues, and (3) learners act target-orientated with respect to the problem's solution.

Key words

Regulated teaching cycle, 5 – E – Model, anchored instruction, problem – based teaching.

Zusammenfassung

Der geregelte Unterrichtskreislauf basiert auf den wichtigen Parametern eines modernen Biologieunterrichts (handlungsorientiert, problemorientiert, schülerorientiert).

Der Unterrichtskreislauf beinhaltet fünf Phasen: Situation/Phänomen – Problem – Handlungsabsicht – Planung – Handlung – Reflexion (fig. 1.) und strukturiert so die Biologiestunden.

Der Unterrichtskreislauf bietet mehrere Vorteile. (1) Der Unterricht folgt einer regelhaften Struktur. (2) Die Lernenden übernehmen und verinnerlichen den hypothetisch-deduktiven Weg des Erkenntnisgewinns bei der Bearbeitung biologischer Sachverhalte. (3) Die Lernenden agieren handlungsorientiert mit Blick auf die Lösung eines biologischen Problems. Diese Vorteile werden am Beispiel des Unterrichtskreislaufs zum Thema „Lotuseffekt" erläutert.

Schlüsselwörter

Geregelter Unterrichtskreislauf, 5-E-Model, anchored instruction, problemorientiertes Unterrichten

1. Introduction

Science education is of great significance. The association of German ministries of education (KMK) has declared recently that scientific education constantly contributes to the pupils' understanding of tasks or problems concerning nature and environment. Consequently, it enables learners to discover possibilities and solutions. Therefore, scientific education is an essential component of general education (KMK, 2005).

In order to understand nature and environment pupils need a fundamental basis, referred to as "scientific literacy" (Bybee, 1997; Gräber et al., 2002). Scientific literacy is achieved through appropriating various competences. In general, scientific literacy consists of scientific knowledge, and on internalizing processes by which scientific knowledge is developed (Scientific inquiry, compare Mayer, 2007). Thus, Prenzel et al. (2007, S. 61) state: „If the level of scientific knowledge continues to develop that rapidly, a different level of scientific literacy is required. In that case it would be vital to give pupils a general understanding of scientific thinking and operating processes"(translation by the author).

Modern biology teaching can no longer afford to consider biological facts only. Rather, a basic scientific background knowledge such as general biological principals or functionalities of organisms will have to be imparted.

Therefore, it seems inevitable to search for innovations and improvements in order to change science education for the better. Yet, it has to be said that a number of characteristics for well-structured biology lessons are, in fact, not too new. Already the consequent use of hypothetical-deductive reasoning (cf. Campbell & Reece, 2006) is oriented to pupil and science. Hypothetic-deductive reasoning offers a general pattern, structuring and shaping biology teaching, and, moreover, provides a learning environment that enables pupils to act self-reliant. The hypothetic-deductive reasoning pattern can be visualized through the regulated teaching cycle. This paper exemplifies the regulated teaching cycle on the basis of modern characteristics of biology teaching and clarifies the teaching cycle exemplarily.

2. Characteristics of modern biology teaching

Modern biology teaching follows moderate constructivism principles. The first approaches can already be found in J. A. Comenius' disquisitions. Comenius demands that teaching should not only consist of quoting important works (starting with the bible or alike) but should much rather focus on personal experiences and their logical connection. In works like "Orbis pictus", published in 1658, Comenius demands that scientific contends should primarily be imparted through direct observation and drawing conclusions (compare Pütz, 2007).

Still, modern constructivism has in fact not evolved into a interdisciplinary field of research before the end of the 1980's (cf. Duffy & Jonassen, 1992, Gerstenmaier & Mandl, 1995). Constructivism is a learning theory which assumes that learners control their learning processes themselves. Therefore, learners construct an individual learning situation which is most effective for their learning. The essence of the constructivist position is the concept of knowledge being formed through internal subjective constructions of ideas and concepts. Learners actively construct their own knowledge, firstly, by linking new knowledge to existing structures, but, secondly, also to inspiring, situational contexts. By the way, constructivism with its view on the subjective way of learning in fact means alternative education (Hartinger, 2006). High-quality teaching distinguishes itself by phases in which the learner is involved in thinking and acting. Klimsa (1993: S. 22) summarizes that "according to the constructivist paradigm, learning implies: percipience, experience, acting and communicating, in any casecomprehended as active and target-oriented processes" (translated into English by the author).

2.1. Action orientation: "The Evergreen"

"Activity-oriented learning" is the essential component of constructivism and, therefore, a main component of modern biology teaching. Object- or action orientation enables pupils to collaborate on the acquisition of knowledge. In practical tasks, pupils do not just gain specialist knowledge. Besides, they learn to take responsibility for their own learning processes and, furthermore, train cooperativeness. According to the action-orientated approach the best possible learning success can be obtained if the learner is acting for him- or herself. Since various senses are appealed, knowledge is easier kept in mind. The original encounter – the experience – strongly implies affective learning targets such as change of interests or structuring values. According to Gudjons (1998) there are five basic principles that characterize action-orientated learning:

- activation of many senses
- self-responsibility of learners
- methodical competence
- product-based approach
- working-methods facilitating cooperative acting e.g. group work

Experiments that are based on hypotheses can already comply with most of Gudjon's demanded principles. Consequently, modern biology teaching in sense of the teaching cycle is "action-orientated".

2.2. The Problem-based approach

Occasionally biology lessons are expected to pick up on questions regarding life such as "How to brush ones teeth?" or "How to keep a pet species-appropriate?" In this coherence it is also meant to pursue pedagogic aims. Yet, it is most important, that modern biology teaching does not relinquish its principle of treating contents science based. In the same way that science operates problem-based, teaching should focus on problems and their solution through action.

Biology teaching should not only aim for pupils understanding and knowing nature. Pupils should much rather understand themselves as being a part of nature und should be able to evaluate this issue. Raising consciousness in scientific terms implies first of all: Exposing and questioning problems. Why do plants need light?

- Why do early flowering plants develop subterranean tubers?
- Why do flowers allure insects?
- Why does effusive fertilizing impair waters?
- Why should animals be kept species-appropriate?
- Why should one brush teeth?

Pupils need to be capable of indicating problems and search for adequate solutions. Recognize and evaluate nature! Acting facilitates recognition. However, evaluation will only be possible through exposing problems.

2.3. Pupil-orientation: Anchored situation

The "Anchored Instruction" (Bransford et al., 1990) is an explicitly relevant approach for arranging learning environments in biology lessons. This approach assumes that the quality of knowledge can be interrelated to its acquisition. Poor learning environments often induce inert knowledge that cannot be used efficiently by the pupils. In order to avoid the acquisition of inert knowledge, this approach uses an "anchor". This "anchor" is used to arouse interest and to control perception and understanding. Thereby the significance of acquiring knowledge is focused during use.

The anchor is a task or a problematic situation that is motivating for as many pupils as possible. It should also contain a general aim reachable through a number of partial aims. The design of such "anchors" should allow pupils to understand the main components of a problematic situation. Using "anchors" avoids new concepts and theories from being merely understood as an accumulation of facts and mechanical procedures, that have to be learned off by heart (and are mostly quickly forgotten). A fair anchor example is for instance presented in chapter 3.1.

The "anchor" produces a pupil-relevant situation – a context. By dealing with the situation, learners as members of learning communities, deal with material resources. Through active dealing with the situation, approaches to the solution are researched within the group. Acquisition of knowledge is therefore a social, situational process. In this process the learner constructs his own individual learning situation and can therefore learn in a best possible way. The process of constructing individual learning situations is most innovative if authentic learning environments are created.

2.4. Learning through inquiry – the 5E model

Combining the three approaches described above, the 5E model (recently amended to the 7E model) intends to structure biology teaching in a scientific way and, moreover, aims to produce an efficient learning environment for pupils.

The 5E model was implemented by the American BSCS (Biological Science Curriculum Study). It intended to revise learning in school. The origins of the 5E model can be found in both the pedagogical ideas of Johann Friedrich Herbart and John Dewey and is therefore a constructional model like the other three approaches above. The actual foundation for the 5E model was the Atkin-Karplus Learning cycle, implemented in the late 1970s (compare Bybee, 2006).

The 5E model is based on the idea of designing inquiry based learning. Thereby "inquiry" is defined by National science education standards (NRC) as being "engaged by scientifically oriented questions", giving "priority to evidence", formulating "explanations from evidence", evaluating "explanations in light of alternative explanations" and finally communicating and justifying "proposed explanations" (Beerer & Bodzin, 2003).

The 5E model consists of five phases namely "Engagement", "Exploration", "Explanation", "Elaboration" and "Evaluation". In the first phase "Engagement" the learners prior knowledge is elicited. It is tried to engage and intrigue the student by an informative entrance of a new topic. In the second phase of "Exploration" the students work in groups and try to formulate hypotheses and generate ideas to proof them. Experiments are also carried out in this phase. In the third phase ("Explain") students present results and review them in the background of the prior knowledge. The teacher may become active in this phase as well by explaining any of the unknown phenomenon. The knowledge being built up so far is tried to be deepened in the phase "Elaborate". This phase requires additional experiments or other activities to broaden the understanding. In the last phase students "Evaluate" both the understanding of the new concept and the learning procedure. Additionally, the teacher evaluates the pupils learning progress.

As mentioned earlier, the 5E model has lately been amended to the 7E model (Eisenkraft, 2003).

Eisenkraft maintained the general structure but differentiated three phases of the 5E model. The first phase of the 5E model “Engage” has been altered to first “Elicit” and second “Engage”. By this it is tried to enhance the role of eliciting student`s prior knowledge without reducing the engaging phase. Furthermore, Eisenkraft modifies the last two phases of the 5 E model. The phases “Elaborate” and “Evaluate” are completed by a phase called “Extend”. In this phase Eisenkraft stresses the transfer of the newly learned information to related topics. Therefore, it is intended to deepen knowledge in this phase.

Both of the inquiry based models intended to implement a new way of learning. The spiral structure of both stresses the importance of revision and reworking new contents. Additionally, due to the constructivist approach of learning, the importance of tying up new concepts to prior knowledge and transferring them to further contends is enhanced. It is also shown that the teacher should not direct the learning process but, in fact, much rather guide the students, providing them with a inspiring learning environment in which they can establish their own learning strategies. Moreover, valuable and appropriable knowledge must be necessarily evaluated by as well the learners and the teachers.

In conclusion, it can be said, that the 5 E and 7 E model both focus on learning through inquiry. Yet, scientific inquiry includes two main aspects namely “inductive - and deductive reasoning”. While inductive reasoning leads to “broad, general conclusions”, deductive reasoning leads to predictions “which are often stated as a hypothesis”. The combination of inductive and deductive reasoning is referred to as “the scientific method” (compare Boone, 1991). However, although the 5E and 7E model both focus on learning through inquiry neither of them specifically emphasizes the phase of formulating predictions or hypotheses. This reveals an evident difference between the regulated teaching cycle and the 5E and 7E model.

3. The teaching cycle in biology

The regulated teaching cycle is, in contrast to the 5E and 7E model, rather based on the hypothetic-deductive approach (cf. Campbell & Reece, 2006, Vollmer, 1987). Consequently, the regulated teaching cycle focuses on hypothesizing and does by this increase the pupils’ self-responsibility. The teaching cycle evoked from an active-orientated teaching. It follows a certain pattern: Problem – purpose – planning - acting – reflecting (cf. fig. 1). It is possible to use the basic structure in everyday teaching. This use has significant advantages:

- The teaching follows a certain structure
- The learner internalizes to work hypothetic – deductively, which is meaningful for dealing with scientific issues
- The learner acts target-oriented in respect to the problem’s solution.

This way of insight offers a pattern to integrate activity-, problem- and pupil orientation within biological teaching in a sustainable way. The

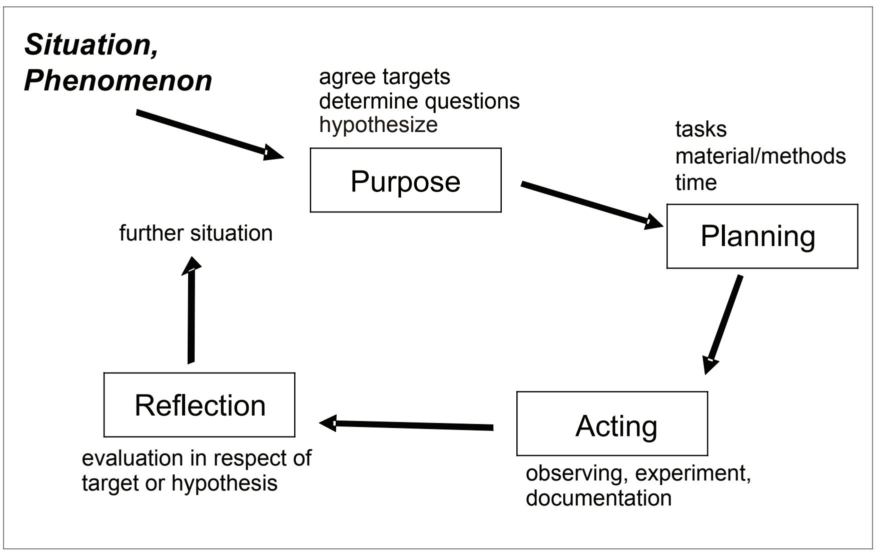

Figure 1: The scientific teaching cycle based on the deductive-hypothetic approach

teaching cycle is characterized by three main phases:

Phase 1. The instruction
The situational instruction should be motivating for as many pupils as possible. Sometimes already the confrontation with the scientific phenomenon itself is sufficient, which would also be the easiest and best case (see example in chapter 3.1). This anchor focuses on a general target. The main aspect is the learners' motivation to explore a scientific topic on their own, to construct problems and to present their results.

Phase 2. The construction
In this phase, the knowledge is supposed to be "constructed" actively. First of all, the targets need to be determined. Later on the question at issue has to be identified, and a hypothesis has to be formed. By this, the problem will be concretized (cf. fig. 1). Subsequently, the procedure is planned. The selection of required materials and methods are prepared practically, the action (observation, experiment, investigation) is accomplished and the results are presented.

The conformation of this construction phase is quite challenging for teachers, since pupils need to be instructed and supported, but have to act self-reliantly at the same time. The teacher as a "coach" should withdraw himself within advanced learning groups ("fading", cf. "cognitive apprenticeship", Collins et al. 1989, "tutorial learning", Pütz et al., in press).

Phase 3. The reflection
During the ensuing discussion, the task is evaluated according to targets, questions and hypotheses. Finally, it needs to be reflected whether the problem has been solved or if a pursued problem appeared, which would demand further clarification.

3.1. A teaching cycle example

Evoked through an appreciable biological phenomenon, a field of tension is being accomplished, that benefits the learner's constructive activity. Sometimes one task can be completed within only one teaching cycle. Yet, it is even more prolific if the instructive anchor is chosen in a way that several teaching cycles arise from pursued situations as shown in fig. 1.

The phenomenon of the "lotus effect" (Barthlott & Neinhuis, 1997) can be used to set an appropriate example. An experiment conducted by the pupils, which is leading towards the phenomenon, functions as a motivating introduction to the topic. Therefore, operating instructions are handed out and the pupils are supposed to carry out the first tasks (fig. 2). The first activity's instruction by simple test set-ups is one opportunity to activate and regulate the learning process primarily.

The experiment elucidates an astonishing phenomenon und forms an anchor for instruction if it is explained, that the self-cleaning-effect is not only beneficial to the plant but also encloses a broad field of application. Houses and cars could be cleaned by rain, dishes that could be used just after rinsing with water – pupils have always been fascinated by the various possible capabilities.

This "lotus sequence" has been successfully accomplished in various grades in both middle and upper school. The phenomenon has always

<u>Material and description of the material for the experiment</u>

Material: Leaves of turnip cabbage, coal dust, drop pipette, cloth, detergent solution (2%), drip pan/catch basin

Execution (1): Trickle a little bit of water onto an intact turnip cabbage leaf. Observe the drop-development and the dripping-off-effect when holding the leaf (1) horizontal and (2) inclined. (Compare to leafs of other plants!)

Execution (2): Powder one of the turnip cabbage leaves with coal dust and repeat the experiment as described in (1).

Execution (3): Polish one of the leaves with the cloth and repeat the experiment as described in (1).

Execution (4): In the run-up of the lesson some of the turnip-cabbage leaves have been sprinkled with the detergent solution (2%). Take the leaves that have dried in the meantime and carry out the experiment as described in (1) once more.

Figure 2: Operating instructions for investigating the lotus effect (compare Barthlott & Neinhuis 1998, Pütz 2003)

been the anchor for required activities in the classroom. At the same time the experiments served as an introduction to the scientific teaching cycle. Therefore, it became clear to the pupils that they need to understand the effect in the first place. Only then will they be able to transfer it to different surfaces.

One question arose in every performed unit: How does the lotus-effect work?

Consequently, the analysis of the functional concept has been defined as the target of the sequence. Since the experiments had been distributed right at the beginning of the lesson, formulating appropriate hypotheses succeeded instantly in each grade. Through tasks 3 and 4 pupils managed to formulate spontaneous hypotheses, assuming quickly that there must be some kind of coat on the leaf's surface (see fig. 3).

By means of tasks 3 and 4 (see fig. 2) further activities within the teaching cycle are also fixed. After the transactions the results were collected.

During observation pupils detected that (task 1) the turnip cabbage leafs facilitate a flashing movement of the drop and (task 2) that the drop cleaned the leaf entirely. A compared leaf did not show this effect. Mechanical abrasion (task 3) destroyed the flashing movement and the lotus-effect. Finally, (task 4) the chemical influence of the detergent solution caused the drop to dissolve on the leaf's surface.

In the subsequent phase of the reflection, the results were discussed and applied to the hypothesis respectively the initial question. Several facts had been detected but, by then, finding a solution in relation to the target had not been possible. There was still a possibility of the initial hypothesis being right even though the initial question had not yet been answered.

With regard to figure 4 it is noticeable that the scientific teaching cycle has been passed through

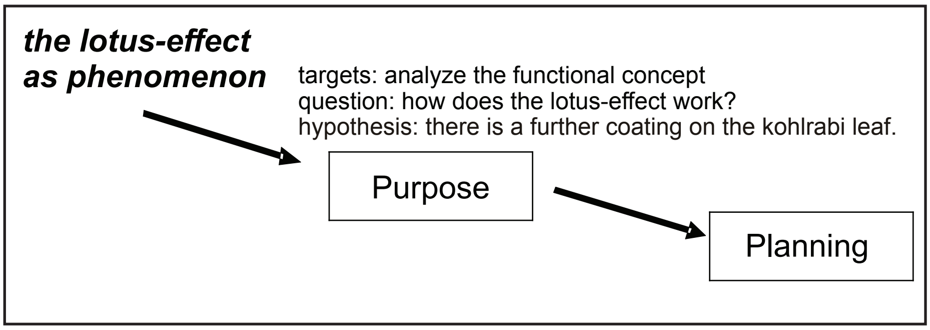

Figure 3: The phase of instruction of the teaching cycle of the lotus effect

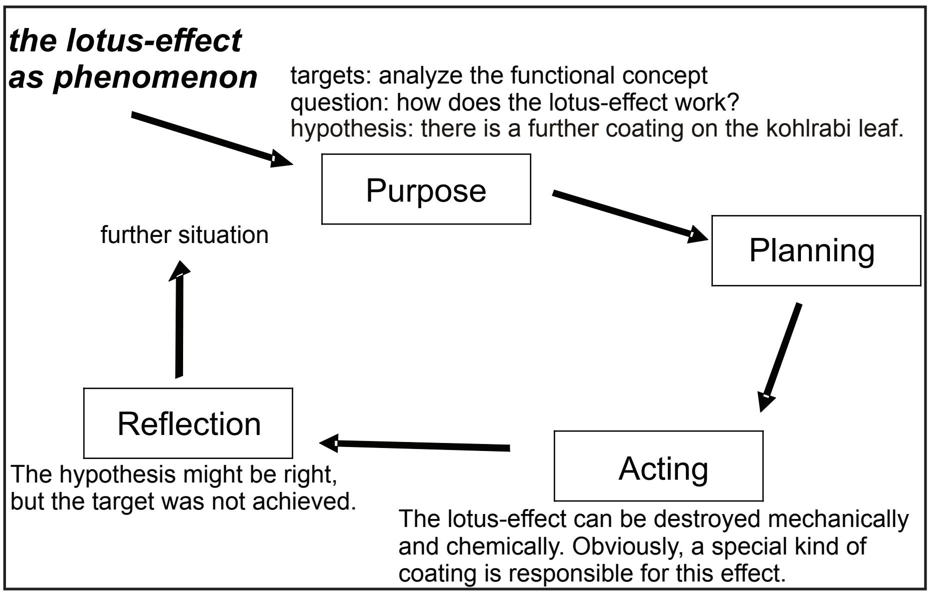

Figure 4: The phase of reflection of the teaching cycle of the lotus effect

once. This teaching cycle is characterized and controlled by the teacher. This is particularly important when introducing the teaching cycle to the pupils for the first time.

Within this topic a teaching cycle is by no means a singular event. Solving scientific orientated tasks respectively placing useful instructive anchors within authentic situations is comparatively complex and demands a series of teaching cycles. This elucidates basic features of scientific and technical problems and, moreover, shows that different teaching cycles regarding one topic support the understanding of the practical use of scientific working methods.

In the present example learners refer back to the hypothesis. In order to verify or falsify the hypothesis, different patterns of action have to be prospected. Each class suggested analysing the leaves anatomically – which immediately started off another teaching cycle (compare fig. 5) Pupils carried out anatomic cuts with different leaves and observed them with the aid of microscopes. By this pupils got to know typical leaf structures and recorded their results by drawing. These assignments remained embedded within the question concerning the lotus-effect. They were not treated separately but were rather connected to a meaningful context and are, therefore, easier memorized.

Still, for the groups the results were mostly just a little progress towards solving the initial question. Yet, comparing cuts of different leaves showed that even leaves, which do not show a lotus-effect, have a cuticle as well (fig. 5). However, they learned important biological facts (anatomy of leaf), and important biological skills like using microscopes, preparing cuts through leaves, and comparing results. These skills and facts are embedded in an overall problem, and, thus, are within an important biological context.

The phase of reflection in the second teaching cycle exemplified, that the hypothesis might be right even if the target has still not been reached. Up to now, all observed classes carried on searching for solutions to the problem. Pupils asked for instance, for different methods in order to search for invisible coats on leaves. Therefore, a third teaching cycle with reference to the "lotus-effect" followed the first two. This teaching cycle focussed on research, whereas the lotus-effect provides a good basis for internet research. The results were collected: When observing the leaf with the aid of a scanning electron microscope, Wax crystals can be discovered on the cuticle. Due to this, the leaves are sub-microscopically roughened. The water-repellent wax coat allows only little adhesion of small dirt grains or water and does therefore cause the lotus-effect (particularly well elucidated on www.lotus-effect.de).

The sustainable effect of the lotus-effect as an anchor for instruction can be emphasized if one regards the direct practical connection. The presented teaching sequence has been implemented in various classes. In each and every case pupils

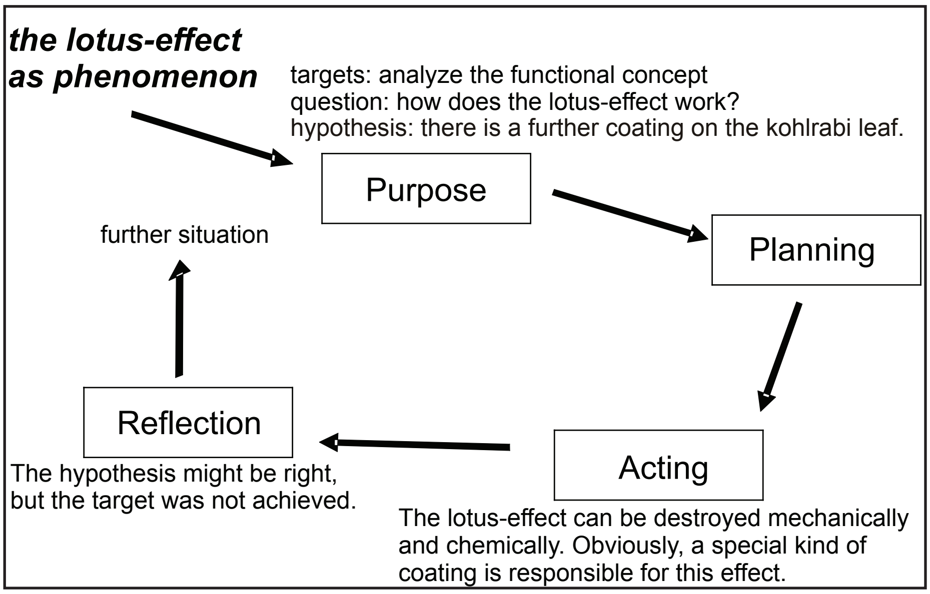

Figure 4: The phase of reflection of the teaching cycle of the lotus effect

pointed out the possibility to synthesize the lotus-effect for example for façade or car paint, roof tiles, bathroom fitting and alike. Therefore, further teaching cycles could be affiliated:

- Do commodities with self-cleaning surfaces exist?
- Can self-cleaning surfaces be manufactured?
- Are there other biological phenomena that could be transferable to technical use (keyword: Bionic?)

3.2. Outlook

Educative and moral instruction such as "Do not smoke!" or "Brush your teeth right!" should not be in the centre of modern biology teachings. The focus should rather be on comprehension through "problem-purpose-planning-acting-reflecting" ("I understand that smoking harms me because…"). Therefore, it is essential to clear out the brimful biological curricula for secondary schools. Exposing problems and acting requires a certain amount of time. Biology teaching seems to lack this time quite often. Teaching biology should not be about piling up the greatest possible amount of factual knowledge, even if newly implemented educational refer to it as competences (compare Pütz 2007). Teaching biology should be about comprehending science. Object- and action orientation supports "comprehension" of problems or phenomena. In the meantime, problem- or science based teaching trains "evaluation". Both, active comprehension and evaluation cultivates the capacity to act.

The consequent use of teaching cycles in biology teachings would therefore improve the often claimed science literacy (Scientific literacy, compare Pütz 2007) and, moreover, would support our pupils in a sustainable way.

In the didactic's point of view, it would be helpful if biology teachers had access to several teaching sequences with different instruction anchors. Consequently, with the aid of teaching cycles, pupils could learn to recognize problems und solve them in a scientific way.

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