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DIDAKTIK-NACHRICHTEN

DiNa

Didaktikzentrum

DiZ – Zentrum für Hochschuldidaktik

www.diz-bayern.de

Editorial

Dear readers,

Are you concerned with the question of how you can make your knowledge and expertise more accessible to students? Or how can you pass on the methodology and the tricks and trades of your field to learners?

Worldwide there are many scientists who in addition to their fascinating subject engage in a further subject, which is at least as fascinating: passing on their knowledge and understanding effectively. Each of us teachers knows that certain issues are difficult for students, while for us they are very familiar and simple. In order to overcome such thresholds and to see the bigger picture, one has to decode the code of the respective discipline.

It is exciting for me that this applies not only to the allegedly difficult subject matter of technical disciplines, but also to key competencies. For instance, take reading in historical studies – a subject area often misperceived as being all about memorizing dates and events.

If a historian says to his or her first-year students „Please read chapter xx until the next meeting“, then it might happen that they do as being told: they read it, maybe even making some notes. But what did the teacher mean? For him or her, reading means: absorbing the text, thinking about the era it covers, recognizing the political and social background, investigating what economic systems were in place then etc., and placing all of this in a regional or global context.

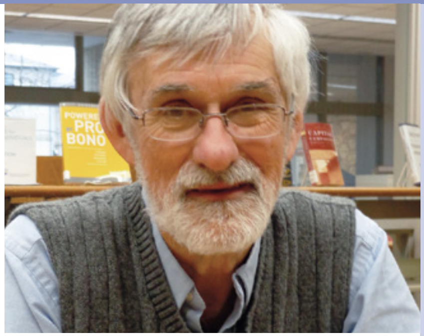
“Decoding the Disciplines” is the name of a method to deal with such difficulties. The example from the story was not chosen at random: One of the “parents” of decoding, David Pace, is a historian. Together with Joan Middendorf, he developed the method at Indiana University Bloomington to help students overcome the corresponding “bottlenecks”. He has been here in Ingolstadt several times to introduce decoding to teachers, and I am very pleased that he has written the following greeting in English for this issue of our DiNa.

“Decoding the Disciplines” is also the name of one of our working groups here at DiZ. Its members come from a variety of disciplines, universities, and German federal states in order to work very precisely on this topic. I am very pleased that we can present their work to you in this edition. If you also want to participate: You are welcome – no matter which subject area you are from! You will find the date of the upcoming meetings of the Decoding working group in the DiZ-program.

I wish you gain many insights!

Yours,

Franz Waldherr



Editorial

In the last twenty years Decoding the Disciplines has revealed a vast territory for pedagogical exploration that is being carefully mapped by scholars of teaching and learning on every inhabited continent. In almost 200 books, websites, articles, and papers (http://decodingthedisciplines.org/bibliography/) they have demonstrated that, by focusing on the obstacles to learning in a single course and then systematically making explicit the steps that students must master to overcome these bottlenecks, new pathways to student success can be discovered.

Decoding is a fundamentally collaborative activity, and the most important breakthroughs in the field have occurred when groups of pedagogical "explorers" have come together to plan shared expeditions. This has most recently been visible at the Zentrum für Hochschuldidaktik (DiZ) in Ingolstadt, where some of the lecturers throughout Germany who are involved in the application and further development of the decoding paradigm meet regularly. Decoding arrived in Germany in 2013 through a series of seminars at the University of Bielefeld and spread rapidly to the Ostfalia Hochschule für angewandte Wissenschaften, where it became one of the central strategies of the university's teaching center. News of Decoding spread from there to the DiZ, which sponsors a faculty learning community in which teachers from a number of German universities come together in Ingolstadt several times a year to explore and expand the approach. The result has been the creation of a team of very insightful scholars of teaching and learning, who are not only using Decoding to increase learning in their courses, but are also making very important contributions to the theoretical foundations of the paradigm.

The present on-line volume captures both the kinds of insights that are emerging from this collaboration and the process that created them. The descriptions of how Decoding has been useful to faculty involved in this project and of the application of the paradigm in particular situations provides a very useful introduction to the approach. The explorations of techniques to make the decoding interviews more effective represent a particularly important contribution to our work. And, finally, the entire collection of articles and interviews captures the way that Decoding can serve as the core of a very productive collaborative partnership among faculty committed to increasing their students' success in their disciplines.

This is a very valuable contribution to the rapidly growing literature on Decoding, and it is fine example of the growing power of the scholarship of teaching and learning in Germany.

David Pace

Decoding the Disciplines – A Roundtrip from Novice to Expert back to Novice

Peter Riegler

All grown-ups were children first.
But few remember it.
Antoine de Saint-Exupéry

"All experts were novices first. But few remember it" one could paraphrase Saint-Exupéry. This does not imply that experts do not want to remember what it was like to be a novice. More often, they simply cannot remember.

As a reader of these lines, you are a person who is skilled in reading, i.e. an expert in reading. Can you still remember what it was like when you could not read? What impression did texts and sequences of letters make on you when they did not yet automatically become words in your mind? How difficult was it for you to form words from letters?

Students often find themselves in a situation similar to novices in reading. They are still struggling to understand individual arithmetic steps, and are far from being able to distill the "story" from the individual steps that the calculation tells. They are still struggling with adopting a certain way of thinking, like recursion in computer science, or recognizing that science does not always provide clear, definitive answers.

Contrast that with experts. Their expertise consists of more than what is obvious. Biologists obviously have internalized biological concepts and master biological processes. They have acquired their expertise over years by incorporating certain thought patterns into their language and routine actions. Such thought patterns contain efficient generalizations and mental shortcuts that contribute to expertise. However, these generalizations and shortcuts might have become unconscious and, hence, will no longer be explicated. The proverbial "as one can easily see" of mathematics often expresses such a shortcut. It is indeed easy to see for the expert, but not necessarily so for others. Such patterns of thought can increase the challenges for students who desire to acquire the skills of the expert or are expected to do so.

Discipline-specific thought patterns are often implicit on the part of teachers. They constitute a part of their hidden, implicit knowledge. These patterns of thought are virtually encoded.

Decoding the Disciplines (Decoding for short) is a process, which decodes the implicit disciplinary expertise of teachers in a structured way and makes it available to teaching. Largely, it has been developed by David Pace and Joan Middendorf at Indiana University (Middendorf & Pace, 2004). This paper will introduce Decoding, while the following articles will examine aspects of Decoding in detail.

Bottlenecks

Fundamental to Decoding is acknowledging that certain aspects of one's own discipline are inherently difficult. These can be concepts, perspectives or (mental) actions. The difficulty becomes apparent on the students' side when learning such issues. However, the difficulty is also on the side of the teachers when they struggle to explicate such aspects of their own expertise.

For students, such aspects can become obstacles to learning. In the terminology of Decoding, they are metaphorically referred to as "bottlenecks", i.e. constrictions that hinder the learning flow of students. Bottlenecks are not only characterized by the fact that they stand in the way of the learning progress for many students, but also by the fact that having overcome them is a component of expertise. Teachers, too, have certainly overcome many bottlenecks in the course of their professional development, but often they cannot remember this.

Like the terms misconception, preconception (Posner et al., 1982; Kautz, 2014), and threshold concept (Meyer & Land, 2003), the term bottleneck indicates hurdles and blunders in the learning process. The term bottleneck can be seen as a super-category of these specific forms of student

Examples of discipline-specific bottlenecks

Mathematics: Students find it difficult to parse expressions, i.e. to break down expressions into their constituent parts (according to a grammar that often is not made explicit). The term $\frac{a+b}{a^2 - b^2}$ is parsed as the “ratio of a sum of symbols and a difference of squares of the same symbols”.

Scientific reading: Students find it difficult to recognize the character of certain text elements if they are not explicitly named as such. For instance the second sentence in the above item on mathematics provides an example for what has been stated in the first sentence, Yet, it has not been explicitly marked as an example.

Engineering mechanics: Students find it difficult to model given mechanical situations by using abstract structural supports.

Electrical Engineering: When analyzing electrical circuits, students find it difficult to introduce a reference system by drawing current and voltage arrows into the circuit diagram. They also often fail to recognize the necessity of such a reference system.

History: Students find it difficult to recognize that the authors of historical sources do not convey events but their views of these events.

difficulties and also includes problematic epistemological attitudes of students. See the box for examples of bottlenecks from different disciplines.

The curse of expertise

Disciplinary expertise is a two-sided coin. On the one hand, it is a fundamental requirement for teachers to be able to teach “their” subject. On the other hand, it is a noticeable obstacle for teaching when teachers have automated important discipline-specific thought patterns to such an extent that they cannot explicate them. Teachers then no longer notice the difficulties related to subject matter. They are cursed, so to speak, to having become blinded by their expertise.

In his contribution to this issue, Niall Palfreyman points out that this curse is unavoidable and may be caused by the way human communication and human thinking work.

The Decoding process

Decoding the Disciplines develops teaching through a seven-step process. The individual steps are described in detail in the standard literature on Decoding (Pace, 2017; Middendorf & Shopkow, 2018). The Figure on page 52 briefly presents the seven steps as a guideline for instructors.

The Decoding process begins with an instructor identifying and describing a bottleneck. The second step aims at decoding the expertise related to the bottleneck by helping instructors to explicate their expertise. This step is often done via interviews. In this issue, the article “Conducting Decoding Interviews with the Structural Model TEACH” provides guidelines for conducting such interviews. The article “The Decoding Interview – An Exemplary Insight” describes the Decoding interview by analyzing a particular interview in the context of an engineering topic. MacMillan et al. (2016) provide insights into the interview process by means of an annotated video recording.

The first two steps of the Decoding process are not about teaching. This might seem paradoxical, as teaching has triggered an instructor to enter the Decoding process in the first place. In the first two steps of the process instructors are not involved as teachers, but as experts of their field! It is only the subsequent steps, which relate to teaching in a direct manner. It is part of the ingenuity of Decoding to separate these two roles of expert and teacher. The problem to be solved arises within teaching, but its cause likely lies in expertise.

The next four steps involve the design of teaching interventions, in order to convey the previously decoded expertise to students, and the design of activities, in order to provide students with practice opportunities and feedback. One of these steps asks teachers to anticipate whether students will react with some resistance to the designed teaching intervention or practice activities. It also asks how to avoid such resistance. The last of these four steps investigates to what extent the changes in teaching have enabled students to overcome the bottleneck addressed.

The very last step in the Decoding process invites faculty to communicate the knowledge gained, either informally through discussions with colleagues or by publishing the results. With its final step the Decoding process acknowledges, like the Scholarship of Teaching and Learning (Boyer, 1990), that teaching is also an intellectual and research activity. Communicating results helps other teachers to benefit from one's work. After all, the bottleneck addressed is very likely to hinder the learning process of students in other courses of the same subject, regardless of location and time.

The individual steps do not have to be carried out completely or in the specified order. It may be appropriate to deviate from the process template, omit steps (except for the first two), or iteratively run through steps several times.

Examples of completed Decoding processes from various disciplines are documented in the literature (see box for some examples). A web-based bibliography (Pace, 2019) lists related publications.

Bottlenecks and intended learning outcomes are related to each other (see also the contribution of Britta Foltz in this issue). The wording of a bottleneck is necessarily negative. If one converts it into a positive phrase, one usually ends up with a formal description of a learning objective. Such descriptions of learning objectives are highly authentic, because they describe what teachers really want their students to be able to do. Teaching center staff know that instructors often find it difficult to phrase learning goals. An interesting and valuable aspect of Decoding is that meaningful learning goals arise almost automatically as a by-product.

Examples of Decoding processes with all steps completed

In the context of marketing, Krishnan and Porter (1998) address the difficulty students have in adopting a customer view. They investigate a teaching intervention that enables students to adopt this view to a higher degree. In the context of history, Pace (2004) deals with the difficulty students have in separating essential from non-essential text elements. In the context of formal logic, Riegler (2019) analyzes students' difficulties with expressing the converse of statements and investigates the effectiveness of a teaching intervention, which addresses this issue.

Ingenious eclecticism

Decoding is highly integrated and integrative. It combines elements of research on expertise and misconceptions, of professional development, of coaching, of collegial counselling, and of Scholarship of Teaching and Learning into a process of teaching development, which acknowledges the difficulties students have in learning subject-specific patterns of thought and action as inherent to processes of teaching and learning. Decoding allows tackling several problems and challenges associated with teaching at universities in one stroke, some of which will be covered in the following.

Decoding focuses on the difficulty of the subject matter in a systemic way. It avoids infertile thinking that seeks the failure of teaching primarily among students, or in a wrong selection of teaching method. (Walter & Riegler, 2016)

Although Decoding the Disciplines focuses on learning discipline-specific thinking and acting, it is an interdisciplinary endeavor. Step 2 of the Decoding process often takes the form of an interview, in which usually two persons from outside the discipline help an expert to explicate the implicit aspects of their own expertise. Hence, interviewers are not required to possess discipline-specific knowledge. In fact, that would be more of a hindrance. This provides valuable opportunities for teaching center support staff to support instructors.

Naturally, teaching center staff cannot have expertise in all the subjects of the instructors they are working with. This might be seen as a barrier. However, from a perspective of Decoding the lack of disciplinary expertise of support staff is an advantage when working with instructors in order to decode their expertise. Hence, Decoding can act as an entry point for teaching center staff in order to work with instructors on discipline specific teaching challenges. Once this door has been opened, steps 3 to 6 of the Decoding process provide plenty of opportunities to work with instructors on issues which are more traditional to teaching centers such as advising on teaching methods (see also the article by Christiane Metzger and Andrea Brose in this issue).

Decoding also provides valuable opportunities for faculty. If faculty members conduct the Decoding interview, Decoding becomes a format that allows collegial consultation, cooperation, as well as interdisciplinary and cross-disciplinary conversations about teaching. It creates occasions for teachers to engage in interdisciplinary and cross-disciplinary discussions about teaching. In Germany, the Decoding Working group institutionalizes such a format. It meets regularly at the DiZ-Center in Ingolstadt. A recent spin-off is based at Aachen University of Applied Sciences and serves particularly those interested in Decoding who are located in the state of North Rhine-Westphalia.

In addition, Decoding allows instructors to make teaching the subject of their research as a form of Scholarship of Teaching and Learning. This in turn allows them to gain reputation via their accomplishments in teaching by using the reputation mechanisms of research.

Finally and almost as a side effect, Decoding helps to answer the question: What should students be able to do at the end of this particular course? The generic, abstract answer is: Act like experts.

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‘Decoding’ from the Perspective of Higher Education Didactics

Christiane Metzger
Andrea Brose

Higher education didactics as a field of application for Decoding processes

The work of university didacticians covers a wide range of activities, for example, the implementation of didactic training events for teachers, coaching for developing individual teaching skills, advising on the development of study programs and modules, fashioning and accompanying teaching development processes, and researching teaching- and learning-related questions. ‘Decoding the Disciplines’ represents a method that offers various starting points for the didactic work in higher education.

On the one hand, the Decoding method can be applied to university didactic contexts in the same way as it is applied to teaching and learning contexts in respective ‘genuine’ subject areas. A special challenge of the didactic work in higher education for the purpose of cooperative teaching development and further qualification is that with university didactics on the one hand and experts on the other, members of different disciplines work together. They share the goal of developing scenarios that support the learning processes of learners as much as possible. In doing so, members of both groups are experts of their own respective fields. They are lead by the need to learn something about the other subject and while being novices at first to achieve a certain level of expertise: The subject-matter scientists acquire didactic concepts and methods while university didacticians need to familiarize themselves with the respective disciplinary context.[1] To a large extent didactics of higher education works with theories, models and concepts for teaching and learning which are less common in most scientific fields (other than education-related sciences) (Scharlau & Keding, 2016). Hence, their concepts and methods such as motivation, competence or learner centeredness are not always easily accessible to members of other disciplines.[2] Even in the context of such learning processes “bottlenecks” may (and do) show up and can be identified by the Decoding method. Corresponding findings can then be used for the development of professional development workshops or consultations for university didactics or for the design of teaching development processes to be used to support learning and to facilitate communication.

Knowledge of subject-specific “bottlenecks” as building blocks of didactic work in higher education

As Decoding processes can be applied to higher education didactics as a learning object, the Decoding the Disciplines working group at DiZ represents an extraordinary opportunity for revelations and insights for higher education didacticians: The focus of the Decoding method is to identify subject-specific difficulties that students typically encounter in the learning process, to deal with them constructively and to develop teaching/learning

[1] Since there are almost no courses of study in higher education didactics (an exception is the Master of Higher Education at the University of Hamburg), people from many different academic disciplines are active in this field, their qualifications for didactic work being an outgrowth of work within their “own discipline”. A survey commissioned by the board of the German Society for Higher Education Didactics (dghd) showed the following distribution of the disciplines of origin (first degree; N = 301 evaluable data sets): 31% educational sciences; approx. 15% linguistics and cultural studies; approx. 10% mathematics, natural and engineering sciences; approx. 7% social sciences or social work; approx. 5% law, administrative and economic sciences; approx. 2% human medicine, health sciences and veterinary medicine; approx. 2% regional and political sciences (Scholkmann & Stolz, 2018). In their work, university didacticians are often not only active in the context of their “home discipline”, but throughout the university.

[2] Or perhaps they are not contextualised in a sufficiently subject-sensitive manner, so that, for example differences in application and evaluation occur that need to be explained in terms of technical culture of the concepts (see ibid.).

arrangements that take these "bottlenecks" into account. Because this is worked on in interdisciplinary groups (something the method effectively presupposes, see, e.g., "The Decoding Interview – An Exemplary Insight" in this issue), Decoding processes offer the opportunity to get to know the subject-specific contexts of various disciplines and to learn about their bottlenecks. This provides university didacticians with genuine professional points of contact for communication with teachers, which is an advantage for the otherwise more or less subject specific work of university didactics. Knowledge about "bottlenecks" and corresponding teaching/learning scenarios can then be introduced into consulting and professional development contexts in order to work on the design of learning scenarios in cooperation with teachers specialized in the subject-matter. In this respect, the subject specificity of the Decoding approach offers an extremely useful supplement to the didactic work of higher education institutions: while teaching and learning as such are subject to general principles, learning processes in concrete terms are based on objects and situations that are shaped by the subject and culture of the subject area, so that the learning of students is faced with different, and subject specific, challenges. By identifying and classifying subject-specific "bottlenecks", it becomes possible to react to them in a didactic way.

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The Decoding Interview – An Exemplary Insight

Peter Riegler

The Decoding interview is at the heart of the Decoding Process. It aims at both making visible and decoding the implicit and often unconscious aspects of expertise (such as strategies of thought and action) in order to make them accessible for teaching afterwards.

If Decoding the Disciplines were not located in the enlightened world of academia, one would probably talk about it in a magical, numinous, and mysterious language to an even larger extent than is the case already: The interview "breaks the curse of expertise". Teachers often find the interview to be "illuminating" and conceive it as a "sudden liberation from blindness" after years of despair in teaching.

One of the mysteries of expertise is that it often contains aspects that are unexpected or that seem to be unrelated to the disciplinary area of expertise. Decoding such aspects is part of the "magic" of the Decoding interview. However, the Decoding interview is little more than a structured process, as Britta Foltz describes in her contribution to this issue (p. 19).

In the following, the Decoding interview will be "disenchanted" by analyzing a specific example. This example illustrates several aspects of Decoding interviews. On the one hand, it provides insights into how an interview is conducted. On the other hand, it provides evidence for the already mentioned phenomenon that sometimes disciplinary expertise is significantly influenced by aspects that at first glance do not appear to be disciplinary.

It needs to be added that the interview is not the only method for decoding expertise. Kaduk and Lahm (2018) have developed a structured writing process that allows teachers to decode their expertise by themselves using pen and paper. Middendorf and Shopkow (2018) list further alternatives to the interview. These alternatives can be conducted individually or in groups and can also involve students.

The Interview process

Usually, three people are involved in the Decoding interview. Besides the teacher who brings in the bottleneck, there are two interviewers. One of them is actively decoding while the second person acts as a support. The roles of the two interviewers are not fixed and can change fluently over the course of an interview.

In general, interviews are more effective if the interviewers are not experts in the field of the interviewee. Otherwise, there is a danger that the interview degenerates into a technical discussion between colleagues, in which the interviewee and interviewers conspire to overlook the blind spots that lead to the bottleneck. On the other hand, it is helpful if interviewers have about the same level of knowledge that the students of the interviewed teachers have at the beginning of the course. Otherwise, the interviewee would have to spend a substantial part of the interview time to bring the interviewers to this level of knowledge and to enable them to follow the explanations related to the actual bottleneck.

Niall Palfreyman (cf. p. 28) suggests the terms "apprentice" and "coach" for the two interviewers and "expert" for the person whose expertise is to be decoded by means of the interview. The (cognitive) apprentice helps the expert to explicate expertise. To do so, he or she tries to understand and model the expert's thoughts step by step. The primary task of the cognitive apprentice neither is to learn the expert's expertise nor to be able to practice it himself or herself.

The coach assists the apprentice in this Decoding process. He or she supports the conversation and in particular makes sure that it does not mutate into a lecture. This is a real danger in Decoding interviews, because teachers love to explain and during the interview they find interested

Fig. 1: Besides the interviewee, the Decoding interview involves two interviewers. Here, David Pace, one of the pioneers of Decoding, serves as an interviewer. He is located at the center of the photograph.

listeners. A further danger is that apprentices get captivated by the subject, for example if the interview allows them to learn something about a topic they are interested in.

Another danger in Decoding interviews is that apprentice and expert work on solutions to help students in passing the bottleneck. During the interview, however, the focus should be on decoding expertise exclusively. In Decoding, the process of finding solutions is deliberately separated from the process of decoding. It is the task of the coach to remind experts and apprentices of this if necessary.

During the interview, expert and apprentice decode how experts proceed when they skillfully master the bottleneck in question, often by referring to a concrete situation or example. For this reason, at the beginning of an interview the apprentice usually asks the expert to give an example of a situation where many students regularly get stuck in the bottleneck.

In order to elicit the expertise systematically, the apprentice essentially asks questions of the following kind in the course of the interview:

- How exactly do you do that?
- What is the next step?
- What would happen if you didn’t do exactly that?

If at a certain point experts cannot answer such questions (immediately), this can be seen as an indicator that the interview is targeting an unconscious aspect of expertise. Apprentices should then support the interviewee gently but persistently in making this aspect explicit.

Experts often describe aspects of their expertise metaphorically or by gestures, sometimes because they themselves lack the language for describing them. Interviewers should put such metaphors and gestures on record, as these are often helpful for students. Also for this reason, it is advisable to video tape Decoding interviews or at least to audio tape them.

Background of the Decoding interview to be analyzed

The interview, which will be reproduced[1] in excerpts below, analyzes the expertise of a professor teaching engineering design in an undergraduate aeronautical engineering program. The bottleneck she observes affecting her students occurs in the context of her class on engineering design.

[1] The conversation of the interview took place in German. The English translation tries to stay to the German original as closely as possible.

In this class, as part of their project work students have to choose a design task, work on it and write a report.
Before the Decoding interview took place, the professor formulated the bottleneck she wanted to address as follows:
Students find it difficult to
1. identify critical components,
2. identify and distinguish load cases,
3. report their work in a comprehensible and systematic manner.

It seems that there are not only one but three bottlenecks here. In any case, the bottleneck addresses three activities occurring at different times as students work on what they are expected to do. At the beginning of the interview and without giving a reason, however, the professor conjectured that the difficulties associated with the three aspects listed above probably relate to each other. In the course of the interview, her assumption turned out to be correct.

Incidentally, the bottleneck formulation above makes it quite clear that bottlenecks are negatively phrased learning goals. If one replaces “students find it difficult to …” by “students will be able to …” in the above formulation, one ends up with valid descriptions of intended learning outcomes. Moreover, these are learning goals in the truest sense, because the professor is strongly concerned that her students overcome the bottlenecks associated with these goals. Otherwise, she would have had no reason to engage in the Decoding process.

Let us proceed and see how the interview evolves. The interview begins with asking the expert to provide a concrete situation in which she observes that her students get stuck as described by the bottleneck.

Asking for a specific situation

Interviewer 1: Could you outline a concrete example that we can use to stroll along?

Expert: A team of students has constructed a row of seats for passengers in an airplane. It is clear that this row must be stable enough so that the passengers can sit on it safely – even when turbulences occur. We don’t want the row of seats to collapse, and each team member must do a calculation for this. So, I do not expect them to calculate [all details of] the seat completely. But the calculations they choose to do need to make sense. It doesn’t make sense to me if they calculate the force required to rip the fabric cover off the headrest. It is irrelevant to safety issues. Of course, this would not be a calculation, which I would accept as that of a critical component, because it has nothing to do with safety.

Interviewer 2: The students can choose the calculation task themselves?

Expert: They can choose for themselves, they should choose for themselves! I prescribe that, because that's part of their task to find out: Where are the critical forces?

The implicit expertise of the professor shines through in at least one passage: For her it is mainly about deciding whether "the calculations make sense." Although she uses an example to make clear **what** (does not) make sense, she does not explain **how** she decides whether something makes sense. This is a first indication that, here, the relevant expertise does not primarily consist of factual knowledge – which is quite often the case in decoding interviews.

The interviewers notice that this "how" is missing and explicitly ask for it. In order to do so, they use the time-proven Decoding question "How exactly do you do that?"

A pivotal interview question: How exactly do you do that?

Interviewer 1: How do you determine, what are your criteria for deciding whether a problem is meaningful or not?

Expert: I am going to answer how I do it. I determine this by thinking: "Would I make a stress analysis of this part?" or would I say "Good enough for now? – sufficient! It won't fail." The component may be overdimensioned for the first step, but that doesn't matter in the beginning of a design project.

Interviewer 1: How do you determine that? How exactly do you do that?

Expert: Exactly! How do I determine that? I determine this by thinking to myself: There are forces acting on the construction in certain load cases. Which part will fail first if it is built and used as currently designed and dimensioned? I try to identify the mechanical weak points, the predetermined failure points in the construction and then I investigate them to see if they are sufficiently dimensioned.

Interviewer 2: A student could not simply copy this? This act of imagination?

Expert: No, unfortunately not.

Interviewer 2: How does this imagination work?

Expert: For me the imagination works in such a way that I actually watch in an inner film [showing] how the construction fails. How it deforms, how it breaks somewhere, how it tears, splinters or buckles. The students don't have this inner film.

Interviewer 1: Who wrote the script for this film?

Expert: Very good question. Who wrote the script for the inner film? I, myself, invariably by destroying a lot of mechanical objects and at the same time by observing how they fail.

Obviously, the professor has a wealth of experience, which she describes as an "inner film". It is not too surprising that she as an expert has this wealth of experience and that her students naturally do not have it, yet. Hopefully, the students will gain such a wealth of experience in the course of their further studies and professional practice. The professor's expertise, however, is not primarily **that** she has a wealth of experience. Rather it is **how** she has acquired it, and more than that, **how** she accesses this wealth of experience. To find out, the interviewers again ask, "How exactly do you do that?"

Once again: How exactly do you do that?

Interviewer 1: How do you decide which film scene to play from your archive, so to speak?

Expert: That's where these load cases actually come into play, because I have to take them into account. What can happen to the row of seats? One case is that I sit on in normal conditions. The other case is that the plane can crash somewhere, and then there are other forces that act on it. I sometimes have the feeling that the students lack the imagination for that even more.

Interviewer 2: So you make a distinction between normal use and extreme cases? In other words, safety-relevant issues?

Expert: Exactly! This distinction is actually made [in the aircraft industry] because in normal use, this row of seats must not be permanently deformed at all, because after the flight it should look exactly the same as before. After a plane crash, the row of seats gets scrapped anyway. In other words, of course it may deform, but it must not deform in such a way that I, as a passenger, can't get out safely anymore.

Fig. 2: Decoding is a serious business, yet Decoding interviews can be cheerful.

In this excerpt, the second bottleneck "identify and distinguish load cases" has been sharpened significantly by adding and emphasizing the aspect of safety. Thus, students are to identify **safety-critical** load cases.

If you are a reader coming from a technical field, you might think, "It's obvious that we are talking about safety-critical load cases." That's right! It is clear to you as an expert! However, is it clear to students? Here, even the interviewers, including one with years of industrial experience in another engineering field, had not been aware of it until this point of the interview.

This indicates an unspoken aspect of expertise that seems so obvious to the expert that she does not address it (anymore). In the further course of the interview, Interviewer 1 (being the apprentice at this point in time) decides to paraphrase the significance of meaningful, i.e. safety-relevant load cases that has just been uncovered:

Interviewer 1: Let's assume that students have selected some load cases. You are saying, the most important thing for you to do right now is to decide, are these load cases worth being investigated?

Expert: Exactly! First of all, I would like to understand what the students have calculated. Because we had said that we wanted to look at the third bottleneck "reporting comprehensibly and systematically." That means I expect a heading. [Telling me] What kind of calculation do I get here? Do I get normal use, abuse or emergency landing conditions? This heading is already missing. That's the very first issue. Although I say, "I'd like to get that heading."

Two things are remarkable about this statement. First, there is a nuance of desperation in the last sentence. In addition, there suddenly appears a connection to the third part of the bottleneck, which at this point presumably only the expert is seeing.

The interviewers could now proceed to decode how the expert formulates headings in order to label sections when she is writing a technical report or some sort of documentation. She suggests, however, that for non-experts (students) the difficulty is not so much in formulating, but in making use of headings of whatever quality. As strange as it may sound at first: a part of the expertise seems to be the use of headings. The interviewers could now ask why headings are important. Decoding, however, does not primarily aim at reason, but rather at the actions of experts, which can be reasonable of course. Hence, a relevant question here is why headings are important for the actions of experts in aircraft construction.

The question "How exactly do you do that?" would not be suitable to clarify this issue. In order to find out why certain actions of experts are important, it often helps to ask what would happen if this action did not take place:

What would happen if …?

Interviewer 1: What would happen if an expert did not write such a heading?

Expert: Let's consider a case of emergency. In aircraft design, calculations must be documented for certification purposes, and in the event of an aircraft accident, they are likely to be requested by the authorities responsible for aircraft certification or investigation of aircraft accidents. If such a meaningful heading is missing there, it is an indicator that the person who did the calculations is not qualified. In other words, either the person who authorized the engineer to assume responsibility for the integrity of the design is liable or, if the engineer has issued an unauthorized approval, he is personally liable. In other words, good documentation concomitantly protects me from ending up in prison at some point.

Interviewer 2: So that's all you have to have in mind?

Expert: Exactly!

Here a perspective has become explicit which seems to be characteristic of the expert's actions: she does a worst-case analysis. Such analyses are quite common in engineering. Usually, however, such worst-case analyses primarily focus on technological aspects. In contrast, our expert (also) considers questions of liability.

Up to this point, the interview has produced two strands of insight that are now gradually merging: Firstly, safety relevant issues or "cases of emergency" are of central importance for the expert when identifying load cases. Secondly, the documentation must meet the requirements that apply for emergency conditions.

Now it is suitable for the interviewers to investigate more deeply. In what follows, they try to explore other partial aspects of expertise that have only been touched upon so far:

Interviewer 1: So I understood it like this: You think about what can go wrong. At what point does the [inner] film come into play?

Expert: So, I will start again with this one: As a design engineer, ultimately I will be responsible. Of course, I don't want to be responsible for someone getting hurt or for my design destroying itself or destroying other things. So I systematically think about what can go wrong, that is, what could I do wrong so that one of these undesirable catastrophes or one of these undesirable events will occur.

Interviewer 1: So, there is even one more step! You don't think about what could go wrong, you think about what YOU could do wrong.

Expert: Right, of course! Because it's all about the liability of the design engineer. What did I do wrong, what did I specify incorrectly? As a design engineer, I have to say which screws are to be used up there. What length they need to have, what diameter, what thread. I do choose that. That's what I am ultimately liable for!

As a reader, you may wish to pause for a moment and phrase for yourself what is characteristic for the professor's expertise, so that she does not get stuck in the bottlenecks she had formulated initially, as her students do so often. What patterns of thought, perspectives or ideas does she use, which her students do not use (yet)? How does her thinking and acting differ from that of her students?

In passing, it is important to point out the following: Although the interview touched upon students' insufficient acts repeatedly, the question of how students can be helped to master the bottlenecks addressed was never at issue. As emphasized above, the only purpose of the interview is decoding expertise. Of course, this is done with having in mind the final goal of helping students to overcome bottlenecks. However, the planning, implementation and investigation of effectiveness of such help is left to later steps in the Decoding process.

Let us return to the professor's expertise. The key here seems to consist of two motives of the expert: Responsibility and avoidance of liability. Firstly, nobody should be harmed. Secondly, she does not want to end up in prison.

Imagine the difference it makes when students approach their project work with or without these motives. With these motives, a focus on security-relevant load cases will probably emerge automatically, even for novices. Knowing about the consequences of poor documentation, students probably will not leave out any headings.

Most likely many students are not aware of these motives so far. What are the consequences for the expert's class? What will the further steps along the process of Decoding the Disciplines look like? As for step 3 (Model expertise), it probably doesn't take more than telling students the motives uncovered in the interview. In any case, simply telling these motives is better than leaving them encrypted.

In the meantime, our expert has been able to help many students to pass the bottlenecks simply by naming the motives. A few months after the interview, she wrote in an e-mail:

"The interview helped me a lot, and indeed this particular bottleneck seems to be much less of a problem for the students now. I already had at least a few teams last semester who had a very good eye for critical components and also understood what is important when documenting a calculation, namely making it understandable for a critical reviewer, e.g. after an aircraft accident investigation."

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Shortly before the editorial deadline (of the original German edition), we learned that the Stifterverband has awarded Prof. Dr. Peter Riegler of Ostfalia University, the initiator of the Decoding Working Group at DiZ, the 2019 Ars legendi Prize. He received this award for excellent teaching at universities and in particular for "teaching as a scientific activity". The jury honored Peter Riegler for his teaching using a research-oriented approach and for his special focus on difficulties students experience when learning subject matter.

Peter Riegler brings together different levels of teaching: The use of research based pedagogy and the systematic investigation of the effectiveness of teaching. In doing so, he constantly puts his own methods and findings to the test. Since 2011 he has refined his approaches several times, both through systematic observation of the effectiveness of his teaching and through reflective debates. He uses a wide variety of methods in teaching. By using Just-in-Time Teaching (JiTT), Peter Riegler is able to use the time spent in class not exclusively to impart subject matter, but to respond to students' difficulties with subject matter.

Peter Riegler supported the DiZ in the implementation of the HD MINT project. Since then we have been happy to work with him on the pedagogy of STEM disciplines in various contexts. Last but not least, he chairs the Decoding Working Group, whose work is described in this edition. We thank him for many ideas and value him as a soundly arguing discussion partner.

Claudia Walter Franz Waldherr

Conducting Decoding Interviews with the Structural Model TEACH

Britta Foltz

Summary

The structural model TEACH presented here facilitates solution-oriented Decoding interviews. TEACH divides the first two steps of the Decoding process into units that are structurally oriented to the needs and procedures of successful coaching and consulting interviews. TEACH applies well-established methods of interviewing and interview planning and allows the interviewer to fill the role of the cognitive apprentice in the first stages of the interview in a way that supports the expert in exploring his or her solution strategies. In later stages of the interview TEACH also provides the opportunity for collegial discourse without interrupting the exploration of the expert strategy too early. The careful documentation of the interview saves the results obtained and supports the further steps of the Decoding process.

Introduction

The Decoding process helps instructors move from the recognition of a possible bottleneck to course design and beyond. The Decoding interview represents a key step in the process and at the same time is challenging for the interview partners. As experts, teachers reveal to the interviewer a hurdle in one of their courses, where students repeatedly struggle with learning difficulties. By conducting the interview, the interviewer helps to uncover the often unconscious expert strategy of the teacher in order to solve the problem in question. Only after this has been achieved will be the related learning situation compared with this strategy.

The conditions for the success of a Decoding interview are manifold. A thorough analysis of various Decoding interviews revealed that the following issues often constitute a challenge:

- creating an atmosphere of mutual trust on a level playing field
- the interviewer's willingness to take on the role of a cognitive apprentice
- selecting and defining a suitable bottleneck
- clear structuring and a solution-oriented interview management
- applying appropriate interview methods
- finishing the interview in a constructive way and securing results.

"Effective counselling consists of a definitely structured, permissive relationship which allows the client to gain an understanding of himself to a degree that enables him to take positive steps in the light of his orientation." (Rogers, 1942: p.18). With this in mind, this article introduces a structural model for planning and conducting Decoding interviews that supports interviewers in their task. It builds on the COACH[1] model established in the context of coaching (cf. Rauen & Steinhübel, 2001). It helps to maintain orientation in the often complex interview situation and to conduct the process in a solution-oriented and successful way. This article also discusses supportive interviewing methods for the identified structural phases of the interview.

The structural model TEACH to be introduced below divides the Decoding interview into five structural sections. Sections 1 to 4 contain steps 1 and 2 of the Decoding process, i.e. the steps "What is the bottleneck to learning in this class" and "How does an expert do these things". The fifth section introduces the transition to step 3, i.e. "How can these steps be explicitly modelled", and thus to the pedagogical implementation of the findings (see Figure 1).

Structuring the Decoding interview according to the TEACH model facilitates a clear separation of the elicitation of the cognitive strategy of an expert from a consideration of the expert's role and actions as an instructor in the lecture hall. In addition, TEACH secures the results for the interviewee by documenting them and thus facilitates the next Decoding step, the finding of metaphors and pedagogical solution scenarios.

[1] COACH divides coaching processes into the phases Come together, Orientation, Analysis, Change, and Harbour. This structure can be transferred to the structure of the Decoding interviews and adapted to their content.

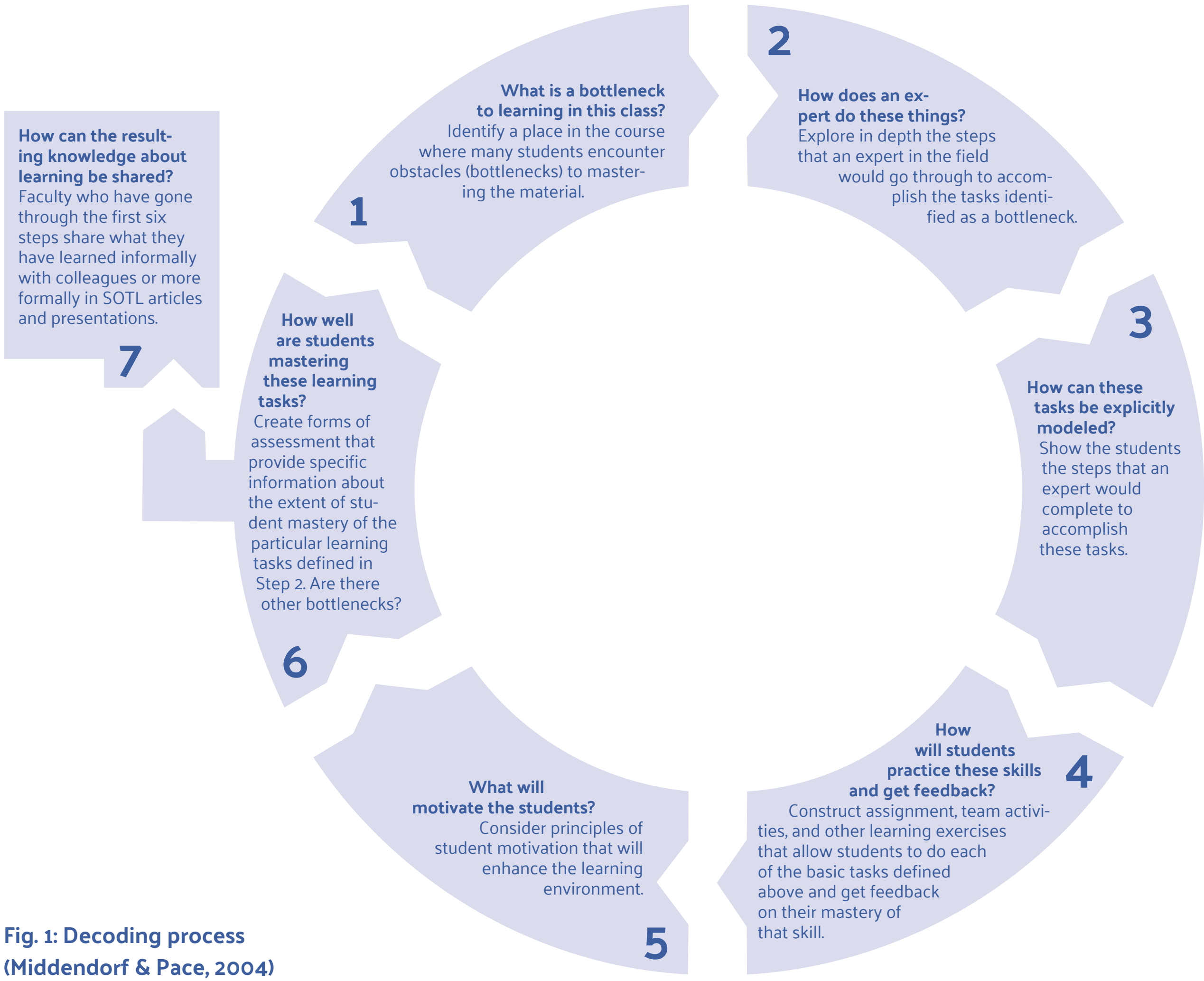

Fig. 1: Decoding process (Middendorf & Pace, 2004)

The TEACH structural model for Decoding interviews

Why a structural model?

The aim of the Decoding interview is to make implicit and unconscious parts of expert knowledge visible and to uncover related solution and action strategies (cf. Pace, 2017: p.44). In this way, instructors are enabled to detect differences between how they think about the problem and their existing concept of how to teach it. Thus, they can derive appropriate actions afterwards.

There are typical challenges for successful interviews:

- The very setting of the conversation as well as its beginning can decide whether it is possible to immerse oneself sufficiently in the expert's world of thought. After all, both sides need a feeling of security in order to open up for dialogue. A clarification of roles and of the course and content of the interview, as well as a good discussion atmosphere, contribute to this. The focus of the interview is to uncover the expert strategy. Criticism and advice are to be completely left out.

- Interviewers, in turn, preferably should be unfamiliar with the interviewee's field of expertise. At least, they need to allow themselves to slip into the role of the cognitive apprentice who is completely unaware of the world of thought presented and its methods. Pursuing such a behaviour is not self-evident in the world of university teaching, where knowledge and expertise have a high significance and a direct influence on one's own reputation.

- The careful elaboration of the bottleneck is also a serious challenge for experts and interviewers. The bottleneck must be specific enough and in particular be influenceable by the instructor in a concrete teaching situation. In steering the interview process, one of the core tasks of the interviewer is to clearly distinguish between expert cognition, the pedagogical concept and the course under consideration. Otherwise, the discovery of the expert strategy and the collegial consultation would be mixed up and the progress of the Decoding process would be complicated considerably.

- Further frequently observed phenomena include meandering between neighbouring or linked bottlenecks and the loss of (intermediate) results due to a lack of documentation during the interview.

- If, in addition, the interview lacks a professional conclusion, those involved miss the chance to initiate the transition to the next steps of the Decoding process directly.

In coaching, the challenges during a session correspond in many respects to those mentioned above. Coaching uses established structural models to provide a remedy by mapping the overall process to the particular session. Hence, such models belong to the basic tools of every coach. They are especially helpful for newcomers as they allow them to structure the conversation, to create a setting that promotes trust, and to make the process solution-oriented. The documentation of the results and the introduction of subsequent steps also find a beneficial place.

For these reasons the TEACH structural model presented here divides the Decoding interview in an analogous manner into five sections that build on each other: T for **Team up,** E for **Elucidate,** A for **Analysis,** C for **Change,** H for **Harbour.** These are explained in the following.

1. Team up – Getting together

This is the contact phase at the beginning of the Decoding interview. For interviewers it is the phase in which they work on a good atmosphere for the discussion. They build up rapport, explain the procedure, the individual phases and the aim of the interview. If the interviewer is supported by a second interviewer, his or her role must be clarified in this phase and explained transparently to all those involved.

2. Elucidate – Enlighten and explain

In this phase, the bottleneck of the instructor is examined. Whether the expert has already done preliminary work or the interview only starts with a vague idea of where the learning hurdle of the students is located, the expert and the interviewer agree on how to deal with a certain learning obstacle. They check whether the bottleneck satisfies typical criteria. They also supplement inherently negative formulations, such as "Students (often) are unable to …", with a positively phrased, competence-oriented goal that describes the learning outcome of the students (step 1 of the Decoding process).

3. Analysis – Analysis of the expert strategy

The aim of this phase is to elicit the expert strategy for solving the problem that has been presented. Here, the focus is particularly on instants in which highly condensed actions or intuitive decision making become visible. Also the significance and meaning of each individual step of the expert strategy is scrutinised. Since the focus is exclusively on the cognitive model of the expert and not on the pedagogical concept of the existing learning unit, the interviewers' own hypotheses or advice can severely disturb the process in this phase. Therefore, they take on the role of the cognitive apprentice, who tries to model the expert's thoughts step by step and continuously reflects them back for monitoring. Despite the focus on the expert strategy, further bottlenecks can emerge in this phase. In order to continue working in a solution-oriented manner, these are recorded in written form. The interviewer scrutinises whether there is an additional hurdle to understanding and if so, which of the two is more important. It is decided whether it is sensible and possible to continue working on the old bottleneck, or whether the process must be consciously focused on the new bottleneck (step 2 of the Decoding process).

4. Change – The step to optimisation

Once the solution strategy has become sufficiently clear, expert and interviewers can turn to the teaching-learning situation. Here, direct differences and unconscious omissions often become transparent. First ideas for possible solutions are collected. This step also provides the appropriate framework in which interviewers can express their own hypotheses and, if desired, bring in forms of collegial consultation. Procedures for further identified bottlenecks are agreed upon.

5. Harbour – Bringing home what you have worked on

Every Decoding interview needs a conclusion, which helps the expert to realize the teaching goals in the long term. The recorded results of the interview are reflected upon and next steps and a reasonable time frame are agreed upon. In addition, the interviewers can receive important impulses for their own approach and interview management. Therefore, the final phase is important for the expert as well as for the interviewer and should take place – even in case of an early termination of the Decoding interview – in order to conclude and appreciate the process appropriately.

Supporting methods in the individual phases of the interview

Like every professional conversation, Decoding interviews benefit from the use of professional conversation skills and questioning techniques. In the following, appropriate methods are presented for each structural section of the TEACH model.

Recommendations for the phase Team up

The setting of the Decoding interview

Middendorf and Shopkow recommend that interviews should generally be conducted by two persons, of whom at least one has no or very little expertise in the field under consideration (cf. Middendorf & Shopkow, 2018). One person assumes the role of the actual interviewer: he or she leads the interview as the person responsible. The second person stays in the background and at the same time is always ready to come to the interviewer's assistance or to continue the interview in parts.

Most Decoding interviews are conducted in a seated position. A suitable seating arrangement and the interpersonal distance between the actors plays an important role (cf. Geisler, 1992: p. 24 and p. 37ff).

An appropriate distance for conversation is between approximately 75 – 120 cm, i.e. a distance that is perceived as pleasant and which could still be bridged by reaching hands (cf. Hall, 1976: p. 125ff). In particular the seating arrangement can have a considerable influence on the climate of the conversation. Two seating arrangements of main interviewer and expert are suitable:

- The face-to-face arrangement
  If expert and interviewer choose to sit face-to-face, this can indicate that the interviewer is concentrating entirely on the expert (cf. Geisler, 1992: p. 39). In particular, this position can be appropriate if a relaxed atmosphere already prevails. A danger inherent to this position is that it is often perceived as confrontational. Geisler attributes to this arrangement a "character of head-on intimidation" (cf. Geisler, 1992: p.39). This position is often associated with situations of "handling", conflict or hierarchical differences.

- The 120 degree arrangement
  This arrangement, where the parties sit at an angle between 90° and 150°, avoids any confrontational character. If possible, the interviewer should take care not to put his or her writing hand between him or herself and the expert. In this way, an open attitude towards the interviewer can be maintained even when taking notes. In this position, it is also easier to give the interviewee space for undisturbed reflection, as eye contact can be interrupted without appearing impolite. A further advantage is that both parties can look at notes or visualisations at the same time if necessary. In general, this seating arrangement is preferable to the face-to-face position.

Of course, an environment should be chosen that protects the interview from disturbances and interruptions. The provision of visualisation aids and writing materials also supports a smooth interview process.

Creating an open atmosphere for the Decoding Interview

Conducting a successful interview requires both parties to enter into a temporary professional relationship. Nestmann et al. point out that without an open, trusting and cooperation-oriented relationship between all parties involved, no promising counselling is possible. (Nestmann et al., 2002: p.129) This process of building relationship is supported when interviewers actively build up rapport with their interview partner. The phenomenon of rapport becomes visible whenever people familiar with each other interact, for instance a couple in a restaurant: One person takes his or her glass and the partner reflects this gesture shortly afterwards and acts similarly. If one person scratches his or her nose, the other person involuntarily grasps his or her face shortly afterwards. In order to support as an interviewer a good conversational atmosphere, it is useful to get involved with the behaviour, the attitude and the speed of speech of the interviewed person and to adapt to it to a certain extent.

If the interviewee is taking part in a Decoding interview for the first time, the roles should be briefly explained, as well as the objectives of the individual steps. The resulting certainty in actions also facilitates an open and solution-oriented interview.

Tools for the phases Elucidate and Analysis

In the phases **Elucidate** and **Analysis** the interviewer supports the expert in exploring his or her thoughts and strategies. The method of **controlled dialogue** makes it easier to stay with the expert's explanations.

Controlled dialogue as an inoffensive method of conducting interviews

A *controlled dialogue* in particular uses two interview techniques: paraphrasing and the use of open questions. By summarising and paraphrasing the expert's explanations on a regular basis, *controlled dialogue* ensures that the interviewer has correctly noted down the expert's statements and has really understood their logical sequence. Furthermore, using this method he or she can help the expert to deepen thought processes without having to offer own hypotheses or to resort to suggestions. When paraphrasing, interviewers start with an introductory phrase, such as “Did I understand that correctly?” or “I have now arrived at the following …” and then repeat in their own words what they have understood.

To invite the interviewee to explore the next step of his or her expert strategy, open questions are used. They always start with a question word (who, how, what, why …) and encourage further explanations and the finding of new perspectives. They are the opposite of closed questions, which always have a yes or no answer.

Through the *controlled dialogue,* interviewers signal interest and attention and control the course of the conversation inoffensively. This method focuses strongly on the factual level. The use of *controlled dialogue* is particularly useful for difficult or unclear content, vague or implied statements and roughly follows the following procedure:

1. asking a question starting with a question word
2. listening carefully to the answer
3. paraphrasing and reassuring
4. asking the interlocutor for confirmation or correction

If the paraphrased content is corrected by the expert, this should not be considered a setback. This reaction also stimulates further reflection and thus promotes the progress of the interview.

On the importance of sufficiently concrete bottlenecks

The definition of the bottleneck corresponds in many respects to the clarification of the assignment in regular consulting or coaching sessions. A thorough understanding of the bottleneck means clarifying what is be worked on and which results are intended. The following features of bottlenecks listed by Pace are helpful for identifying appropriate bottlenecks:

- “They affect the learning of significant numbers of students.
- They interfere with major learning in a course of courses.
- They are defined clearly without jargon.
- They are relatively focused and do not involve a large number of very disparate operations.“ (Pace, 2017: p. 28)

A sufficiently specific determination of the bottleneck is of crucial importance if the later interview is to be solution-oriented. Too vague formulations lead to confusion and ambiguity in the Analysis phase, because the expert then easily jumps from one topic to another and tries to call up different strategies at the same time. Here, helpful questions are:

- Which course is affected?
- Exactly where are students always struggling?
- How do the difficulties of the students show up? How exactly do you recognise these difficulties?
- Is there a teaching-learning situation in which you (can) actively address this topic?

If the latter question cannot be answered with yes, the bottleneck is not suitable for processing with the method. The prerequisite is that there is always at least the possibility of creating a learning situation for the students in which the expert can present his or her model for overcoming the bottleneck to them.

While a bottleneck is always formulated negatively, the additional formulation of a corresponding, positive and competence-oriented learning objective can be helpful as additional information.

- What exactly should the students be able to name, analyse, evaluate, classify, and to what context should they do so once the bottleneck has been overcome?

This positive formulation of the learning objectives can be refined at the end of the interview. This helps to assess the usefulness of the gained knowledge with regard to the pedagogical implementation.

Uncover the expert strategy

In consultation sessions, strategies of any kind can be elegantly developed or uncovered using examples. Similarly, the expert strategy can also be uncovered in a Decoding interview on the basis of a concrete situation or a typical example. The standard example taken from the lecture often proves to be unsuitable, as it can always lead to digressing into the pedagogical concept and procedure in the lecture. However, the aim of the interview is to find out how exactly the expert himself or herself approaches the problem. Therefore, the example used to illustrate the strategy should also correspond to the expert's personal world of thought and not to the way he or she tries to communicate the content to others.

Therefore the question is not "What example illustrates the bottleneck (for others) particularly well?", but "How and by what example do you yourself think about this bottleneck and illustrate it to yourself?" The expert first describes this in detail and then develops his solution strategy step by step.

There are also many helpful open questions for the analysis of the expert strategy, from which the interviewer can draw. Examples can be found, for example, in Pace:

> „Here are a few of the variations of the question "How do you do that?" [...]
> What does that tell you?
> What information are you getting from that?
> How do you know which element of the problem to focus on first?
> What are you looking for at this point?
> Are you visualizing anything as you do that?
> Why is doing that important?
> [...]
> How do you know, which method to apply at this point?
> How do you know when you have hit a dead end?" (Pace, 2017: p. 38)

The structure of these questions is typical for consulting and coaching sessions. The aim is to uncover and question especially generalizations and omissions. In particular, questions should be considered, which are asking for

- the form of representation:
  "How exactly do you do that/represent that/formulate that ..."
- the explicit order of the steps:
  "What comes after that?", "What happens next?" "Is this the only way to proceed at this point?"
- the triggers of the next step:
  "How do you know you have mastered this step?", "How do you know you have to do exactly this now?", "How do you decide that you ...?", "Is it completed this way?"

If the expert deviates from his or her expert strategy at this stage of the process and reports on how he or she communicates the subject matter to the students, it is important to point this out in a friendly manner at the appropriate place and to lead back to the topic. These issues concerning pedagogical concepts are important to the instructor. Therefore, they have to be handled in an appreciative manner at this phase of the interview. It can have a reassuring effect to point out that the topic of "implementation" will definitely not be forgotten and find its place later on.

Maintaining orientation in spite of linked bottlenecks

Often the bottleneck that the expert is addressing seems to change during the conversation. This may be because of linked bottlenecks that become apparent. Here it is useful to insert a short reflection:

- Does the old bottleneck still work as the subject of the Decoding interview?
- Does a new one have to be chosen?
- Is it enough to note down the new learning obstacle that has just arisen such that it can be considered later?

If the conversation investigates multiple bottlenecks without reflection, it becomes very challenging for all participants to stay oriented. In addition, it becomes almost impossible to secure usable results.

Decoding the Disciplines		
Date	Expert:	Interviewer:
Bottleneck (negative)		
Learning Outcome (positive)		
Expert strategy		
Number	Individual steps of the expert strategy	Annotations by the Interviewer: Sugges-tions, hypotheses which could be mentioned at the end of the interview

Fig. 2: Documentation form for Decoding interview

Documentation of results during the phases Elucidate and Analysis

The goal of the **Analysis** phase of the Decoding interview is to reveal the expert's solution strategies with respect to the given bottleneck. If this strategy is not documented during the interview, many details will be lost for later Decoding work. The experience of many interviews and coaching sessions shows that writing down the strategy during the process also slows down the process in a beneficial way. Careful documentation of the interview therefore is useful. Either the expert can note down the individual strategy steps, which adds a further level of reflection to the interview through the necessary condensation. Alternatively, the interviewer notes down the steps secured by *controlled dialogue*. This documentation is facilitated by the form depicted in Figure 2, for example. This form has already been used successfully in various interviews and should be seen as a guideline. Its structure supports the documentation and can be abandoned or changed at any time, e.g. to document decision loops or visualisations.

Audio recordings of the Decoding interview are highly interesting, too. They capture the details of the interview and thus provide insight for the expert as well as for the interviewer. Nevertheless, these recordings have to be transcribed and after that the result has to be filtered to obtain the explicit expert strategy. This rather time consuming process can be a hindrance or even stop the Decoding circle. Therefore, it seems to be advisable to combine the note taking with the audio recording.

Recommendations for the Change phase

The aim of the **Change** phase is to allow an initial comparison with the corresponding teaching/learning situation after the expert strategy has been elicited. To this end, the interviewer summarises the achieved results on the basis of his or her documentation and leads into the reflection phase. Here questions are helpful, too. Examples include:

- If you compare your initial solution strategy with your pedagogical concept now, where do you see differences?
- At what point do you think students often leave the path described here? What do they do instead?
- Are there any decisions/steps that are very important for your strategy? How are they implemented in class so far?
- Can you spontaneously think of a metaphor that illustrates this part of your strategy?

With the consent of the expert, a collegial consultation or discussion may also take place in this phase. There the interviewer can contribute his or her own observations and ideas in an appreciative manner.

The results of the **Change** phase should also be recorded (in writing) either by the interviewer or the expert.

Recommendations for the Harbour phase:

In the last phase, the aim is to close the interview in a professional manner and to suggest the transition from the recent findings into concrete measures. In order to facilitate the development or optimisation of appropriate pedagogical concepts, next steps should be discussed. Here, possible questions for reflection would be:

- Looking at your results so far, what do you need to continue working with them in the coming weeks?
- Do you already know what the next step will be?
- What needs to be clarified before you can tackle step 3 of the Decoding process “How can these steps be explicitly modelled”?

The answers to these questions are also documented. The written documentation of the whole interview as well as the audio recording can then be handed over to the expert for further use. Finally, the interviewer him- or herself has the opportunity to ask for feedback on the process in order to gain helpful impulses for future interviews.

Conclusions and outlook

The structural model TEACH presented here, in combination with the described methods of conducting conversations, has already been successfully applied in Decoding interviews and has been evaluated as helpful. It transfers established procedures from coaching and consulting practice to the special format of finding bottlenecks and to the elicitation of the expert’s solution strategy. Decoding the Disciplines was designed as a process in which instructors support and interview each other. At the same time, many university lecturers state that they do not have sufficient knowledge in the area of advisory skills and interviewing (cf. Wergen, 2011). TEACH is to be understood as an aid to successfully conduct solution-oriented interviews from the very beginning.

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Bottlenecks: From Static Words to Slippery Concepts

Niall Palfreyman

Abstract

This article argues that: (a) Teaching as *telling-that* fundamentally undervalues the abstractive nature of learning, and fails to empower students to construct their own abstractions. (b) Abstractions are contextualised stories about *discovering-how*. (c) Contextualised stories are communicated more faithfully through *construction activities*. (d) *Learning conversations* use teaching bottlenecks to refine our understanding of our domain of expertise, and to design construction activities for teaching.

Bottlenecks: a visceral teaching tool

When I started teaching, it seemed to me self-evident that knowledge is data content that is stored, processed and applied by experts, and that teaching is the process of telling students the content they need to know. Sure, we need to tell it in ways accessible to students. We need to tell it in fun ways, weaving humour into our lessons. We need to approach simple instances before moving on to more abstract content. We need to tell the practical applications of content in Real Life. But still, in the end it was just telling.

Yet as forty years of my teaching career passed, I grew increasingly frustrated with my ability to actually get students to understand the science I was supposedly teaching them. Yes, I could tell them how to multiply together (2×2) matrices, and some could then actually do it; but it did not then follow that they could also multiply together (3×3) matrices. Yes, I could tell them the general formula for multiplying two matrices together; but it did not then follow that they could apply this abstract rule to specific matrices. I could account for some of these problems by scolding the students for not listening, or myself for not telling effectively, but the problem was far too frequent for either position to be the entire story.

The basis of *teaching as telling* is the idea, expressed by Ferdinand de Saussure, of *denotation:* that we think and communicate by accessing and manipulating signs and models that *intrinsically* denote information about the mind-independent events and processes around us. For example, I find my way to Sydney Gardens in Bath by means of a map, or model. We can distinguish between the *vehicle, structure, target* and *content* of this model. The model's vehicle is the set of marks on paper; those marks possess a *structure* of internal relationships; the *target* of my model is the 'real', mind-independent city of Bath; and the model's *content* is the set of relationships that its structure asserts about its target (e.g., "Sydney Gardens is at the south end of Sutton Street").

From the denotational viewpoint, I teach by offering my students linguistic structures (spoken or written models) that denote the content I want them to learn. 'Sydney Gardens' *denotes* a place in Bath, 'hexagon' denotes a type of polygon and 'gene' denotes a coding sequence of DNA. If I indeed find Sydney Gardens at the south end of Sutton Street, my map denotes Bath truthfully: it makes a true assertion about it. If I cannot find Sydney Gardens at the south end of Sutton Street, my map denotes untruthfully: it makes a false assertion. In both cases, however, the vehicle intrinsically denotes Bath. If the vehicle were instead a recording of "Ironic" by Alanis Morissette, it would not denote Bath.

Functionalist theories of cognition regard conceptual knowledge as denotation: I possess an internal model that helps me find my way around Bath. Yet this idea of concepts as denotative models neglects (see Ramsay 2017) two questions of central importance for teaching:

- While models might arguably represent *knowing-that* Spain is in the European Union, how would they capture *knowing-how* to catch a ball?
- How are new concepts constituted and reconstructed through experience and teaching?

Knowing-that and *knowing-how* are clearly distinct, and Pace and Middendorf's (2004) term *bottleneck* refers directly to this tension between facts and skills. For example, each year in my first-semester mechanics module, I tell my students the simple fact that the concept *centripetal acceleration* (directed *inwards)* is essential for solving circular motion problems, and that the term *centrifugal force* (directed *outwards)* is misleading. Then, each year in the follow-up module, I hear remarks like:

- "Centripetal force pushes objects outwards from a circle."
- "Centripetal force is ***F***, so centrifugal force is ***-F***, and therefore ..."
- "One could solve this exercise using centripetal acceleration, but I prefer centrifugal force, so ..."

Apparently, these students cannot interpret my simple statement. Yet why not? This is a classic example of a bottleneck in communication. My *intended* learning outcome is that students know: *"Use centripetality to solve circular motion problems"*. However, the *actual* lesson they take home is: *"Seek out a standpoint from which centripetality appears centrifugal"*. Each year, this bottleneck causes me physical pain; its recurrence frustrates and depresses me, leaving behind feelings of incompetence and despair.

Bottlenecks are a central component of *Decoding the Disciplines* (Pace & Middendorf 2004) – a process of dialogue with the aim of developing discipline-specific teaching skills. Their pain is a visceral symptom of a certain 'stuckness' in my teaching. Yet bottlenecks are also a springboard for collegial conversations with the potential to transform this 'stuckness' into new teaching competence. To accomplish this transformation, we must first explore how such bottlenecks arise from the conflict between my centripetal *telling-that* and the students' centrifugal *knowing-how*. In this article, I hope to persuade you of the following:

- Teaching as *telling-that* fundamentally undervalues the abstractive nature of learning, and fails to empower students to construct abstractions for themselves.
- Abstractions are contextualised stories about *discovering-how*. As every dog-trainer knows, it is not the *telling-that,* by means of pulling on a dog-lead, that teaches a dog to walk stably alongside her human, but the contextualised *practice* of walking in this way. *The ability to walk at heel enacts the practice of walking by someone's side.*
- Contextualised stories are communicated more faithfully through *construction activities.*
- *Learning conversations* use teaching bottlenecks to refine our understanding of our domain of expertise, and to design construction activities for teaching.

Cognition is not denotational

Hutto and Myin's (2013; 2017) argument against denotation focuses on *natural* explanations: explanations on which everyone agrees, since they exclude all supernatural or anthropomorphic components. Specifically, Hutto and Myin point out that the only way to naturalise the definition of denotation is in terms of *covariation:* my internal map denotes the city of Bath because its structure covaries with the structure of Bath. For example, suppose I stick a thermometer to my kitchen window to read the temperature outside. We might claim that since the thermometer reading reliably increases and decreases with outside temperature, it therefore denotes the temperature: the thermometer *denotes* the outside temperature because it *covaries* with that temperature.

Yet contrast this with the situation of pancreatic β-cells that reduce high blood glucose concentrations. Blood glucose stimulates β-cells to secrete insulin, which in turn breaks down blood glucose in a reciprocally activating feedback loop. Here, we might claim that since the insulin level reliably increases and decreases with blood glucose level, it therefore denotes blood glucose level. However, there seems something amiss here, since even as insulin rises, it lowers the glucose level. In such a mutually causal system, does insulin rather 'denote' or 'control' blood glucose?

The situation of sea tides varying with the position of the Moon brings this home even more clearly. We cannot say tide level *denotes* in the sense of being an *intrinsic* carrier of information about the Moon's position – too many other factors such as flow-rate are also relevant to tidal levels. Indeed, the notion of any vehicle *self-sufficiently carrying* information about something else is more expressive of how we interpret the vehicle, than of how it dynamically covaries with other processes. How, for example, does the graphical sign "Bath" covary with the city of Bath, other than through interpretive convention? This is the thrust of Hutto and Myin's Hard Problem of Content:

- If functional imaging reveals neural activity in rats that correlates with a route through a maze, we might assume this activity is a self-sufficient structural representation of that route.
- The naturalised form of this assumption is that the neural activity denotes the route by virtue of covarying with it. Yet when I catch a flying ball, the position of my hand covaries with the ball, but it does not *denote* the ball; rather, it reflects *my* intentional reaction to the moving ball. Similarly, the neural activity results from constraints imposed by the rat's intentionality with respect to the maze, undermining the idea that it self-sufficiently *denotes* the route.

To redress this deficit, enactive accounts of perceptual neural activity must take account of its reciprocal dynamical coupling with the intentionality of perception.

Along similar lines, Harvey (2015) presents his Hard Problem of Public Vehicles:

- If we observe language experts using speech, writing, maps and plans to communicate meaning, we might assume these contain *public vehicles* – words and sentences – that intrinsically denote those meanings.
- The natural form of this assumption is that words covary with their targets: the utterance *'jump'* covaries with the incidence of jumping. However, mere covariation between sounds defines neither words nor their denotational targets. A monolingual English speaker would be incapable of discerning even simple word-divisions in spoken Arabic – their meaning is in the eye of their beholders. Hence, the idea that utterances *intrinsically* denote meaning is contradictory.

To redress this deficit, enactive accounts of language use must take account of *languaging:* the reciprocal negotiation of *shared* meaning associated with vehicles.

With regard to teaching STEM abstractions, I offer the following Hard Problem of Categories:

- If we observe science experts speaking of *particles, organisms, genes* or *berries,* we might assume these abstractions denote categories of instances.
- The natural form of this assumption is, for example, that use of the abstraction *‹Berry›* covaries with objective instances of the category *Berry*. However, covariation between abstractions does not define either conceptual boundaries or experts' categorisation of instances. After a century of careful scientific discussion, the precise conceptual boundaries of a *‹Particle›* (Teller 1997), *‹Organism›* (Bouchard et al 2013) or *‹Gene›* (Keller 2003) are still obscure. And how many people would spontaneously classify a zucchini as a *‹Berry›*, or a banana plant as a *‹Herb›?* In each of these cases, the problem is that abstractions are constrained not by objective categories, but by how we think things work.

To redress this deficit, enactive accounts of abstraction must take account of its reciprocal coupling with the intentional, lived praxis of *using* concepts.

Each of these Hard Problems rejects the assumption that denotation is a natural relation: that my students might not yet know what a gene is, but I do, and that even if I am unsure, I can appeal to an objective, mind-independent definition of genes. If we as teachers reject denotation – as these

Hard Problems say we must – we need an alternative view of knowing, learning and cognition that acknowledges how covariations in perception, language and abstraction arise out of our reciprocal, biological coupling with our experience. How does such an enactive view influence our teaching?

All communication entails concept-revision

There is a well-developed alternative to denotation. Whereas Saussure saw denotation as an intrinsic attribute of models, his contemporary Charles Sanders Peirce emphasised meaning as an inherently three-way contract between vehicle, target and *interpretant* – the denotative linkage between vehicle and target within some interpreting agent. For Peirce, denotation is not intrinsic to the sign-vehicle, but emerges out of the interpreting agent's dynamical meaning-making process, termed *semiosis*. It is only through semiosis that meaning emerges; beforehand, the vehicle is not a vehicle, and the target is not yet a target.

While this shift may seem minor, it has enormous consequences for teaching. For as Kull (2018:455) points out, semiosis implies an autonomous *choosing* of the denotative relationship between vehicle and target. Thus, we start to see how Peircean semiosis circumvents the Hard Problems: information, language and abstraction no longer intrinsically denote events, meaning and categories. Rather, they implement an ongoing dynamical process by which agents freely *choose their interpretation of perceptual events, actions and instances,* then habituate these choices into long-term abstractions available across contexts.

This perspective implies a merging of acting and learning into a single cognitive process – *enaction* – that encompasses both the semiosis of meaning and the construction of knowledge. Knowledge informs semiosic interpretation, and habituation constructs knowledge from interpretation. This understanding makes it difficult to sustain the conventional distinction between denotative *recall* and constructive *concept-formation,* since even simple factual recall entails a semiotic explosion of potential meanings, which in turn reconstruct our knowledge. Consider this question:

- What is the capital city of France?

At first sight, this appears to be a simple recall question. So now answer this question:

- What is the capital city of Botswana?

Suddenly the nature of the question changes. My quest for meaning goes beyond mere recall and requires me to examine my associations with the concept ‹*Botswana*›. So: not a recall question. What about this:

- What is the capital city of Holland?

This requires us to distinguish between the concepts ‹*Capital*› and ‹*Seat of Government*›. For many of us, this cognitive process entails a slight conceptual revision. What about this question:

- What is the capital city of Germany?

For Germans born before 1975, this is *almost* a pure recall question, but elicits a brief consideration of the political events of 1989-91. So: not merely a recall question. And, to come full circle, are we so very certain that we can *completely* dissociate the following question from our knowledge of 300 years of European political history:

- What is the capital city of France?

These examples suggest that what we conventionally regard as pure recall activities may be more complex than we thought, since even trivial recall questions such as "What is 2+3?" involve recognising something as an instance of some conceptual category.

"Of course!", I hear you say. "But that doesn't mean that all learning involves conceptual revision. To recognise a cat, I don't need to revise my concept ‹*Cat*› – but only *apply* it!"

Yet from a semiotic perspective, there is no clear distinction between applying and revising a concept. If my sensory *action* of looking encounters a perceptual experience associated with cats, it evokes in me a semiosic *process* that folds together a perceptual gestalt, intentions, context and motor responses over milliseconds. My concept ‹*Cat*› is then the habituated similarity running through such past recognition processes. To understand the nature of learning, we must be clear that this concept does not exist in an external world yet is also not purely my own invention. Applying the nascent concept in my everyday attempts to make sense of experiences *enacts* it as a synaptic trace. Thus, concept and instance arise co-dependently in my mind as the gradual, self-evidencing continuity underlying a history of similar perceptual experiences. Indeed, *every* sensory act is simultaneously a construction process: *each time semiosis involves a concept, the associated knowledge constructs shift slightly.*

Bottlenecks are then precisely those situations in which learners *actively resist* this natural reconstruction of concepts. For example, Dunbar et al. (2007) used an explanatory film-clip to explain carefully to Harvard students how the tilt of the Earth's axis determines the seasons. Yet in subsequent tests, 95% of these students held fast to their implicit prior belief that seasons arise because the Earth is closer to the sun in summer. How can this be? These results make no sense from a denotational perspective: if an expert authority offers them a factual model, can students not simply insert that model into their 'knowledge base'? Why would they resist the otherwise natural reconstructive tendency that was the intended outcome of the film-clip?

Yet from the enactive perspective of learning as habituation, Dunbar's results make perfect sense. Ruth Millikan (1989) defines purposeful action in terms of *proper functions.* Suppose a bacterium possesses the cognitive habit *T* of tumbling when the ambient concentration of phenol (a toxin) rises. We say *T* has the *proper function* of avoiding phenol if (a) *T* does indeed avoid phenol, and (b) the bacterium possesses *T precisely because of T's past ability to avoid phenol.* This definition enables us, for example, to claim that the gene variant *HbS* in humans has the proper function of protecting against malaria because it (a) confers this protection on its possessor, who (b) has inherited *HbS* from her ancestors precisely because it conferred this protection on them.

Similarly, Dunbar's students' proximity explanations of warmth serve the proper function of keeping them warm in winter by keeping them huddled close to heaters, and they acquired this habit precisely because it kept them warm in past winters. But precisely there lies the problem with denotational accounts of learning: it is not proximity explanations, but huddling up to a heater, that keeps students warm in winter. The products of learning are not primarily denotational models, but the interactional *behaviours* that implement the proper function of such models. Bacteria are selected for their *toxin-avoiding* habit, and humans are selected for *suppressing* replication of the malaria parasite, rather than for the DNA variant *HbS* that conditions this suppression. Dunbar's students value keeping warm, rather than alternative explanatory mechanisms, and they *know* that huddling up to a heater keeps them warm.

Cognition consists, not in denotation, but in *skills:* successful, contextualised behaviour.

Enaction: *Knowing-that* is constructed from *knowing-how*

So far, we have answered the first of the two issues raised by Ramsay (2017). The primary products of learning are not the denotational facts of *knowing-that,* but rather the skilful behaviours of *knowing-how.* Yet we cannot deny that knowledge also appears to be populated by concepts whose usefulness lies in the very stability that enables them to be transferred across diverse situations. To derive guidance for teaching abstract concepts, we must address Ramsay's second issue: *How are new concepts stably constituted and reconstructed through experience and teaching?*

This question raises two interrelated issues. First, despite their lack of denotation, concepts nevertheless exhibit *covariance*: stability through time and across contexts. Einstein (1916) introduced the term *covariance* (or *covariant relation*) to describe the stability of physical laws through time and across observers; we should not confuse it with our earlier term 'covariation'. For example, the pancreas skilfully regulates blood glucose to a stable optimum level, yet this optimum is denoted nowhere within the pancreas. Rather, it is implicitly enacted as a covariant relation between the competing dynamics of blood glucose up- and down-regulation. Second, the dependence of knowledge on proper functions compels us to think about learning in terms of *selective adaptation*. However, Di Paolo (2005) emphasises that learning requires a definition of adaptation that applies *within* an individual organism, since natural selection's all-or-nothing criterion of survival only makes the benefits of useful behaviour available to an organism's offspring. We therefore ask: *How do covariant relations become internally selected to implement the learning of stable concepts?*

Hoffmeyer (2010) notes that semiosis always involves *downward selection of stochastic variation*. Light-generating bacteria react stochastically to their chemical environment in the photophores of bobtail squid, but the squid uses a nonlocal flow of N-acyl-homoserine lactone to downwardly coordinate this variation into a coherent camouflage when at the ocean surface. The termite symbiont *Mixotricha paradoxa* moves by downwardly constraining stochastic flagellar activity of bacteria clinging to its cell surface, and downward flows from the amygdala select stochastic synapse formation, shaping our learning in emotional situations.

Favareau (2015) points out that the constructive process by which meaning relationships emerge must bootstrap itself from this cacophonous, recursively upward and downward flow of influence between events, structural relations and nonlocal flows. This *scaffolding* process constructs initially tentative, but increasingly stable, structures that capture relations that are covariant across multiple instances of semiosic choosing. This in turn canalises further construction into a cooperative co-arising of knowledge and meaning.

Palfreyman and Miller-Young (2019) show how downwardly selective systems can spontaneously engender scaffolding (see Fig. 1). Such systems contain local structural relations and nonlocal flow distributions that recursively constrain each other in the following way: local relations determine the dynamics of the flows, while themselves being susceptible to stochastic variation which is in turn downwardly constrained by the flows. For suppose some spontaneous local configuration of flows in a downwardly selective system constrains almost to zero the stochastic variation in a collection of structural relations, thereby conferring on that collection a transiently stable collective identity. Now

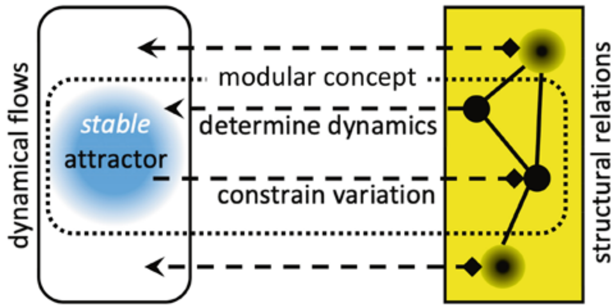


Fig. 1: Emergent scaffolding of a stable meaning-structure.

suppose further that this collective in turn determines flow dynamics of which the current configuration is a stable attractor. In this case, the collective will scaffold a mutually stabilising structure/flow module.

Over time, this module comes to exhibit a family of responses to outside events that serve the proper function of self-stabilisation, since the module's emergence and existence are selected on precisely this criterion. Downward selection provides us with a coherent account of learning as the scaffolding of modular structures by adaptation under the single selective criterion of stability: if the emerging concept does not stabilise itself, it is unstable and so dissipates. Enaction is like a rock resting on the seabed that allows randomly drifting sand to accumulate around it, thus stabilising itself further: *stability begets stability*. Modular structures emerge as autonomous entities that enact anticipatory habits that proactively stabilise the modules' own identity by interpreting incoming signs.

Furthermore, this module is a concept, since it can scaffold abstract covariant relations. Kashtan and Alon (2005) used a genetic algorithm to select neural networks on their ability to compute two different logical functions possessing a common, covariant component. When they switched selection intermittently between these two functions, the networks developed a modular subnetwork that implemented that covariant component. Covariant relations in the organism's environment provide stability across changing environmental circumstance, and this stability can accrete in downwardly selective systems as a modular concept, scaffolding its semiosic capacity both downwards (within the nascent concept) and upwards (interactions with other concepts).

This brings us to our initial question: How do covariant relations become internally selected to implement the learning of a stable concept such as ‹*Organism*›*?* Favareau (2015: 251-253) grounds such abstractions in what is "said about things" – a history of "counterfactual possibility[, ...] general outcomes and ends [...] and effects that might conceivably have practical bearings". In short, the grounding of the abstraction ‹*Organism*› is a coherent *story:* covariant relations constrain my expected narrative of interactions with organisms in ways relevant to my stable well-being.

To summarise this discussion, a concept is a modular story of anticipated interactions with my environment. The concept does not denote content, but is enacted in, and scaffolded from, a model consisting of structural relations that remain stable, or covariant, across my past experiences of that story.

Models underspecify stories

This narrative view of concepts continues a twentieth-century trend in educational psychology, which traditionally emphasised the assumptions of *substance-ontology* and *amodality.* We often regard teaching as induction into a shared, mind-independent Reality populated by things, particles and substances, and our knowledge of these substances as consisting of amodal (sensory-independent) assertions. Yet in the last half-century, these apparently self-evident axioms have come under increasing pressure from biological research, which instead emphasises *process-ontology* and *sensory grounding.*

Substances are comfortingly reliable: they only change when we act upon them. If a billiard ball is red, it remains red until I repaint it. This leads us to regard it as objectively red – even when we stop looking at it. But colour is not so much an objective attribute as a phenomenological process: an interaction between my sensory apparatus and my environment. For example, it may surprise you to learn that in the two (3 × 3) colour groups on the right, the two central fields reflect precisely the same frequency of light.

Maturana and Varela (1980) argued that we cannot regard biological organisms and their cognition as substances, since their structure continuously renews itself in a self-maintaining exchange *(autopoiesis)* of matter and

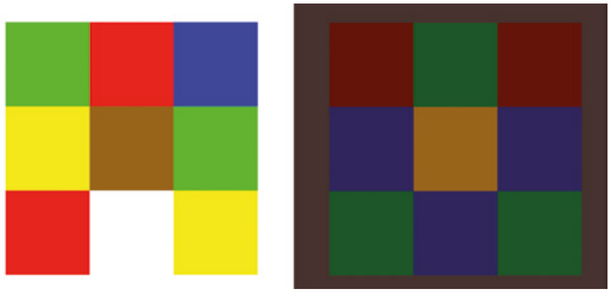


Fig. 2: Colour groups

energy with their environment. This process-orientation also applies to knowledge and learning: if someone teaches me something, they do not *force* my bodily substance to transform. Rather, they invite my life-process to respond, which in turn effects a reorganisation of that life-process. According to this biological view, learning is not the storing of data, but rather the forming of habits out of my freely chosen responses to stimuli.

Furthermore, Barsalou (2008) presents extensive evidence from ethology and neurobiology that the abstract concepts resulting from this reorganisation are far from amodal, being instead grounded in intrinsically modal, sensorimotor interactions with my environment. Think of tying your shoelaces. Usually you wind the lace around your forefinger, but if one day you have injured your forefinger, you wind the lace around your thumb, sacrificing very little technical elegance. This flexibility demonstrates that both the forefinger- and thumb-based skills are expressions of a single abstract gestalt that is nevertheless grounded in the *modality* of your past visual-kinaesthetic experience of shoelaces.

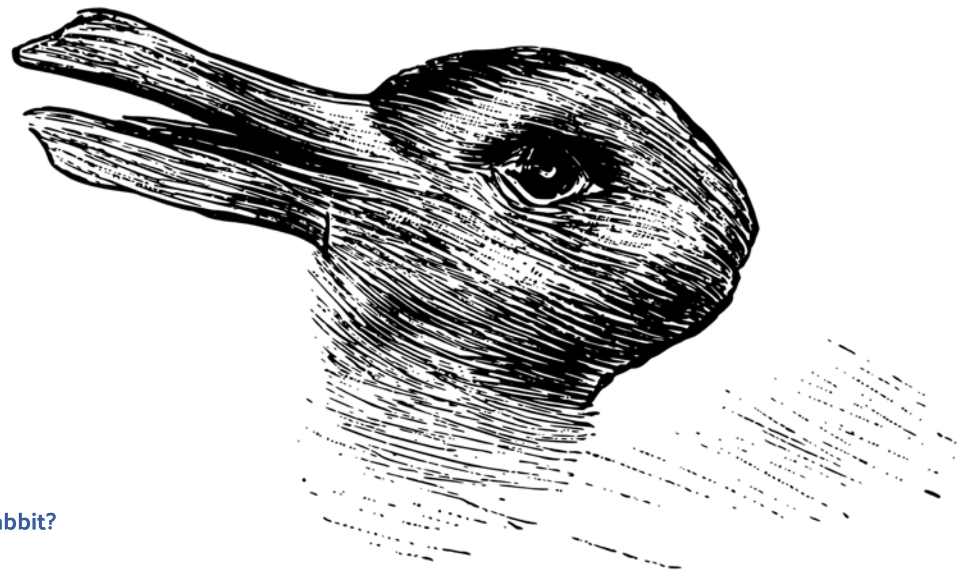


Fig. 3: Duck or rabbit?

There is wide evidence that such modal, dynamical gestalts underlie all thinking. The influential Conceptual Metaphor Theory of Lakoff and Johnson (1999) grounds all linguistic behaviour in sensorimotor coupling, and Thelen and Smith (1994) demonstrate its relevance for Piaget's account of concept formation. Piaget (1954) studied perseverant behaviour in 7-12-month-old babies that had become accustomed to an exciting toy being hidden under a yellow (rather than blue) cloth. If we suddenly and visibly hide the toy under the blue cloth, the child again reaches for the yellow cloth. Piaget explains this behaviour in terms of amodal symbol manipulation: the child is on her way to constructing the amodal symbol *Object,* that she has not yet differentiated from her own actions.

Yet Ahmed and Ruffman (1998) note that although the child *reaches* for the yellow cloth, her *eyes* fixate on the blue cloth. Indeed, Thelen and Smith interpret the child's behaviour not as the lack of a differentiated concept, but as a habitual motor gestalt, that she transfers into a new context that abruptly hides toys under non-yellow cloths. Their analysis weans our view of learning away from the storage of conceptual categories, towards the habituation of modular action gestalts within dynamical, sensorimotor stories. Suddenly, concepts acquire an intrinsically *temporal* aspect.

The idea that meaning is inherently time-bound forms a thread throughout modern philosophy. McTaggart (1908) noted the discrepancy between our notion of time as a *structural* relation between individual instants, or as a phenomenological *flow* of becoming, and Gödel (1949;1995) demonstrated the physical relevance of this discrepancy between the structural concept of time in relativistic mechanics and the dynamical flow of causality.

Gödel (1931) also demonstrated a corresponding discrepancy between structural assertions and their meaning. Later, Wittgenstein (1953) argued by reference to the ambiguous duck-rabbit picture (sse Fig. 3, from the 23.10.1892 edition of *Fliegende Blätter),* that seeing is not a passive "seeing-that" of the structural properties of our environment, but rather an active "seeing-as": a dynamical semiosis of narrative meaning out of those structural properties. Building on these ideas that structure underspecifies meaning, Penrose (1995) later proved that symbolic computation underspecifies the dynamics of human cognition.

Bruner (1992) emphasised the narrative nature of our meaning-making. When I read or hear the word *"Dog",* my semiosic search for meaning draws on past experiences of dogs – for example, my joyful discovery as a child that dogs were not after all as frightening as I had imagined. These experiences have an emotional, intentional quality that sets them apart from fragmented database entries. They are narrative *vignettes:* subjective stories of past sensorimotor coupling that make sense of the word currently presented to my senses.

This dynamical account of conceptualisation answers several currently open questions in cognition – in particular, *symbol-grounding* and *blending.* For example, the *grounding problem* asks how my brain manages to simultaneously bind the concept *‹Dog›* to two distinct *‹Dog›*-instances. Barsalou (2008) describes concepts as perceptual symbol systems that are grounded in modal simulations and bodily perception. On this view, my concept *‹Dog›* is the accumulation of dynamical commonalities of an entire history of past sensorimotor experiences. When I construct meaning from some concrete perception of a dog, that perception determines the initial conditions for a mental simulation that runs according to the dynamical constraints of my concept *‹Dog›*. Thus, binding a concept to two distinct instances is simply the triggering of two simulations with distinct initial conditions.

The *blending problem* (Fauconnier & Turner 2002) asks how we merge separate, often unrelated, concepts into novel inventions. Orr's (1986) analysis of problem-solving conversations between service engineers shows how blending draws on our essentially dynamical ability to weave distinct conceptual stories into a single coherent account. Crossley (2002) also describes how we use blending to construct from separate life-roles our unitary concept of a personal Self.

The thread running through all this work is that concepts are not simply structural categories, but rather habituated, sensorimotor stories. However, this does not mean structural categories play no part in conceptualisation. To apply the concept *‹Screwdriver›* effectively, I clearly need a dynamical understanding of dealing with screws and screwdrivers. Yet I must also first recognise the relevance of this understanding to my current situation. I therefore need a recognition-structure – a set of structural relations that enable me to recognise the relevant concept in a particular situation. In other words, the situation must present *signs* that *communicate* to me that the concept *‹Screwdriver›* is at all relevant here.

Category recognition occurs very early (Störmer et al. 2019) in visual processing, and Evans (2013: 15) makes a fundamental distinction two kinds of cognitive elements: *lexical* categories of meaningfully relevant structure, and the *concepts* to which these lexical categories provide access. When we make sense of signs in our environment, we first recognise their lexical structure, and this structure then triggers a simulation of the relevant concept. Thus, Evans distinguishes between structural *models* – the categories we use to recognise and communicate signs – and dynamical *stories* – the lived meanings to which these models afford access.

Before drawing lessons for teaching, it is worth summarising our discussion so far by paraphrasing Glasersfeld's (1995: 51) definition of Constructivism. A *learner* is an autonomously cognising subject constituted from *structural models* and *experiential stories:*

1. I *cannot* directly communicate a concept to a learner through linguistic structures – neither sentences nor other public models.
2. Rather, the learner actively *interprets* linguistic structures in terms of her existing structural models, *abduces* lived experiential stories from these models, then *deduces* from these stories operational relations that *predict* future events.
3. The proper function of the learner's cognition is to help her to act in ways that pre-emptively stabilise her well-being in the face of environmental challenges.
4. The purpose of learning is *not* to discover the objective structure of mind-independent reality, but to *enact* (downwardly select) structural models that are covariant across successful stories, and so help the learner to abduce stories that promote her well-being.

Teaching concepts through construction activities

This mismatch between structural communication and dynamical meaning poses a challenge for teaching. Suppose you wished to communicate to an English-speaking Martian what it is like to eat a banana. How could you possibly succeed if the Martian lacked any bodily experience of bananas or eating? *Clearly, the lexical structures we use to teach are fundamentally unsuited to conveying the essentially dynamical-modal nature of concepts.*

Campbell (2018) discusses some implications of this insight. If learning is the constructing of anticipatory relationship with a changing world, effective teaching *cannot* consist in the purveyance of structural content that is often emphasised in higher education. Rather, teaching should derive structural relations as secondary entities from the primary goal of enabling learners to enter into active, anticipatory relationship with turbines, parasites, polynomials or whatever.

Yet to teach, we must use language structures. I could, for example, tell you that a parabola is specified by the structural relation $y=ax^2+bx+c$, yet verbal reporting by mathematical experts (Watson & Mason 2005) suggests that their ability to think abstractly lies rather in their understanding of the concept *Parabola* as a family of lived manipulations (shifting, stretching, rotating, ...) of ‹*Parabola*›-instances. Even when thinking abstractly, these experts always work with instances, between which they nevertheless are able to transform skilfully and elegantly if the situation requires. My parabolic equation is indeed an easily communicable structural model, but it underspecifies the subjective dynamics of *using* parabolas.

Herein lies the critical bottleneck of all teaching and communication: I can never communicate my dynamical story directly to you, but must instead offer you a structural vehicle in hope that this will elicit in you a similar story. Yet this is not as hit-and-miss as it might seem; Marton (2014) suggests a way past the bottleneck. Over forty years of educational research, Marton has concluded that learning commences with the learner perceiving a dynamical contrast in her experience, then generalising these contrasts into a dimension of experience, and finally abstracting structural relations from the covariant dependencies between these dimensions.

Watson and Mason (2005) demonstrate how we can use construction activities to follow Marton's path in teaching. Suppose I wish to convey to you my concept ‹*Hexagon*›, and present you with this linguistic vehicle:

- A hexagon is a six-sided polygon.

This provides you with a recognition structure that enables you to check whether a candidate polygon is an instance of ‹*Hexagon*›. You can then discover for yourself further hexagons by conducting your own manipulations of the initial figure. But has this communicated to you my understanding of hexagons? Probably not. Please now fetch pencil and paper and perform the following construction activity:

- Draw a hexagon in which two opposite sides lie perpendicular to each other.

Would you have thought of this shape if you had not performed this activity? And what about this activity:

- Draw a hexagon, *four* of whose sides lie perpendicular to their respective opposite side.

Or this:

- Draw a hexagon, *all* of whose six sides lie perpendicular to their respective opposite side.

These construction activities have probably extended your concept ‹*Hexagon*› by several new stories of legitimate hexagon-manipulations. Of course, you could have discovered them on your own, but these activities guide your conceptual revision in the direction of my somewhat unusual set of experiences. Any structural vehicle must necessarily fail to specify completely its intended dynamical meaning, so if I wish to communicate my dynamical understanding of ‹*Hexagon*› to you, I must provide you with subjective experiences that extend your concept in directions of my choice.

Any attempt to communicate a *dynamical* story must pass through the *static* bottleneck of *structures*. We deal with this problem constantly in everyday conversation, but usually our respective experiences have sufficient commonality that our differing interpretations of our shared vehicles do not impinge on our awareness. Such bottlenecks, however, do intrude in relation to two important teaching phenomena: *expertise* and *conflict*.

Expert bottlenecks: the Doom of expertise

First, our semiotically impoverished linguistic vehicles serve only to trigger the dynamical understanding of our students. If details are missing from this trigger, students fill in these gaps from the dynamics of their own personal stories. *But we as experts necessarily delete details from our models!* Indeed, this is the very essence of expertise: we delete distracting elements from our models precisely in order to replace the tiresome checking of structural details by skilful praxis. When I as an expert manipulate hexagons, I transfer the properties of one or two quaintly convex hexagons onto the entire family of hexagons, since I know that this suffices in the majority of cases, yet I also keep a weather eye open for possible exceptions. Yet my students know nothing of these exceptions unless I think to tell them.

This information deficit of my linguistic vehicles leaves my students plenty of leeway for misinterpreting the stories I wish to communicate to them. As Korzybski (1958) noted: the model I present to students necessarily deletes, distorts and generalises the elements of my story, greatly complicating their task of constructing meaning from language.

Emotional bottlenecks: the Doom of conflict

Secondly, the problem of impoverished models is exacerbated if my students already possess coherent stories that directly contradict mine. In such cases, they utilise the gaps in my structural vehicles with their own deletions, distortions and generalisations, in order to make it fit better with their own story. In fact, students flatly reject structural data if these conflict with their own stories about how the world functions (Koichu *et al.* 2013).

We observe this effect in Dunbar *et al's* (2007) students when they reject the axis-tilt explanation of seasons. Dunbar's explanatory film-clip, pedagogically skilled though it may be, is a structural product of someone else's thinking, and is communicable only to the extent that it elicits matching stories in its audience. It simply *cannot* deliver the contextualised, subjective experience of radiative heating. If its audience bring to the film their own stories of exaggeratedly eccentric orbits and convective heating, they will interpret it in relation to these stories, and pigeonhole the Earth's tilt as a bothersome irrelevance.

The more tightly such stories are woven into the narrative of our own identity (Crossley 2000), the higher is our investment in them. If I think of myself as a spontaneously creative person, and understand detailed knowledge as opposed to that narrative, it may well be that the technical exactitude of many scientific disciplines will awaken in me strong reactions of anxiety, anger and despair. Such emotional bottlenecks accentuate even further my tendency to invalidate evidence structures that contradict my own stories.

A ray of hope: learning conversations and construction activities

We have seen that enaction generates two generally valid challenges for teaching. In order to communicate a concept, I must cram my story into a structure that you must then unpack into a story. In order to cram my story into a structure, *I* must distort the story; in order to unpack the story, *you* must distort it in conformity with your understanding of the world. Two pedagogical tools seek to resolve these essential dilemmas of communication:

- *Learning conversations* derive from the interview techniques of Grinder and Bandler (1989) and Dilts (2017), drawing on ideas arising from Bohm's (1996) reflective dialog. They characterise steps 2 and 3 of the *Decoding* process (Pace & Middendorf 2004) and fulfil two purposes: uncovering and resolving communicational distortions and conflicts.

- *Construction activities* are based on *variational teaching* (Marton 2014) and the Chinese teaching method *bianshi* (Huang & Li 2017). Both methods make use of our ability to construct concepts as covariances out of changing features of our experience. Construction activities characterise steps 3 and 4 of the *Decoding* process.

Learning conversations

Learning conversations prepare the ground for construction activities. They can take place between students or between students and teachers, but here we focus on conversations between teachers. The three participants in a learning conversation have distinct roles: an *Expert*, an *Apprentice* and a *Coach*. The starting point of the conversation is when the *Expert* recognises a bottleneck situation that regularly arises when she teaches some specific conceptual competence from her discipline, that she herself is able to perform with expert elegance. For example, we review below a bottleneck situation that arises when a physicist teaches the use of the concept ‹*Centripetal acceleration*›.

The *Apprentice* is curious to learn precisely the conceptual competence that the Expert wishes to communicate in the bottleneck situation. He seeks to elicit the distortions that the Expert employs to perform this competence elegantly, in order to uncover the conceptual story underlying the competence. *It is therefore very important* that the Apprentice's area of expertise is far removed from that of the Expert, since he might easily otherwise collude with the Expert in obscuring these distortions. Two collusions can arise if Expert and Apprentice come from the same discipline: they collude in being blind to the difficulties of the bottleneck for laypersons; or they collude in using the same technical expression without recognising differences in their respective understanding of that expression.

The *Coach* supports the Apprentice in this endeavour by observing and facilitating the conversation between Expert and Apprentice. Typically, Apprentice and Coach will alternate roles seamlessly during the course of the learning conversation.

The goal of the learning conversation is to *operationalise* the linguistic structures of the Expert by eliciting the detailed operations that the Expert employs in the praxis of her expert competence. To achieve this, the learning conversation focuses on the following distortions that commonly lead to communication bottlenecks:

- **Underspecified nouns:** *"In this algorithm we use a <u>loop</u> to …" Which specific* loop do we use? For-loop? While-loop? The distinction can be critical for student understanding.
- **Underspecified verbs:** *"When we <u>analyse</u> this equation, we find …" How, precisely,* do we analyse the equation? Do we look at its functional form? Its solutions? Its derivative?
- **Magical information:** *"Students are too <u>lazy</u> to …" How exactly* would *I* recognise that they are lazy? Which behaviours indicate it? Might an alternative explanation be relevant?
- **Modal verbs:** *"Equations <u>should</u> be written neatly underneath each other." Why* should they? What would be the consequences if we did not write them underneath each other?
- **Generalisations:** *"<u>All</u> evolutionary changes arise from mutation and recombination."* Are there *exceptions?* What about changes arising from environmental perturbation?

Construction activities

After eliciting the Expert's conceptual competence, we seek an effective means of communicating this competence to students. Since concepts are intrinsically narrative in nature, they often do not easily lend themselves to communication via intrinsically *non*-narrative linguistic structures. A particularly useful pedagogical approach in such cases is *construction activities,* in which learners become acquainted with the contextualised dynamics of a concept.

Construction activities derive from the *constructionist* thesis of Seymour Papert (1991). In constructionist learning activities, students collaborate in building physical artefacts.

This social process provides them the opportunity to compare, test and revise their various stories. We have already seen several construction activities in relation to the concept ‹*Hexagon*› above. In contrast to a common misconception (Kirschner et al 2006) of constructive learning activities as undirected meandering by students, these hexagon activities are tightly focused investigations tailored to a specific intended learning outcome.

Ference Marton (2014) has investigated over forty years the necessary conditions of learning concepts through construction activities. He identifies four steps of concept construction: *separation, contrast, fusion* and *generalisation.* We have already encountered *separation* and *contrast* in our earlier questions regarding capital cities, while generalisation was the leitmotif of our hexagon activities. While we have insufficient space here to discuss Marton's work in detail, his term *fusion* is particularly relevant when designing construction activities. For fusion describes how new concepts arise from our growing awareness of a covariant relationship (Watson, in Huang & Li 2017: 97, uses the term *dependency relationship)* between two covarying attributes of our experience. We study a concrete example of fusion at the end of the coming section.

How it all fits together …

The centrifugal/centripetal example from the beginning of this article provides a practical demonstration of learning conversations. The presenting bottleneck is this:

Expert *(frustratedly):* My students simply cannot let go of the idea of centrifugal force!

The initial response of the Apprentice to this negative statement is to convert it to a positively formulated, specific, contextualised and operational learning outcome. So he may for example ask:

Apprentice: *(positively formulated)* What would you like your students to learn *instead?*

E: They need to understand that what they think of as a centrifugal force actually arises from accelerating an object centripetally towards the centre of a circle.

A: *(specific)* Is there a specific step/aspect of this that is your intended learning outcome?

E: When they think of circular motion, they should think in terms of acceleration inwards to the centre of the circle.

A: *(contextualised)* Are there external, contextual conditions that might make this learning difficult?

E: Yes. In school they are told that centripetal force throws things *outwards.*

A: *(operational)* How will you recognise that they have acquired the ‹*Centripetal*› concept?

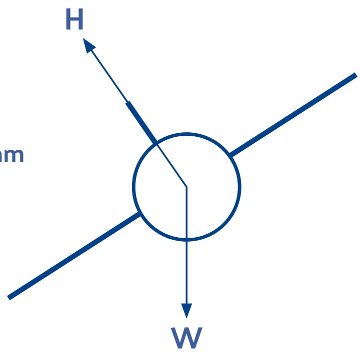
E: They will no longer speak of being thrown to the outward side of a swerving car, but rather of the outward side of the car swerving inwards against them.

As soon as the Apprentice has uncovered this learning outcome, his aim becomes to unpack the Expert's story of centripetality from the structural model that she has until now used to pursue this learning outcome. To achieve this, the Expert must now transition to a very different role: she is no longer the *teacher* of the expert competence, but the *practitioner;* indeed, a crucial (and often quite difficult!) aspect of the Apprentice's work from now on is to keep the Expert in role as practitioner – *not teacher.* Consequently, the Apprentice now helps the Expert to operationalise the individual steps that she goes through when exercising this competence. In other words, the Apprentice encourages the Expert to bring all nouns, verbs and adjectives into the same sensory-specific form that she herself would use when tackling a concrete problem in circular motion:

A: Could you please select a very concrete, specific circular motion task in which you would like your students to demonstrate their understanding of the concept ‹*Centripetal*›*?* It should be a situation that you as an expert can handle with elegant competence.

E: A typical exercise might involve an aeroplane flying with constant speed around a circle with constant radius.

Fig. 4: Free-body diagram of an aeroplane.



The exercise might be to calculate the necessary angle of tilt of the wings for the aeroplane to fly leftwards around this circle.

A: *(Specifying adjectives)* Can you give me example values for this speed and radius?

E: The speed might for example be v=250m/s, and the circle radius maybe r=2000m.

A: *(Specifying verbs)* I see. And how exactly would you as an expert start tackling this problem?

E: I would first draw a diagram of the forces acting upon the aeroplane.

A: *(Specifying verbs)* How exactly would you draw this diagram? Could you draw me one now?

E: Oh, do we really have to? It's just an aeroplane on which various forces are acting!

A: *(Gently, but firmly insisting on operationalising the procedure)* I think it would help me to understand.

E: *(Somewhat grudgingly)* All right, well, it looks like this. (See Fig. 4)

A: *(Specifying nouns)* Ah, thank you – now I understand. So what exactly are the forces you have drawn acting on this aeroplane?

E: The wing-lift **L** and the gravitational weight **W**.

A: (*Tests completeness)* Are there any further forces acting on the aeroplane?

E: No.

A: *(Questions magical information)* How exactly would I recognise that there are no further forces in this situation?

E: Force diagrams contain only the forces of external agents acting upon the aeroplane, and only air (lift) and the Earth (gravity) act upon this aeroplane.

A: *(Tests own understanding)* Don't the jet engines also act on the aircraft?

E: Well, yes, of course the jet engines push the aircraft forwards, but the air resistance acts backwards with exactly the same force, so they cancel each other out. That's why I left those forces out of the diagram.

A: *(Questions magical information)* How do you know as an expert that they cancel each other out?

E: *(Thinks perhaps: "My goodness, this Apprentice is rather dim!", but answers pleasantly)* Because the flight speed is constant, so there cannot be a net forward force.

A: *(Tests own understanding)* But if I look up at the aeroplane from the ground, don't the jet engines constantly try to push it out of the circle?

E: Well, a diagram of the entire circular flight would be somewhat confusing; that is why I leave out the form of the flight path, and only enter the physically relevant forces.

A: *(Tests own impression of high importance)* That almost sounds as if it were very important to draw a force diagram, rather than a diagram of the flight path?

E: But of course! You *must* draw a force diagram!

A: *(Analyses modal verb 'must')* So what would happen if I drew a diagram of the flight path instead?

E: *(Almost explodes with frustration)* But, ... but then you wouldn't see the centripetal force pushing the aircraft into the centre of the circle!!

A: *(Gently, but slowly with eye contact)* Are your students aware of how important this choice of diagram is?

E: ... Hm. I'm not certain. Possibly not ...

This is the turning point of this conversation, where the Expert becomes aware of the structure of the bottleneck. Notice that the conversation makes enormous demands upon the patience of all participants. The only route to the bottleneck's structure is by playing off the Apprentice's conscious incompetence against the Expert's unconscious competence, but notice also how important it is that the

Apprentice relinquishes all ego. His entire goal is to elicit the Expert's competence – often even at the expense of his own dignity. It is for precisely this reason that we need a Coach. S/he supports the Apprentice at stressful points in the conversation by gently affirming the usefulness of the Apprentice's insistence on operationalising actions that to the Expert appear unnecessarily pedantic.

After eliciting the origin of the bottleneck, several possibilities are available. In this particular case, the Expert became aware that the choice of diagram was connected to the concept *‹Inertial force›*. In order to develop this concept in her students, she used Marton's process of conceptual fusion: she presented inertial force as a covariance between accelerating bodies in a sequence of construction activities using elevators, aeroplanes, spaceships and whirling buckets of water.

Conclusions

The central message of this article is that our language never transfers meaning directly, but instead scaffolds the dynamical meaning that our conversation partner then independently develops. This is the origin of bottlenecks in teaching.

I have *not* discussed three important topics. First, learning conversations demand a relationship of mutual trust between all participants, demanding of Apprentice and Coach the skill of building and maintaining rapport with the Expert. Second, I have not discussed how learning conversations resolve emotional bottlenecks by negotiating deeper lying conflicts. Third, I have not described in detail how one translates conceptual stories into construction activities. All three skills are straightforwardly learnable – ideally in live training – but each would overstretch the constraints of this article.

In contrast to the frequent assumption amongst university educators that learning is the storing of structural models, I have argued here that learning consists instead in acquiring contextualised skilful habits. Communicated content *never* consists of amodal, substantive statements, but is *always* grounded in subjectively lived, sensorimotor *stories*. This insight explains the many bottlenecks that arise from attempting to communicate such stories as structural models. It simultaneously suggests *learning conversations* as a means of escape from bottleneck situations by elaborating the deeper conceptual stories underlying such models. This process both refines our own narrative conceptual understanding of our domain of expertise, and translates this understanding into construction activities that elicit intentionally similar stories in learners.

I suggest that the transition from substance- to process-ontology implicit in this process is the great challenge of our time – in teaching and in society. Student knowledge is not a static structure of assertions, but a capability that matures through ongoing praxis. Students are not databases into which we upload facts, but living organisms that co-determine the development of their expertise. Teaching is not an off-the-peg didactic technique, but a maturing praxis that unfolds in the instant of pedagogical encounter. And I do *not* require myself to be the perfect teaching practitioner, but simply a self-enacting story of ongoing improvement.

This transition also brings with it wider social consequences, since substance-ontology only achieves relevance by attributing values to its substances. It persuades us that a plastic bag is a static shopping utensil, rather than a process that continues after I have thrown it away. Societally, we must learn to value, not absolute attributions, but rather the creative covariances that emerge from dialogue between differing perspectives. In the above learning conversation, it is precisely the stubborn *naivety* of the Apprentice that prompts the Expert to confront her skilful deletion of alternative diagram forms. The measure of our worth as practitioners is not our *performance*, but our attentiveness to such bottlenecks in our praxis and the improvements to which they point.

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Decoding the Disciplines from an Instructor's Perspective

Instructors are always busy, especially those at Universities of Applied Sciences, where the teaching load accounts for the major part of the weekly working hours. What then leads instructors to engage with Decoding the Disciplines? What makes Decoding so valuable to them that they spend their scarce time practicing it? Claudia Schäfle is a professor of Physics at Rosenheim Technical University of Applied Sciences and provides answers in the following interview. Peter Riegler asked the questions.

What brought you to Decoding? Why is it appealing to you?

At first, I couldn't associate the term with anything. I had no idea what Decoding is about. However, the enthusiasm of some of my esteemed colleagues practicing Decoding made me curious. Additionally a specific conceptual challenge in my fluid mechanics class lead me to participate in a meeting of the Decoding Working Group in order to better understand this challenge.

In that meeting of the Decoding Working Group I was fascinated to see how the "bottlenecks" of different topics were decoded with great depth and accuracy. Decoding helps me to recognize on a higher level what the difficulties are. Especially by listening to others, I learn a lot for my own teaching. Finally, I find the special atmosphere of the group to be very positive, as it brings together people who are willing to learn and grow in their teaching through mutual listening, intensive questioning, analysis and decoding of expert strategies. This is only possible with mutual trust.

Which expectations, ideas or hopes made you to join the Decoding Working Group at DiZ?

For quite some time I have been searching for answers to a number of questions, which I hope Decoding will provide. The questions are all related to students' difficulties and conceptual misconceptions, which I regularly encounter in an almost predictable way after 10 years of teaching at university. It all relates to how I can improve my teaching such that students overcome these misconceptions more effectively and built up a correct understanding. For me Decoding offers the opportunity to recognize my "expert strategies" which in turn allows me to teach in more precise and differentiated ways.

How does participating in the Decoding Working Group influence your daily work?

Decoding enables me to change my perspective. It can reveal my own "blind spots" in relation to teaching. As an expert you often construct a kind of red thread in order to show how a certain topic is logically built on top of each other. With respect to some points, however, you do not realize that you overleap something or that previous experiences are required in order to develop an understanding. In the course of the Decoding interview about my conceptual challenge in teaching fluid dynamics, two things became clear to me that I would not have seen on my own.

Decoding makes me sensible to the need to pay attention to "bottlenecks" in teaching, to formulate them as precisely as possible, to collect them and, if necessary, to bring them into a Decoding interview. It influences how I think about teaching - not as a finalized construct, which has to be delivered, but as a constantly new challenge requiring to reflect on my actions and students' learning, as a field of research.

How would you describe to a colleague what Decoding is about?

Decoding is a process of identifying difficulties related to subject matter, which I, as an expert, do not perceive as such. It enhances my abilities to find out what mental steps a novice has to take in to order to comprehend something and to recognize its implications. Through the Decoding process teaching can develop more depth and impact. Let me illustrate this with an example:

In a Decoding interview, an expert (lecturer) says that he does not understand why students cannot make sense of a simple differential equation while writing it down on piece of paper with a few symbols. Although he refers to this equation repeatedly in various classes over the full program, he does not understand why students do never really understand it. We, the apprentices of the interview, see purely a simple equation with x, y and other symbols on the sheet of paper. Through questions like "What does it mean? How do you recognize what it means? How do you do that? What do you imagine? …" it is revealed in the course of the interview that for the expert these symbols are linked to vivid and deep meanings from his practical life. For the expert, the equation expresses a principle of growth: if something occurs in larger amounts, the growth rate will be stronger. In his mind's eye, the expert sees, for example, huge quantities of bacterial strains growing. He sees and almost physically experiences the enormous significance of this equation. By means of the above questions, we interviewers as apprentices mirror to him that his powerful images are not present with us as apprentices and that we only see a plain formula in front of us. The Decoding process enables the expert to recognize this and to consider what steps the apprentices should take in order to experience the world of thought behind the equation, so that the formula can become more meaningful and vivid to them as well.

The Decoding Working Group at DiZ

The working group currently meets three times per year. While each meeting is dedicated to a particular topic, learning and practicing Decoding are regular items on the agenda. Meeting dates are listed on the DiZ website. Participating in the working group does not require formal membership and is open to all interested parties.
Subsequently, some members relate why they participate in the working group.

Thomas Blotevogel

I had registered for the working group for the very first meeting because I hoped that it would provide me with suggestions and ideas for the direct improvement of my courses. This hope has been more than fulfilled. On the one hand, after a few working group meetings, I am much more attentive in my courses and I can see much better where the students have fundamental difficulties in understanding. On the other hand, the Decoding interviews helped me to uncover a particular bottleneck and gave me a lot of ideas to (hopefully) help the students to overcome this bottleneck. This is very important for me. I am really looking forward to the next meetings of the working group and the interesting discussions, not only about decoding. I am also looking forward to meeting all the other participants from all over Germany!

Thomas Blotevogel is a professor at the Department of Mechanical Engineering at the University of Applied Sciences Würzburg-Schweinfurt in Schweinfurt.

Britta Foltz

I am participating in the Decoding the Disciplines working group for these reasons: The intensive collegial exchange as well as the special pedagogical format of Decoding regular provide inspiration. After each meeting, I return to daily working routine with new ideas.

Britta Foltz is a lecturer at Aachen University of Applied Sciences.

Inna Mikhailova

Before I came to teaching, I was studying autonomous learning systems. I could never disqualify the robots that I programmed in my industrial job as being lazy or undisciplined. I would never do it to my students either. The only constructive way to deal with teaching problems is to seriously look into learning and thinking. With Decoding we do exactly that.

I want to point out why it is the right framework for me:

- Instead of general theories for everything, it focuses on specific bottlenecks.
- With the decoding interview it offers a clear structured approach.
- Everyone is valued and able to critically question the method.
- It is possible to develop feasible suggestions for the improvement of the teaching methods.

I have only recently joined the community. Firstly I learned to rephrase negative critique: “My students can’t …“ into positive learning goals. Than during an interview I realized that I use myself simplified concepts, while teaching the complex version to my students for the sake of completeness and correctness. Without the interview, I would`ve never been able to realize this drawback. I am looking forward to more discoveries that are awaiting us in the framework of Decoding.

Inna Mikhaylova is working at the faculty of Mathematics and Natural Sciences at the Hochschule Darmstadt – University of Applied Sciences.

Peter Riegler

Soon after my appointment as professor, I had a deep but eventually healing teaching crisis. In the course of this crisis, I realized that students fail not primarily, because they are too lazy or too poorly educated, as we often assume. They often fail because subject matter is difficult. Not for us teachers – but for the students. Everywhere there are pitfalls and obstacles: misconceptions and threshold concepts; non-explicit, subject-specific thought patterns – bottlenecks, that is.

Since then I have dream.
I have a dream that as teachers we learn to understand better what makes our subjects difficult to learn and teach.
I have a dream that teachers work together in order to identify such difficulties.
I have a dream that teachers view the identification of such difficulties and the corresponding further development of teaching as a joint research task.
I have a dream that universities and universities of applied sciences are universities of the Scholarship of Teaching and Learning.

The Decoding working group makes this dream become true. Fantastic!

Peter Riegler is a professor at the Department of Computer Science at Ostfalia University of Applied Sciences in Wolfenbüttel.

Stefan Schreiber

Recently, while grading an exam: The path towards the correct solution had already been left by the student. Let's see what can still be saved. However, it is immediately clear to me that bending moments and transverse shear forces do not match. Stop - Why do I see this instantaneously, but the student obviously does not? Even when reading an analog clock, the "decoding of the clock time", numerous steps are necessary for this supposedly simple task. Analyzing and segmenting the "expert view" in "super slow motion" during an interview in the course of a Decoding process is an extremely valuable method for identifying potential mental bottlenecks for students. It helps me to focus my own teaching on just these bottlenecks and, hence, to make it easier for students to master subject matter. Often in a lecture, it is not so much a question of "what" is taught but rather of "how".

Stefan Schreiber is a professor at the Department of Mechanical Engineering at the University of Applied Sciences Würzburg-Schweinfurt in Schweinfurt.

Elmar Junker

After a few years of teaching, I realized: If as an instructor I deliver the best performance, the best devised "teaching show", the students will not learn more than via "mediocre" instruction. That has provided impetus to switch to Peer Instruction and Just in Time Teaching and to focus more on the students' misconceptions. Eventually, this has led to better students' learning gains and I enjoy teaching (even more).

Now, Decoding is next natural step for me: The revelation was being an observer of a Decoding interview. There the person interviewed could not understand at all why a certain subject matter did not make it across to the students, although students did study using well-prepared worksheets. For me as an outsider – and the other observers as well – it was immediately clear what the problem was, i.e. where the bottleneck was. The Decoding interview helps me to recognize my misconceptions about teaching and to question my expectations and assumptions. With the help of feedback (Johari window) during and after the interview the interviews helps to reduce my "blind spots" in teaching.

Elmar Junker is a professor at the Department of Applied Natural Sciences and Humanities at the Rosenheim Technical University of Applied Sciences. He teaches physics, building physics and astronomy.

The Decoding Alphabet

Peter Riegler

Christian Kautz

For me, “Decoding the Disciplines” is one of several approaches that provide a starting point for finding out where students‘ are struggling, why this is so, and how one can provide targeted assistance in overcoming students‘ difficulties. In addition to the enormous effect that a Decoding interaction can have on one’s own teaching, Decoding often reveals fascinating results that can provide valuable impulses for discipline based education research. By decoding expert thinking, new questions arise as to how the thinking of novices differs from that of experts.

Christian Kautz is head of the Engineering Education Research Group at Hamburg University of Technology.

Assessment An integral part of the Decoding the Disciplines process serving to find out whether interventions triggered by Decoding have been effective.

Bottleneck A concept, task or line of thought where students frequently get stuck in their learning. Decoding the Disciplines investigates how experts are able to pass disciplinary bottlenecks.

Curse of Expertise While disciplinary expertise is a prerequisite for teaching it is also a major obstacle. Over time concepts become so clear to teachers and processes become so automatic that it gets increasingly harder for them to make them explicit.

Decoding the Disciplines The double D of Decoding the Disciplines emphasizes that expertise is disciplinary in nature to a considerable extent and that important parts of it might be implicit and, hence, need to be decoded.

Emotional Bottleneck The Decoding the Disciplines process can lead to considerable changes in teaching. Students might resist such changes. Metaphorically speaking they might get stuck in emotional bottlenecks. An integral part of the Decoding the Disciplines process is to anticipate such resistance / emotional bottlenecks in order to better cope with them.

Formative Feedback A core element in the Decoding the Disciplines process emphasizing that students need to practice and receive feedback.

General Although the focus is on decoding disciplinary knowledge Decoding the Disciplines is general in that it is applicable to any discipline.

How exactly do you do that? A question often asked in the course of a Decoding interview.

Interview The interview is a core element in the Decoding process and is the very place where expertise gets decoded.

JiTT Just in Time Teaching A teaching approach often practiced by those engaged in Decoding the Disciplines as the identification of Bottlenecks is an intrinsic part of JiTT.

Knowledge Decoding acknowledges that knowledge and ways of thinking are mostly disciplinary. Decoding also acknowledges that knowledge, in particular that of experts, can be implicit.

Learning Improving student learning is the ultimate goal of Decoding the Disciplines. However, it is also a learning experience for the people involved.

Modeling A core step in the Decoding the Discipline process where instructors model their expertise to students after having decoded their expertise.

Novice The converse of expert. Facilitating the transition from novice to expert is what Decoding the Disciplines is all about.

Others Although Decoding the Disciplines tends to focus on aspects of disciplinary expertise it brings in others from outside the discipline under investigation. These others often serve as interviewers in Decoding interviews as they are not affected by the curse of expertise in the discipline under investigation.

Pace & Middendorf Effectively the parents of Decoding the Disciplines.

Questioning Decoding the Disciplines questions folk explanations why students do not succeed in their learning process. And it uses questioning as a strategy for decoding expertise.

Resolve Decoding the Desciplines resolves bottlenecks, the curse of expertise, and important aspects of disciplinary expertise.

Sharing Another integral part of the Decoding the Disciplines process. Students' bottlenecks and ways to overcome them more often than not are rather universal. Hence, sharing one's results with other teachers helps making teaching more effective on a larger scale. Decoding the Disciplines is a way of doing Scholarship of Teaching and Learning.

Teaching This is what Decoding the Disciplines is all about: Making teaching a more meaningful and effective endeavor.

Unifying Decoding unifies a multitude of approaches and intellectual practices, including but not limited to coaching, collegial collaboration, research in expertise, and the Scholarship of Teaching and Learning

Vetting Decoding the Disciplines endorses both meanings of vetting: The careful examination of learning obstacles and teaching interventions to make sure that they are suitable as well as providing care to students.

Writing as a means of Decoding Lahm developed a self-guided writing process that allows conducting the Decoding the Disciplines process without the need of an interview.

eXpertise The object of Decoding.

Yes, we can! Mindset of people engaged in Decoding. As in "Yes, we can help students overcome bottlenecks!"

Zest Decoding brings zest to those practicing it, be it a zest for teaching, a zest for learning, a zest for understanding, a zest for cooperating, a zest for research.

Step 1 – Identify a bottleneck
Identify an activity or task in your course that students are supposed to learn but often fail. The activity may well be a mental activity.

Step 2 – Decode what experts do
Explore in depths the steps that disciplinary experts go through to accomplish the activity or task identified as a bottleneck.

Step 3 – Model expertise
Give your students the opportunity to observe how you accomplish these activities as an expert.

- Perform the (mental) steps in front of your students using a subject-specific example.
- Explicitly highlight critical operations.
- Use metaphors or analogies for the (mental) steps.

Step 4 – Give students practice feedback
Construct tasks or learning activities that allow students to perform the activity identified as a bottleneck and receive feedback.

Step 5 – Motivate students and anticipate resistance
Create a learning environment that encourages students to perform the activity identified as a bottleneck. Identify possible emotional bottlenecks (for example, due to student prejudice or fear).

Step 6 – Assess student progress
Create assessments that provide information on the degree to which students can perform the activity identified as a bottleneck.

Step 7 – Share what you have learned about your students' learning
Share your findings informally with colleagues or more formally through publications or presentations as a form of Scholarship of Teaching and Learning.

Authors

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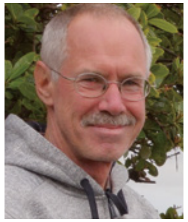
Dr. Christiane Metzger holds a doctorate in linguistics and completed the postgraduate master's degree in higher education at the University of Hamburg. She is head of the Center for Learning and Teaching Development at Kiel University of Applied Sciences. Her work focuses on course and module development as well as the investigation of student motivation and learning.



Niall Palfreyman is professor of mathematics and physics in the Bioprocess Informatics degree program at Weihenstephan-Triesdorf University of Applied Sciences in Freising. There he also serves as a teaching mentor. For more than 40 years, he has been working on the question of how knowledge, learning, competence, freedom of action and life can arise within the framework of a naturalistic view of the world, and what positive influence an understanding of this process of creation can have on our teaching.

Prof. Dr. Peter Riegler studied physics. After working in industrial research and development in the areas of telecommunication and automation technology, he has been professor of mathematics in the Department of Computer Science at Ostfalia University since 2002. His research area is discipline based education research.

Dr. Andrea Brose is head of the Center for Teaching and Learning, the teaching center of Hamburg University of Technology (TUHH). After many years of teaching mathematics at universities in Germany and the USA, she and her team are currently focusing on quality development in teaching engineering subjects. Dr. Brose plays a leading role in the TUHH's internationalizåation efforts, for example in welcoming delegations from universities from all over the world, especially in educational matters, and most recently in the successful application for the TUHH's EU call "European universities", for which she is responsible at the TUHH.

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