› THE BINARY BRAIN – LEARNING HOW TO TEACH COMPUTER SCIENCE TO STUDENTS OF ELECTRICAL ENGINEERING

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ABSTRACT

This article presents a learning portfolio written during the Basic Teaching Qualification in Higher Education at the Centre for Teaching and Learning in Higher Education Saxony (HDS). This document provides insights into my personal learning process and contains reflections on my teaching practice and how it was influenced by attending various didactics-related courses of the HDS. Hence, it is a compilation of material and information from these courses as well as of results of exercises. My individual comments and insights show how I adapted, inter-connected, and applied the contents and experiences of these courses to my teaching. I also discuss challenges in applying some guidelines and ideas for future application of didactic methods and theories.

INTRODUCTION

After receiving a full-time teaching position at the University of Applied Sciences in Dresden, I started questioning myself about the quality of my didactic training. What are the fundamental skills in didactics necessary to teach entire modules at university? Having studied media computer science, I only gained a basic knowledge of cognitive processes involved in the perception of information through (mostly visual) media. Although having supervised student theses and practical seminars for almost ten years at Technische Universität Dresden, I had little knowledge of learning and teaching related models. Moreover, one of my first tasks was to teach fundamentals of computer science to electrical engineering students in English. The topics in this module had not been part of my recent research and teaching and thus I had to prepare the course from scratch, based on the German material of a colleague. At this point, I decided to participate in the Basic Teaching Qualification in Higher Education at the Centre for Didactics in Higher Education Saxony (HDS) in order to improve my theoretical and practical knowledge in teaching and didactics.

1. PERSONAL BACKGROUND AND AIMS

An illuminative early exercise in the qualification program of HDS was the construction of a personal learning biography. The main insight here was to realize how strongly these personal experiences influence our ideal conceptions on how to teach. The timeline of learning, teaching, and teachers shows that I had diverse experiences myself. While Kindergarten did not leave many impressions, my personal elementary school experiences were rather bad. Today, I attribute many of the problems with my peers to the hassles associated with the German reunification that many families had to face. My learning biography improved significantly after changing to secondary school (Gymnasium) with a much steadier group of schoolmates and more experienced teachers. However, I also had personal experiences that learning goals of teachers and students can differ significantly (also see the following sections). My grades depended strongly on my personal interest in the topics and teaching personalities such as my history teacher. Although she basically did not use any kind of media, she gave vivid lectures on historical events and fostered discussion in her classroom.

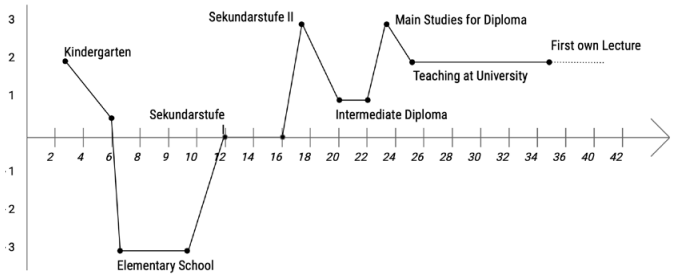

Fig. 1: Learning Biography (illustration by the author)

From this experience, I gained a life-long competence in taking minutes, e.g. in meetings, and reconstructing meaning and context for myself. In contrast to the intermediate diploma in media computer science, there was much more freedom to choose topics of interest in the main studies for the diploma. I was especially intrigued if my interests coincided with significant »teaching personalities«, such as in software engineering and media design. The example of those professors remains my own ambition as a teacher (see section 4). After the diploma, I started working at university and wrote my dissertation. Right from the start, I involved students in my research by supervising theses and practical seminars. I did not gain actual experience in lecturing and instead was trained to deliver as much information in as little time as possible, e.g. at conferences where I presented my own research. My personal impression was that I taught in a rather intuitive way, with both successes and failures that I could not analyze and justify properly. From constructing this learning biography, I realized that personal learning experiences, expectations, and preferences have considerable impact on the organization and contents of my own lectures. My personal aims can be summarized as follows: Foster my ability to convey competencies and knowledge as efficient and pleasant for students as possible while becoming the »teaching personality« that I would like to study with myself.

2. LEARNING ACTIVITIES

The most challenging elements of Module 1 in the HDS qualification program consist of the three tasks that had to be completed outside of the workshop setting. In the following sections, I present my results about content reduction, analysis of a learning setting, and student motivation. Finally, I address the interaction with peers during Module 1.

2.1. Content Reduction

Since my personal focus during Module 1 was my lecture on Computer Science, I attempted to reduce all the contents of one semester in a brief introduction. I found this exercise extremely hard and think that I failed to some extent. This »fly-over« mode required me to remove any details, while still making the actual connections between the different topics intelligible. Although I started out with a textual format, I soon realized that I would exceed one page of text. This made me come up with three summary slides to serve as a kind of mind-map that I provide the students with. Later during a workshop on evaluation and feedback, I realized that such summaries should ideally be produced individually by the students themselves for better learning success.

The feedback received from my peers of Module 1 at the closing workshop supported my own suspicions that the content was not reduced enough. While the style of writing and content was regarded as positive, the task of content reduction was not truly fulfilled. In the time of forced remote-learning due to the corona crisis, I actually provided students with the text at the beginning of the semester and asked them to construct their own mind-map. Most of the students in the course participated and this gave me an opportunity to comment on their work and sometimes stress important points that had been missing from the mind-maps.

2.2. Analysis of a Learning Setting

The course »Computer Science 2« comprises lectures and practical exercises (German: Praktikum). Its target group are international students of electrical engineering in the 3rd semester of their bachelor degree. The study group is of a small to medium-size, with ca. 15 registered students of which an average of 6 students attend lectures and exercises. In the previous term, »Computer Science 1« covered main concepts about algorithms, binary calculus, Boolean algebra, and programming in C. At the end of the semester, students should be able to understand the object-oriented (OO) programming methodology and analyze real-world problems, design object-oriented solutions, and realize them practically using programming in C/C++. In this section, I analyze the situation of learners and myself, the teacher, and our interactions. The situation of international students can entail particular difficult and diverse challenges when compared to their peers from Germany at the university.

One of my main topics of interest is student attendance and I am going to focus this issue in my analysis of learners and teachers in the learning setting of my course on computer science. The analysis is based on the Five-sided Model for Analyses of Learning Settings by Karola Kunkel (Fig. 2 and pp. 12-15 in this issue).

Learners

Due to informal inquiries during as well as before and after lectures, I found out that the learners in this course come from diverse countries such as South America (e.g. Mexico), North America (e.g. USA), North and Central Africa, as well as Asia (e.g. Bangladesh). The result is a highly heterogeneous background in prior education, knowledge, and codes of conduct at a higher education facility.

In a meeting with members of the international office at HTW Dresden, I became aware of the fact that international students receive support from them until they begin with their studies, at which point their faculty takes responsibility for their affairs. This handover between institutions before and after they enroll might cause some uncertainty and problems.

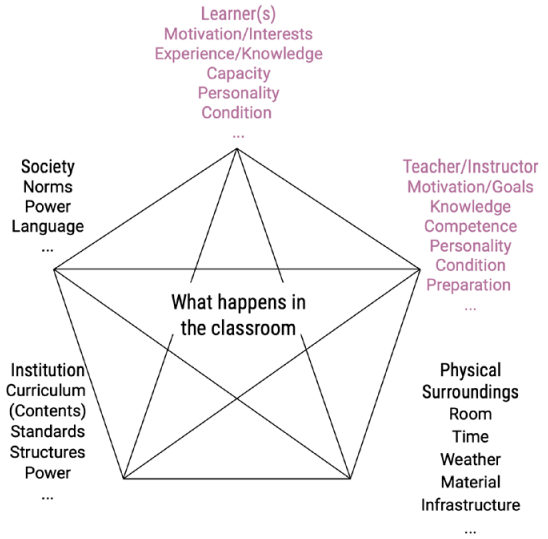

Fig. 2: Five-sided model for Analyses of Learning Settings developed by Karola Kunkel

In order to gather information on their unstable attendance in the practical exercises, I initiated an open floor at the beginning of a lecture session. I started by explaining the »Iceberg Model« for assessing competence (see Fig. 3). I adapted the model to understand why the observed attendance by me as a teacher cannot explain all of the students' reasons to not attend a lecture or exercise. First, I shared my perspective on their lack of attendance, e.g. the tasks are too easy or too hard for them or that the style of teaching and support is not to their liking. Second, I asked them for their reasons and collected them on the blackboard. Overall, it became apparent that the lack of attendance was due to personal or health related issues as reported by the students, not a general motivation issue.

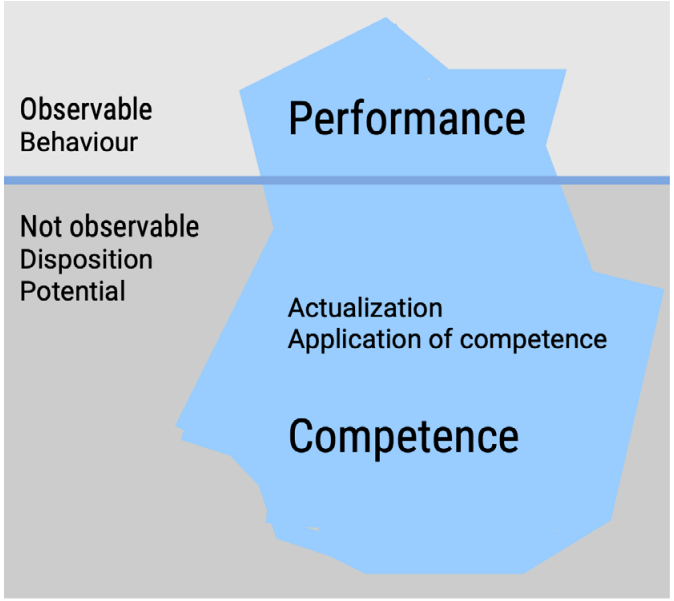

Fig. 3: Iceberg-Model for assessing competence (author's interpretation of a model suggested by Sebastian Walzik)

However, I still suspect some issues either on the student or teacher side after the self-reported reasons. After this open discussion, I noticed a slightly more stable attendance in the exercises.

2.2.1. Teacher

My main goals as a teacher are to provide continuity both in exercises and lectures and provide coherent, real-life examples in most situations. My focus is very much on a clear presentation of contents, which is assisted by practical demonstrations (live-coding) during the lectures and frequent, joint recap-sessions to give students a chance to self-actualize themselves and their already gained knowledge. Sometimes I do not trust students in their independent learning, which I try to strengthen in the future (see section 4). While I see myself as a competent and knowledgeable advisor regarding the course content, I should enable students more to acquire self-competence and personal growth.

My self-assessment was deepened by attending an HDS course on self-management and awareness in teaching. Most of my lectures are neatly prepared in order to provide knowledgeable and competent lectures. I realized that, especially in the small group of students, a more relaxed and open approach can sometimes benefit both students and teachers.

2.2.2. Interactions

Sometimes I internalize certain problems from students, although they have their own responsibility to stay focused and on track with the course. To this

end, I try to be aware of “problem ownership” and communicate in an open fashion with the students. Recently, I used some time of the lecture for a break and personal interactions, e.g. to explain the course on teaching in higher education that I attend. From the peer visits, I got a lot of positive feedback with regards to student interaction and the open working atmosphere. I also think that live-coding sessions make the students realize that I sometimes make mistakes and that fault-tolerance is both targeted at them and myself.

I think that one of the main interactions that can be improved between teacher and students is with the institutions itself. My inquiries with the students and the mentioned hand-off between international office and faculty revealed several issues on a meta-level. Moreover, I suspect that the contents across the courses of the curriculum might be more tightly coupled or integrated (math, electrical engineering, and computer science).

Societal issues with regards to the student’s integration might exist, to which end they receive intensive German language training in the first semesters. Other than that, the physical surroundings are mostly fine (small seminar rooms for lectures, PC labs for practical exercises).

2.2.3. Lessons Learned

From the analysis of the learning setting in my course on Computer Science, focusing on teacher and students, I can draw several conclusions. For instance, the »Iceberg Model« (see Fig. 3) helped to establish a deepened awareness for myself as a teacher and the students. The focus on »problem ownership« helps to determine where relevant parameters are and which of them may be adjusted to ensure better and consistent teaching and learning successes.

Due to the manifold challenges that my international students face, I initiated an exchange between colleagues involved in the bachelor course. Experiences and suggestions were discussed and institutional limitations were discovered, such as the challenging harmonization of German and English lectures.

2.3. Student Motivation

I believe I was one of the few students with an almost 100% attendance at lectures as well as exercises. Attendance made sure that I followed a regular structure throughout the semester, without the need to set a personal study program. Since I am a quite eager note-taker (see above my experience with my history teacher), I had a device to keep myself engaged even with the more boring topics (and lecturers). Hence, my main question with regards to student motivation was: Why don’t they attend?

The importance of attending educational institutions has been realized early on (Hancock et al. 2013). Especially the relation to the educational outcome can be proven: »Attendance matters for achievement, and every day counts.« (ibid., 6). Although the findings of the study relate to the public school system in Western Australia, it proves my personal impression of attendance as key to educational success. Many studies report strong correlations between students’ attendance and performance in higher education as well (Devadoss & Foltz 1996; Durden & Ellis 1995; Romer 1993; Park & Kerr 1990; Schmidt 1983).

A study with focus on the causal relationship also found that »Attendance is found to have a small, but statistically significant, effect on performance.« (Rodgers 2001, 12). It has to be noted that attendance is only one factor among many others for the academic performance of students. Other factors include: students’ effort, previous schooling, parent’s educational background, family income, self motivation of students, age of students, learning preferences and entry qualification of students (Durden & Ellis 1995).

Newman-Ford et al. (2008) evaluated attendance in higher education and their results showed a strong, statistically significant correlation between learning event attendance and academic attainment (see Mortiboys 2010, 87). For the problem of attendance, Mortiboys lists two main reasons that contribute to absenteeism:

- They do not understand the value in attending.
- Actually, there is no value in attending.

In order to support these reasons, I looked up student voices on an internet forum targeted at students in the United Kingdom. In some statements I found evidence that regardless of the two reasons mentioned by Mortiboys, attendance can also be hard if there are external factors that neither lecturer or students can influence. In conclusion, improving attendance in my opinion is crucial both for improving grades and to

keep the motivation of both students and lecturers up. From my research and reasoning, I recommend the following practical steps:

- Engage in an open discussion with students about their attendance and the effect on their learning success and grades
- Improve teaching wherever possible: Mix different media, experiment with approaches such as Flipped Classroom, provide appropriate material and hints about suitable literature for self-study
- Offer directions for personal support, such as guidance counseling of your university, self-help groups, etc.

2.4. Peer Interaction

My lecture on Computer Science 2 was visited by 5 peers from Module 1. With this relatively large number of visitors, I had the chance to receive their feedback at the very beginning of the lecture period (two visitors), in the middle (two visitors) and at the very end (one visitor).

The feedback I received from my peer visitors served to encourage me in providing even more structure for the contents and keep up the mix of media (slide projections, blackboard, live-coding sessions, rounds of questions). I also got the feedback that my slides contain too much text, which is evidence that using them both as script and presentation media has its problems. I received many positive notes with regards to my use of the room, the open atmosphere, and switching between languages if necessary.

My own classroom visits provided me with the opportunity to compare my own style of teaching to my peers. I visited a lab introduction with a small group of students and a lecture with a medium-sized group. Both times I kept rather detailed notes to give an accurate report of my observations. While both visits showed very motivated teachers, I could always provide some hints with regards to the conduct of the concrete event.

Another valuable part of Module 1 and the entire workshop program is the exchange of personal experiences, sometimes rendering the atmosphere similar to a self-help group. Meeting and discussing issues related to teaching with motivated scholars is a motivation in itself. Moreover, the theories and models presented in the program lay a strong foundation for discussing and implementing novel approaches in teaching practice despite the occasional skepticism of colleagues.

In the next section, I collect the models and theories that had the strongest impact on me and my teaching.

3. TEACHING PHILOSOPHY

This section describes the theoretical background, which I gained during Module 1 and which guides my teaching practice now (see section 4).

3.1. Shift from Teaching to Learning

The most important part of the teaching philosophy, which lays the foundation for every other consideration, is summarized as »shift from teaching to learning«. This idea is shockingly simple, but requires effort to be implemented. Instead of imparting knowledge, teachers should direct active learning and facilitate the understanding of a topic. The activation of the student that is needed for this approach will in fact enable him or her to actually understand, apply, and transfer the knowledge thus gained.

It is clear that this demand is more than justified in the current age of information, where the challenge is not to retrieve information but to interpret, select, combine, and apply the vast amount of available information in novel ways.

An important tool that stands for this shift is the constructive alignment concept. The idea is to align the intended learning outcomes both with the teaching and learning activities that lead there and the final assessment, i.e. tasks that prove that the learning outcome was achieved. To define and align all of those three aspects, Bloom's taxonomy of learning objectives can help (see Fig. 4).

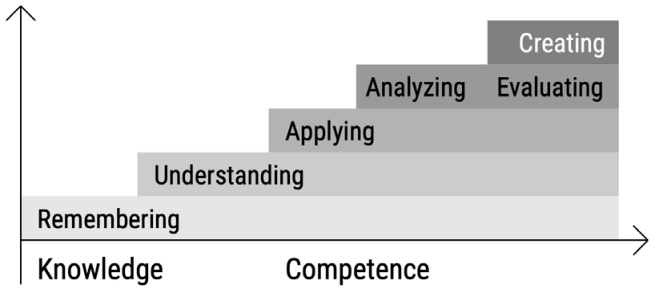

Fig. 4: Bloom's taxonomy of learning objectives (illustration by the author)

In the case of computer science, a skill such as programming should be taught in practical trainings and an exam should validate if the guiding principles have been understood.

Regarding motivation, the self-determination theory by Deci & Ryan (2017) has become a guiding principle. They identify three main drivers of motivation: autonomy, competence, and relatedness. Both students and teachers can be addressed with this model. Autonomy is usually provided for the teacher with regards to the organization and the contents for a lecture, seminar, or exercise. Students can be hence given autonomy if they are able to choose what to do within learning situations, select different tasks, contents and difficulty levels (Ringel 2019). Competence is experienced by the teacher if his or her teaching is received by the students and they actually learn something. For students, this experience of having competence happens if the content is understood and they succeed in their learning goals. Relatedness can be established by communication in both ways and well-provided feedback.

3.2. Communication and Feedback

Communication needs to consider the responsibilities of sender and receiver. The sender should make it clear on which level the message is sent and the receiver should be aware that his or her interpretations might not coincide with the sender's.

Schulz von Thun identified four aspects of a message: self-revelation, factual information, relationship, and appeal (von Thun 2006). It is advisable to

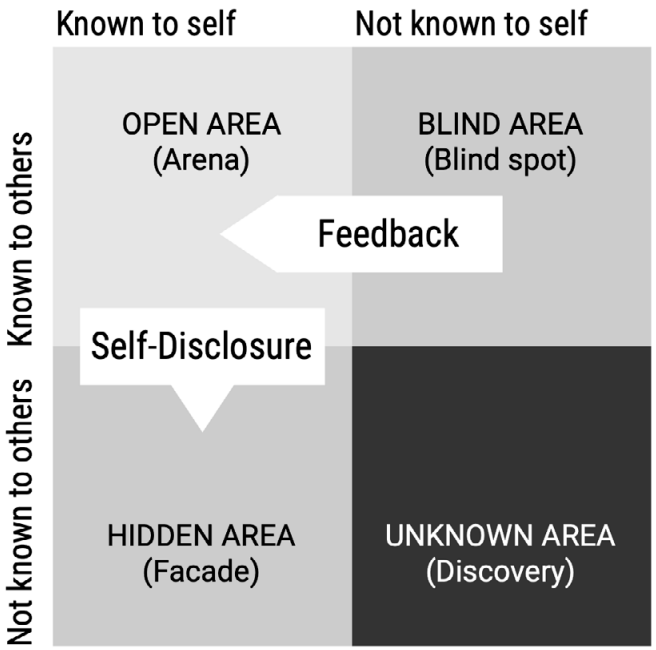

Fig. 5: The Johari Window Model for feedback (illustration by the author according to Luft & Ingham 1955)

communicate on the level of factual information and self-revelation and make them clear when sending a message.

The importance of feedback can be better understood when considering the Johari Window Model (see Fig. 4). It shows how self-disclosure reveals information previously unknown to other people and how feedback should reveal information that is not known to oneself but to others.

Another interesting approach to communication is Schulz von Thun's »Werte- und Entwicklungsquadrat« (Square of Values and Development). Here, the aim is to identify a positive value that corresponds to a negative trait discovered in another person. Consequently, a counter-trait is described, which the sender of the feedback suggests the other person to achieve. Using the positive value, the negative trait can be described only as a danger if the underlying, positive value is exaggerated. This communication approach is supposed to be advantageous over the commonly used »feedback sandwich«, which shrouds a complaint in two positive messages. Apart from being transparent, usually the messages are not well-connected. The described square of values stays on one topic and is less crooked.

3.3. Group Processes

Tuckman's model for the dynamics and development of groups lays a strong foundation for guiding group work of students (Tuckman 2001). I experienced that making the usual steps apparent to students is a considerable help and avoids needless frustration: Forming, Storming, Norming, Performing, and Reforming. Especially the storming and norming phases can be strenuous and knowing that rivalry and conflicts are very common and need to be overcome during the norming phase relieves much stress.

However, there are always unexpected situations that need to be dealt with. It is always easy to come to quick conclusions while there can be numerous reasons for a student's reaction, predisposition, or learning progress. Hence, I try to uphold an open, friendly, and sensitive atmosphere and communication. Discussions both with the whole group and one-on-one discussions should be allowed.

Enforcing the building of groups even in lecture settings can foster support between students and a better overall as well as individual performance. My conclusion is that group work opportunities should be used as much as possible.

3.4. Evaluation

Group work, as any teaching endeavour, should include meaningful ways of evaluation. A workshop provided me with helpful insights on evaluation and feedback. For instance, quality management (e.g. from OECD) suggests four levels of evaluation: Context, Input, Process, and Product (CIPP model). It is notable that currently with exams and teaching evaluations at the end of a semester, there is a strong focus on the product, and hence, a summative evaluation. The product can be seen as the learning outcome in the theory of constructive alignment (see section 3.1). The problem with summative evaluations is that their results can only be applied in new installations of a course, most of the times with a whole new group of students.

Hence, it is also interesting and worthwhile to consider preformative and formative evaluations. Preformative evaluations take place before a course starts and focus on the Context and Input. Instead of feedback, this feedforward can considerably influence the selection of material, contents, and methods. Consequently, formative evaluations take place during a course and can lead to adaptations of the Process using this feedwithin.

Novel teaching methods such as flipped (or inverted) classroom already implement all three forms of evaluation and I am very interested in implementing this or other methods.

4. TEACHING PRACTICE

Within the Module 1 workshops, when considering my role as a teacher, two descriptions came to my mind: being a role model vs. acting as a performer. Both aims stem from my own expectations towards a teacher (see section 1). As already stated, the personal learning preference seems to considerably shape the organization and content of any lecture. A teacher needs to be a role model, meaning that he or she needs to be knowledgeable and competent regarding the course contents. However, without being a decent performer, lectures might become dull and strainful. This is also reflected by my assessment of statements regarding the role as a teacher done in Module 1 (see Table 1). As consequence for my future teaching, I need to work on allowing students to find their own paths and help them develop general learning strategies (shift from teaching to learning).

STATEMENT	SITUATION	ASSESSMENT
I want to transfer my knowledge	Lectures	++
I am a facilitator	Exercises Lab work Consultations	-
I am a presenter	Lectures	++
Students are independent learners	Exercises	–
I help students to develop complex thinking	Lectures Exercises	–
Students actively influence course content	Lectures	–
I regularly solicit feedback from my students	Lectures Exercises	–
I help students to develop learning strategies	Exercises	–
I am an advisor	Consultations	++
I try to transfer as much knowledge as possible	Lectures	++

Table 1: Assessment of statements regarding the role as a teacher (excerpt)

In the following, I will list methods, techniques, material, and media from Module 1, which inspire and guide my teaching practice.

4.1. Methods and Techniques

The most important trait of Module 1 was the style of teaching by example employed by the facilitators of the course. The abundance of techniques that was used to convey material and incite reflection showed clearly how the methods work and whether they are suitable for the personal teaching practice:

- Think-pair-share
- Grouping and growing of groups
- Spotlight presentations
- Demonstrations and role play
- Energizers (Brownian movement, etc.)
- Crafty visualizations
- Reflection
- Storytelling and personal anecdotes
- Collection of ideas
- Personal notes
- Speed dating
- Discussions
- Guest speakers
- Quotations and reading aloud
- Imagination (dream journey)
- Poster creation
- Brainstorming
- Card collection

I think that most difficulties with my groups of learners in computer science will arise when trying out ener-

gizers. This is due to the fact that computer science students tend to be less sociable, even if this is a cliché.

The most notable method is »think-pair-share« because of its versatility and applicability both for large and smaller groups of learners. I often applied a discovery outside of the HDS courses called Knowledge Alphabet (Birkenbihl 2007). Every student can construct a list of words based on the letters of the alphabet on their own. Later a joint collection of words on the blackboard can help to exchange and construct an alphabet for the whole group.

4.2. Material and Media

Adapting material and media to the learning contents is an important tool to create a lively and activating learning atmosphere. During Module 1, I experienced:

- Music and audio cues
- Flipboard, Pinboard, Blackboard
- Using the room (e.g. the floor)
- Piece-by-piece construction
- Breaks
- Partner interviews
- Handouts
- Slideshows

In my own teaching, I try to use as many changes of media as possible. I still see myself falling back to slide presentations very often, since they also serve as a script for the lecture and exam. Given more time for preparation, these two functions should not be joined any longer.

CONCLUSIONS

Many strategies for teaching exist, but their applicability and practical use as well as adaptation to specific contexts can be hard. Whether there is a »holy grail« in teaching is a recurring question for me. The »science of teaching« seems much different from other professions or sciences. While definite answers and »holy grails« may exist in some of those, didactics is a field with much more contingencies. Hence, I will start investigating the concepts of constructivism and systemic thinking in the future.

Within Module 1, there was a lot of emphasis on students' autonomous, active, self-guided and self-motivated learning. How to activate and advocate this is a tough question for me. The mindset of teachers and students needs to be aligned and I think to that end a certain theoretical foundation is needed to convey some basic knowledge.

In this teaching portfolio, I have compiled the most important exercises, theories, models, and experiences that I became acquainted with during the course of Module 1 and several other workshops from Module 2. I am planning to complete the entire certificate program and look forward to deepen the insights already gained and discover new theories and models. Most importantly, I look forward to the active exchange with people engaged in teaching at the workshops to come.

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