THE WORM HAS TO TASTE TO THE FISH, NOT TO THE ANGLER!
THE STUDENT-CENTERED “SUSAN”-CONCEPT FOR LEARNING

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Abstract

It is now already 20 years after signing the Bologna Declaration. But unfortunately, the “Shift from Teaching to Learning” still did not reach most of the study programs in engineering. This is shown in the study structures by the strong believe in the power of the traditional lecture-and-lab style. The professor typically still plays the role of the mediator between the “cloud of knowledge and wisdom” on one side and the students on the other side. Clearly, this time has gone since the digitalization of life has reached education. Nowadays, students don’t ask the professor when they don’t understand any topic - instead they watch YouTube videos!

The student-centered “SUSAN”-concept presented in this paper is an approach to react to this challenge. It should be a sustainable (SUS) and animating (AN) approach for learning. The “SUSAN”-concept is based on principles for effective and intensive learning which are known in pedagogics since more than 200 years. Simply said it is about:

1 The learner: he is the master of the process
2 The learning: it is holistic ("Head, Heart and Hand")
3 The teacher: he is only a companion of the learner

Unfortunately, these old findings have not been accepted broadly in engineering education for generations. Instead, education mostly was fenced into a system of classes with frontal teaching. In the last years, the neurology of brain has given us more understanding of the brain functions during the learning processes. By the “SUSAN”-concept we try to apply this new knowledge together with the old findings to university learning in the field of mechatronics. The current focus is on electrical and electronics engineering but can easily be transferred to other subjects.

In the course of this paper we will first make an excursion through the teaching/learning history, second we shortly introduce the learning theories explaining the background of the “SUSAN”-concept. Thirdly, we present the “SUSAN”-concept and the different learning methods used.

Keywords: Student-centered learning, context and problem-based learning, project learning, new learning / teaching models, learning and teaching methodologies.

1 INTRODUCTION - THE PROJECT BACKGROUND

More than 30 years ago the first author of this paper started teaching electronics at Heilbronn University. Based on experiences during his own studies and the examples of the colleagues his teaching methods in the beginning have been classical: lectures in the classroom and some ready prepared experiments in the lab.

However, the result was very frustrating for him: Most students developed no motivation for the topic and furthermore the learning result was very poor! To transfer the own personal fascination of electronics to the young people did not work and even the well-structured teaching could not create stable basic understanding of electronic systems.

What to do? Giving up and leaving the job? Trying to put more pressure on the students? Or thinking about basic changes of the teaching approach? The decision for the last option started years of “trials and errors”, “attempts and fails”, “fascination and frustration” which directed the teaching approach towards the student-centered learning with high emphasis on intrinsic motivation by own experience.

Fig. 1 and Fig. 2 show the difference between the teacher-centered and the student-centered learning models. This visualizes the long track of transformation the teacher has to go through if he wishes to change his teaching approach.
In the following historical excursion, we first try to summarize the crucial topic of the role the teacher plays in the learning process.

2 TEACHING METHODS – A SHORT HISTORICAL RIDE

Education has been a part of human living since earliest times. It was not following a structured plan but it happened naturally as a part of growing up in a group. Not only parents but the whole number of people sharing the life together in a group or village had educational impact on the offsprings [2]. The offsprings have been growing in experience, abilities and personality by examples and interaction with adults.

2.1 Ancient models and experiences

The first schools and professional educators were found in ancient Greece. The schools developed around famous philosophers (e.g. Plato, Aristoteles, Zenon, and Epicure) and were more a community than an educational institution. Their task was mainly the discussion of philosophical questions and not the training of people. Plato described the “Socratic method” which was about a discussion based on different standpoints with the aim to “stimulate critical thinking and to draw out ideas” [3]. The second “institution” were the sophists. A sophist was a specific kind of teacher in Greece in the 5th and 4th century BC. Mostly they were travelling and timely employed by rich people. Their teaching topics had started from philosophy and rhetoric but including mathematics, athletics or music [4].

In the Jewish history the education of “disciples” has been one important task for the “masters” (rabbis). The word “rabi” has the meaning “my teacher, my master”. The task of the rabbi is to teach the “Torah”, the written witness of God towards his people [5]. The teaching of the “rabi” Jesus Christ towards his disciples mainly took place through living together (personal example), preaching (structured speech), parables (real world examples) and mission (hands-on-training).

In trying to work out a common line of this ancient models we find

- a close personal relationship of teacher and learner
- sharing life together builds an important learning environment
- orientation of education founding on a philosophy of life
- common discussions on the topics as learning strategy

2.2 Medieval education and first school institutions

The education in the middle ages was mainly influenced by two mainstreams: the church-connected, Christian faith on one side and the humanistic ideal, oriented at the classical ancient models on the other side. For the first one the ideal pupil should “not remain angry, not to be spiteful, not contradicting the professors but receive with confidence what is taught him” (Columban (543 - 615) and Bede (672 - 735), Celtic/English monks [6])
The German reformer Martin Luther (1483 - 1546) as a church person promoted Christian schools in responsibility of the cities and not the church [7]. He also proposed to send all the children to school [8] [9] which only privileged people could do at that time. This was in marked difference to the aims of the humanists. His educational concept was “literacy to promote piety” [10].

We observe in this centuries as a main directions
- a clear gap between the teacher and the learner
- the learner as the object of the teaching
- the aim of education is to make the learner a useful part of the (religious and political) society

2.3 Modern age - compulsory education and alternatives

The first models of learner-centered education and self-controlled learning date back to Comenius (1592 - 1670). He was a teacher, organizer of schools, a scientist, formulated a general theory of education and was also a writer of textbooks [11]. Comenius believed that “everything should be presented to as many as possible senses of the child, using pictures, models, workshops, music etc.” [12]. His methodology is written down in his work “Didactica Magna” (1657) and describes “education according to nature” [11].

Jean-Jacques Rousseau (1712 - 1778) considered his book “Emile, or On Education” to be the “best and most important” of all his writings [13]. He also was promoting a child-centered education, which was nature-oriented. The personal experience of the child guided by a tutor was his teaching approach [14].

The Swiss reform pedagogue Johann Heinrich Pestalozzi (1746 - 1827) was the first mentioning the holistic learning strategy of “Head, Heart and Hands” [15] [16] [17]. Today this concept got new application in several fields now called the “3H-Approach” [18] [19] [20]. The “SUSAN”-concept and the MEXLE-system are deeply influenced by this strategy [21].

In 1592, the duchy of Pfalz-Zweibrücken in Germany has been the worldwide first political territory introducing the compulsory education for all boys and girls [23]. This was the beginning of the period when the education of kids became a task of political state. However, having the education in the hands of the political system the temptation to “educate” the kids according to the needs and ideology of the current potentates started. This helped to educate “obedient citizens, officers and soldiers” instead of developing the personal potential of the kids [24].

The Prussian system of education (starting in 1763) looked very interesting for other countries and according to this example the rest of Europe also has instituted state-oriented mass educational systems in 19th century [24].

The compulsory educational systems had several negative outcomes “killing” the concepts of the reform pedagogues
- levelling the different talents through strict learning plan
- destroying the richness of kids’ creativity [25]
- developing an orientation towards marks, not striving for understanding (“bulimic learning” [26])

3 Teaching Methods - Current Models

In the last 100 years several methods for teaching/learning have been defined and described. This chapter only gives a short introduction to the four most important models. Every model then will be compared to the student-centered learning approach, which is defined by the Bologna Process [27].

3.1 Behaviorism - the Black-Box-Model

Behaviorism is based on the model of a “stimulus-response”. The first experiment proving this was “Pavlov’s dog” (1897) which was trained to react on the stimulus of a bell. The system functionality in Behaviorism can be described by a Black-Box-model. (Fig. 3).
The learner is considered as a reacting system, which can be conditioned to respond to external stimuli [28]. Behaviorism as a psychological school based on an article of John B. Watson (1878 - 1958) "Psychology as the Behaviorist Views it" (1913) [29]. Every educator is using this model in many situations, e.g. if you use a special sound to get the class quiet. Also the promise of sweets or money to the kids for doing well or bring good marks back home is such a conditioning. Even the marks themselves build a system with positive and negative conditioning.

**Behaviorism = Conditioning a person by proper stimuli**

Behaviorism is not using the responsibility, creativity and intellect of the student to develop himself through the learning. It might have been the proper solution for the time of industrialization when every worker, engineer and officer should have fulfilled his tasks in a reliable way. In general, we will not survive without any conditioning in education. But, the perspective towards the student as the "material to be processed" or the "dog to be educated" does not fit to the world of today and tomorrow.

*If you put fences around people, you get sheep* [30]

In the framework of the SUSAN-concept we try to avoid this approach. Behaviorism is neither developing the available engineering potentials nor the personality of a student.

### 3.2 Cognitivism - the brain as a “computer”

Cognitivism sees learning as a process of acquiring and storing information [28]. Still today, a lot of teaching promotes this approach. It has its emphasis on facts and memorizing. The functionality of the cognitive process is receiving and keeping information for long time (Fig. 4).

The learner builds his knowledge by an ongoing process of acquiring and memorizing of information. This process is typically used at school if you learn words of a foreign language.

The “cognitive revolution” inside psychology started with Noam Chomsky’s (*1928*) critique of behaviorism (1959) [32]. For decades, the latter was one predominant theory in psychology. It is successfully used for psychological treatment (cognitive behavioural therapy) until today.

Cognitivism has worked out many quite successful learning strategies, but it failed to activate the motivation of the student. Treating yourself as a sort of computer has a certain lack of humanity and is definitely not developing creativity. To overcome this, the cognitive approach has been expanded by several authors. One example is the Cognitive Emotional Pedagogy (CEP) created by Joni Mäkivirta. CEP adds parts from constructivist learning theory associated with creativity and emotionally distinct experiences [33].

For the “SUSAN”-concept we use some parts of the CEP-approach.
3.3 Constructivism - building my own understanding

Constructivism was also developed in the second part of 20th century. The “great pioneer of the constructivist theory of knowing” was the Swiss psychologist Jean Piaget (1896-1980) [34]. Many well-known teaching methods are based on the constructivist learning theory. They believe that “learning occurs as learners are actively involved in a process of meaning and knowledge construction as opposed to passively receiving information” [35]. The constructive learning model can be described as a circle from experience to understanding (Fig. 5).

![Constructive Learning Model](image)

The constructive learning is the natural way kids are building their access to the world by interaction with it. The “Montessori Education” is using this approach and therefore “involves free activity within a prepared environment” [37].

Based on the constructivist theory the model of “Empowerment Didactics” was mainly developed by Rolf Arnold (* 1952) [38] [39]. This model assumes that knowledge cannot be generated from outside. The teacher only can create the proper framework for the learning process. A widespread quote of Gregory Bateson (1904-1980), who was an English anthropologist, social scientist and cyberneticist, visualizes this by a nice example:

> You can lead a horse to water, but you can’t make it drink.
> The drinking part is up to the horse.
> Yet even the horse is thirsty,
> It can’t drink unless it is led to the water.
> The leading part is your business. [40]

The “SUSAN”-concept takes intensive use of this learning model, since it is the most student-centered of all the three approaches. The concrete realization is discussed in the next main chapter.

3.4 Connectivism - connecting nodes and resources

Connectivism is somehow an alternative to the classical learning theories for the Internet-age. Nowadays it is much easier to network to lots of people around the whole world and also to have access to extremely broad information. This has dramatically changed the technical possibilities for learning and scientific work, too. Connectivism was first mentioned by George Siemens (* 1970) in 2005 in his article “Connectivism - A learning theory for the digital age” [41]. George Siemens himself gives the best definition of Connectivism:

> Connectivism is the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning (defined as actionable knowledge) can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing.

Fig. 6 shows a visualization of the learning model of Connectivism.
Besides of the extremely large possibilities created by the networks it is a real challenge to keep the learning on the track. Otherwise, the chaotic system is going to lead you somewhere. Therefore, the successful integration of this approach to a learning environment will need very careful design.

4 THE “SUSAN”-CONCEPT - TAKING THE BEST OF ALL

Designing the “SUSAN”-concept for learning it was first needed to clarify the main baselines for it. We decided for the two main basic topics:

Learning should be sustainable and animating

The “SUSAN”-concept was developed on the base of the “LENA-Modell” [43], which was created by Rolf Arnold for adult education. The adult learning institution WIFI from Austria is using the LENA-Model very broadly [44] [45]. There is also a very inspiring book from Rolf Arnold on this topic [46].

4.1 Sustainability - how not to forget

Sustainability is a big challenge for learning. It needs careful design of learning strategy to keep the learned stuff for long term available for use. The “forgetting curve” shows that the information in memory is lost very quickly (Fig. 7). The often-misinterpreted learning Pyramid tried to show the needed ingredients (Fig. 8).

In the depicted structure, assumed retention rates are shown. Both retention hypotheses do raise the question: what are the strategies to overcome the unwished forgetting effect? The learning therefore needs good strategies to become sustainable.

Summarizing the results from the standpoint of sustainability, it shows that it is best to discuss and practice a topic and then teach it to others. Therefore, the old professor’s wisdom is also proofed:

“If you want to understand a topic, create a lecture on it!”
4.2 Animating - activating the emotions

Learning is much easier, when your intrinsic motivation for the topic is strong. This is a knowledge everybody has from his own experiences. It means one of the teacher’s roles will always be to find ways to activate this motivation in the learners. It was not very surprising, when the research in the field of the neurology of brain also ended up with the same result. The application of these results to the teaching/learning practice today is called “Brain-friendly Learning”. Several publications on this topic are available for the practical application [49] [50] [51] [52].

A nice and structured presentation of the “5 States of Learning in the Brain” is shown in Fig. 9:

The short explanation of the 5 states given by Satyen Khashu [53] follows in Table 1:

<table>
<thead>
<tr>
<th>No</th>
<th>Title</th>
<th>What for?</th>
<th>What is happening?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WHY - Curiosity</td>
<td>Create attention</td>
<td>Arousal, sometimes confusion, anticipation</td>
</tr>
<tr>
<td>2</td>
<td>Uh-oh - Healthy Concern</td>
<td>Trigger healthy</td>
<td>Cortisol released, Healthy in short bursts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Create an interest</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>WOW - High Energy</td>
<td>Energize and Create Emotions</td>
<td>Noradrenalin created, Amygdala engaged</td>
</tr>
<tr>
<td>4</td>
<td>YES! - Enthusiastic Confidence</td>
<td>Celebrate, fun, neural growth</td>
<td>Dopamine released, Frontal lobes engaged</td>
</tr>
<tr>
<td>5</td>
<td>CHILL - Reflection and well being</td>
<td>Focus inwards, reduce stress</td>
<td>Cortisol level drops, Amygdala deactivated</td>
</tr>
</tbody>
</table>

What we have learned from this: the positive emotions towards the learned topic is crucial for the success of learning. The outcome is: we have to build a motivating environment for good learning.

4.3 The “SUSAN”-concept - learning elements used

In our case, we did a heuristic approach instead of initial study of scientific papers and reading books touching the topic of learning. We started at the point when we worked with the students trying to optimize the learning environment for them and together with them step by step. The guiding principles have been to create a sustainable and animating learning environment for them. Only later, we came in touch with the theories and the examples of the learning concepts. In this chapter, we will shortly discuss the learning elements we have used up to now.

4.3.1 Theory and practice closely connected

The common structure of teaching in our faculty is to give lectures in the classroom. Typically, in the subsequent term a lab time with ready prepared experiments is offered. We found out that the close coupling of practical experience to the theoretical part is helpful for learning and motivation (Multimodal Learning)
4.3.2 Real life experience as the starting point

It is a well-known practice in teaching that one should start with something which is part of the already existing experience of the learners. From this, it is easily possible to raise questions or define relevant problems. We are using this practice in a setting, starting with an experiment or practical question before looking for the theoretical explanation. (Experience and problem based Learning)

4.3.3 Learning under self-control

Especially at the “fresh” student’s cohort the difference in pre-knowledge and experience is very high. To take them all to the same classroom in the same time always will result in excessive demands for one sub cohort and boring underload for another sub cohort. A solution we used is the preparation of the material at home and then discussing and training in time of the lecture. (Flipped Classroom)

4.3.4 Developing teamwork skills

Most of our students will take a job at a company after finishing the university. Therefore, it is very important to know what skills are expected from their future employers. Among others, the teamwork skills are highly requested. Education for an engineer should develop this competence by practical training. For this, we use the teamwork structure for the lab projects. Group size typically will be 3 to 5 people. They have to organize their work in self-responsibility. The educator plays the role of an external mentor for the project. (Cooperative Learning)

4.3.5 Do your own project

The lab time in our case is divided in two parts. At first, the practical part of the learning takes place. In second half of the term, the students are working in groups on self-defined projects. There is a very high motivation when students can not only select a project from a list but also bring own ideas for the projects. (Self-defined learning goals, project-based learning)

5 CONCLUSIONS

The “SUSAN”-concept is still very young and in continuous development. In this paper, we have tried to build some theoretical base from side of pedagogics and learning models to get a deeper understanding of background and effects of the concept which was developed by a try-and-error approach.

The realization of the “SUSAN”-concept in hardware, software and web-tools is the MEXLE-system (Multimodal system for Experiments and LEarning), which is the toolkit used for the learning in the classroom and at home. The MEXLE-system is described in a second paper called “Active learning in engineering - MEXLE an open source lab-in-a-box system for students in electrical engineering, electronics, signal processing and programming classes” [55].

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REFERENCES
