TOWARDS A DEFINITION AND IDENTIFICATION OF LEARNING OBSTACLES IN HIGHER SOFTWARE ENGINEERING EDUCATION

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Abstract

At first glance learning obstacle seems to be a well-defined term based on the definitions of the terms learning and obstacle. To our knowledge, there is no satisfying definition and even no overview of existing ones in the field of higher software engineering education. Of course, software engineering is abstract and complex by its nature and this might be one of the biggest learning obstacles for our students. In order to improve our – already student-centred didactic – we ask ourselves where the still existing learning obstacles come from and where they are located. By trying to answer these questions, we present our approach to come to a first overview to existing learning obstacle dimensions as well as a working definition for learning obstacles in higher education. At the moment, we derived six learning obstacle dimensions. We explain each of them by a working definition and provide an example. In a discussion section, we raise our current open questions and considerations the whole topic of learning obstacles entails.

Keywords: Learning Obstacles, Software Engineering Education, Constructivism, Cognitivism, Cognitive Load Theory, Learning Strategies, Learning Dimensions.

1 INTRODUCTION AND MOTIVATION

The landscape of higher education didactics has already changed towards a student-centred, activating and thus, an inductive one. Although we are well on track, students in our software engineering (SE) courses still have multi-layered problems and difficulties due to the nature of SE with its abstractness and complexity. To improve our teaching in a next iteration, we have to get to the bottom of things.

Currently, we ask ourselves the following questions: Where are these difficulties and problems rooted? What preconceptions do students bring along in our courses? Which factors prevent students from learning software engineering? To our opinion, this can be summarized to the question concerning existing learning obstacles in SE courses. This is also the underlying question for this paper. Before the professional specialization to existing learning obstacles in SE, we tried to get an understanding about a common definition of learning obstacles. To our knowledge, there is no satisfactory definition for learning obstacles. Therefore, within this paper, we give our first insights to the above raised questions and present our approach to get a holistic overview of the existing mental models, conceptions and the related problems and difficulties students have in learning. Our focus is on the target group of students in SE but the definitions and dimensions found are not limited to it.

The remaining paper is structured as follows: In Section 2, we explain our key considerations to get a holistic overview about learning, the foundation of current didactics in learning theories in general and thus first identified accompanying learning obstacles. Sections 2.1 to 2.5 describe the theoretical basis whereas the Sections 2.6 to 2.8 present the derived overview and dimensions of learning obstacles. Section 2 ends with a discussion about open questions. Section 3 provides conclusion and outlook.

2 TOWARDS A DEFINITION AND IDENTIFICATION OF LEARNING OBSTACLES

In order to be able to establish a definition of learning obstacles, it is vital to lay a foundation in learning currents in Section 2.1, specifically, constructivism and cognitivism, since we base on these two currents. Thereupon, we present the three learning dimensions (see Section 2.2) – cognition, emotion, and environment. These three dimensions span up the triangle and build the basis for our big picture. Section 2.3 is necessary to clarify the Constructivist Learning Environment in a detailed sense.
With the Sections 2.1, 2.2 and 2.3 we have a theoretical framework of where and how learning happens. The Sections about Learning Strategies and the Cognitive Load Theory (see Sections 2.4-2.5) are presented to get a broad view on learning from multiple perspectives and to be able to derive learning obstacle dimensions (see Section 2.6).

This shall contribute to create a big picture of learning¹ (see Section 2.7) and accordingly derive a framework for learning obstacles in higher software engineering education (see Section 2.8).

### 2.1 Objectivism and Constructivism

Objectivism (behaviourism and cognitivism) and constructivism are often regarded as incompatible. Both currents differ in major assumptions. They have different human ideas and concepts about learning processes and human behaviour. Nevertheless, there are overlaps between these two currents [1].

On the one hand, the main assumption of objectivism is that knowledge can be transferred from teachers to learners. The teacher can also be replaced by technology [1]. The objectivism sees the mind of the learner as a processor, which is analysing, resequencing and structuring the learning content. Furthermore, objectivism sees humans as relatively passive beings. They only receive information from their environment and in turn, the environment is regarded as an unchangeable reality. Consequently, objectivism-based instructional design is more focused on the idea of providing information for learners and non or only little interest is shown for the processing of the learning content [2], [3].

On the other hand, constructivism is founded on the idea, that humans are creating their own reality and knowledge. Therefore, knowledge cannot be transmitted from teachers to learners. A teacher can only provide learning content or experiences and facilitate the learning process [1]. Based on learners interpretations of their own experiences, knowledge is constructed individually or socially [1], [4], [5]. In contrast to the objectivism, constructivism sees humans as active beings. Their mind is a tool, which helps them to build not only their own knowledge. They are constantly interpreting their experiences and constructing their own reality [1], [2], [3].

As later seen in 2.3, there are overlaps between objectivism and constructivism. Both currents have common aspects, which could be used to provide different views on learning processes and how these could be designed in an ideal way [1], [2].

### 2.2 Learning Dimensions

Most publications on learning cover one of the following three aspects: Cognitive, emotional/motivational, and social. There are merely few references that take all of these – complementarily interrelated – perspectives into account, such as Illeris [6], [7]. The basis for this multidimensional model is a “very broad and open definition of learning covering all processes that lead to relatively lasting changes of capacity, whether they be a motor, cognitive, psychodynamic […] or social character” [6, p.397]. He defines the dimensions every learning process includes as follows (see also triangle in Figure 2):

a) The **cognitive dimension** is the dimension of learning content […] knowledge and skills” [6], p.399). Therefore, the learner’s function is to construct meaning and ability; based on Piaget [8], Flavell [9] and Vygotsky [10].

b) The **emotional/psychodynamic dimension** covers feelings and motivation, i.e. sensibility, and has the objective to achieve mental balance; with reference to Anna Freud [11].

c) The **social dimension** can be described with the facets communication, cooperation, and thus signifies the level of environmental integration [12].

While the processes that come with learning can be divided into “an external interaction process between the learner and his or her social, cultural and material environment [see c], and an internal psychological process of acquisition and elaboration [see a, b] in which new impulses are connected with the results of prior learning” [6, p.396].

As a whole, these dimensions and processes compose “the tension field of learning” [6, p.399], because every form of learning will always include the three dimensions.

¹ Remark: Terms in italics can be found in the referenced Figures.
These Section shall – based upon the learning currents in 2.1 – on the one hand give an introduction into learning and, on the other hand, constitute a holistic and extensive picture of learning. This is done due to the fact, as Illeris states, that often only one process or one dimension of learning is taken into consideration, i.e. they are studied separately. Therefore, the next Sections have a deeper and more focussed look at learning (Sections 2.3-2.5).

2.3 Constructivist Learning Environment

Constructivist Learning Environments (CLE) combines objectivism and constructivism, which are often portrayed as incompatible. Jonassen [1] believes that both currents are complementary and offer different perspectives to the learning process. His model shows how teachers can design CLEs and how these can be used to guide learners by creating their own knowledge. In [1] he distinguishes between components and instructional activities. To create a CLE, following components are required:

- **Problem, project or question:** CLEs are normally focused on a problem, question or project. This should be authentic and offer enough space for problem manipulation. It is the learner's goal to understand these and to solve or finish them. For the whole process, different tools are provided [1], [13].

- **Related cases:** These can help the learners to see how other people solved similar problems. Furthermore, they can provide another approach and help the learners to enhance their cognitive flexibility [1], [13].

- **Information resources:** Additional information should always be related to the problem or project. Furthermore, they should be used just in time to avoid any confusion or overload and the learners should be able to select which resources they want to use Sweller [1], [14], [15], (see 2.6).

- **Cognitive tools:** These are often computer-aided tools which help the learners to structure and organize their knowledge (e.g. reference management, tools to create figures and tables, etc.). Their main intention is to lower the required cognitive energy for the learning process [14], [15] (see 2.6).

- **Conversation and collaboration tools:** The learning environment should also provide the opportunity to interact with other learners. It is important for the learning process that the knowledge is shared and communicated to other people. A CLE should contain collaborative tasks as well.

- **Social contextual support:** This requirement refers mainly to the teachers. They should not stop continuing their education and take part in further trainings regularly. Furthermore, the teachers should be able to set up a course properly and consider all relevant materials (e.g., a programming course requires other material than a lecture in philosophy).

To enhance learning in a CLE, a teacher should act rather as a coach than as a teacher. A successful CLE needs instructional activities [1]:

- **Modelling:** The teacher works as a role model. He or she shows the learners how to do something. This approach is very often seen in different craftsmanship.

- **Coaching:** This activity aims at an improvement of the learners’ skills. The teacher will observe the learners and give them feedback. He or she tries to do critical reflection on his or her own. Even when the learning process is getting more complicated, the teacher will try to motivate the learners.

- **Scaffolding:** The teacher tries to find tasks that are more complex for the learners. As learners skills are improving, the teacher will reduce his or her assistance. In the end, the learner should be able to solve all the tasks without support.

2.4 Learning Strategies

We focus on learning strategies, since we take the view that learning strategies do not classify in that way as learner types and learner styles do it (Learner types, learner styles and learning strategies are still not out of discussion). The term learning strategy is not clearly defined: As already described by Martsch [16], we lean on Baumert [17], Friedrich and Mandl [18] and Weinstein and Mayer [19] who describe learning strategies as planned sequences of action, trying to achieve a teaching/learning goal. In addition, Wild and Schiefele [20] consider cognitive and behaviour–related learning activities.
Learning strategies include behaviours and thoughts that activate learners, to regulate their motivation and the process of knowledge acquisition [16], [19].

Learning strategies contribute in learning success [21], [22], [23]. Thus, in our view it is possible to reverse them and retrieve learning obstacles (in 2.6). In the following, we present the learning strategy classification by Wild and Schiefele. It bases upon the classification of Weinstein and Mayer [19], but extends it. We chose this classification scheme since it bases on a constructivist understanding of learning processes [16], [24].

Three groups of strategies are distinguished: Cognitive Strategies, Metacognitive Strategies, and Resource Management. Several subscales make up each group as it can be seen in Figure 1. The classification is two staged. The first level describes three categories: Cognitive learning strategies, metacognitive learning strategies and strategies to use internal and external resources. The subscales represent the actual learning strategies that are concrete detectable. Elaboration, repeating and organisational strategies are subsumed to cognitive learning strategies as well as critical thinking. Aspects concerning planning, monitoring and regulation are assigned to metacognitive learning strategies. The last category describes strategies for internal and external resources. This is a bigger category and involves attention, time management and effort that are assigned to internal resources since they deal with the “inner” behaviour of the learner without external influence, whereas cooperation, the creation of learning environment and the usage of information resources concern the external resources of the learner.

In addition to the classification of Wild and Schiefele who considered only cognitive aspects, we use motivational/emotional learning strategies from Friedrich and Mandl [18].

2.5 Cognitive Load Theory

The Cognitive Load Theory was developed by Sweller in [14], [15] as a model, which should illustrate the difficulties of a complex learning process. It can also be used as a guideline for instructional design and furthermore, it provides insight to the cognitive process of developing schemes. A scheme is a cognitive shortcut, which allows the learner to activate knowledge or a certain behaviour very fast and efficient. In the creation of cognitive schemes, three loads are involved:
• **Intrinsic cognitive load**: This load is directly related to the learning content. The more complex the content the higher the cognitive load. For learners, it is more difficult to understand an abstract information (e.g., a programming language) than learning something, which is familiar to them. An instructional designer or teacher cannot control this load in a direct manner.

• **Extraneous cognitive load**: The extraneous cognitive load is caused by an unsuitable learning environment. This often happens, when the required information is presented in an inappropriate way to the learners. In contrast to the intrinsic load, the instructional designer can directly control this load and minimize it by using a proper didactical concept and well-designed teaching materials.

• **Germane cognitive load**: As an opposite of the intrinsic and extraneous, the germane cognitive load is responsible for the learning process. It can be controlled by the instructional designer and teacher as well, but they should try to make sure, that the learning process is promoting the learners and does not appear as a burden to them.

As a basic principle for instructional design, Sweller [14], [15] mentions that every learning environment should be designed in a way, which minimizes the extraneous and maximizes the germane cognitive load. Suitable didactical methods for the learning content should be chosen as well. This allows a partly influence to the intrinsic cognitive load.

2.6 Deriving Learning Obstacles

In this Section, we give our first insights in existing learning obstacles. All in all, we derived six dimensions of learning obstacles, either from the CLT (see Section 2.5) or from learning strategies in Section 2.4. As a working definition, we suggest the following:

A learning obstacle can be at least assigned to one of the five dimensions – namely emotional, epistemological, didactical, resource-related, and metacognitive – and represents an obstacle that prevents a learner in any manner from learning.

The psychogenetic learning obstacle (6) is excluded in this definition since we do not want to focus on learning disorders and learning disabilities.

Prospectively, we have to validate these dimensions and we do not claim them to be exhaustive. In the following, we explain the identified learning obstacle dimensions and provide an example for each obstacle.

1 **Emotional Learning Obstacles**: This obstacle is derived from the learning strategy that concerns motivational and emotional aspects [18]. It includes all influences that concern the internal attitude of the learner not exclusively related to the learning object, but also to external influencing factors.

   o **Example(s)**: Family accident or bad experience, bad grade in a subject

2 **Epistemological Learning Obstacles**: This obstacle is derived from CLT, exactly the intrinsic load and mostly found in literature [25]. It describes a misjudgement of the learning object and/or the individual competencies related to the learning object.

   o **Example(s)**: “I’ve heard the learning content is difficult”, misconceptions

3 **Didactical Learning Obstacles**: This obstacle is derived from CLT [25], exactly the extraneous load. It describes external interferences regarding structure, setting and type of material for a course.

   o **Example(s)**: Deflection in an overcrowded room

4 **Resource-Related Learning Obstacles**: This obstacle is derived from the learning strategies concerning strategies for internal and external resources [20]. This is the most complex one. Obstacles in concerning internal resources involve effort and time management, whereas external resources involve information gathering, cooperation, and environment. Either this is unknown, or these resources are not accessible and/or available.

   o **Example(s)**: Learning to program is not possible only using a paper, a computer is necessary, all types of difficulties during a cooperation among individuals.

5 **Metacognitive Learning Obstacle**: This obstacle is derived from the learning strategies concerning metacognitive strategies [20]. This obstacle deals with self-controlling.
6 **Psychogenetic Learning Obstacles:** This obstacle is derived from the Cognitive Load Theory [25], exactly from the germane load. This obstacle includes genetically determined dispositions. This obstacle reduces the germane load.

- **Example(s):** a person with dyslexia

### 2.7 Big Picture

After explaining the theoretical foundation and the derived learning obstacles, we can now present our learning obstacles located in the big picture of Learning Dimensions (explained in Section 2.2).

In Figure 2, you can see the triangle that symbolises the learning dimensions (cognition, environment and emotion) and processes. The triangle was taken from Illeris [6] (see Section 2.2) and extended by our obstacles. We now sum up the explanation of Illeris to the triangle. His development of the triangle starts with the vertical double arrow between the environment and the individual. Next, the second double arrow is placed: It represents internal processes of the learner and describes the “integrated interplay between two equal psychological functions involved in any learning, namely the function of cognition, dealing with the learning content, and the emotional or psychodynamic function, providing with the necessary mental energy of the project” [6, p.398]. The single dimensions are explained in 2.2.

We specified the learning environment in Section 2.3 where we describe the Constructive Learning Environment in detail. This design model visualizes how teachers can design a learning environment that guides learner in his/her knowledge creation. In addition, we added the dotted line to clarify the internal and external views on the learning process: Cognition and emotion span out the internal view on the learners process whereas the first described double arrow respectively the environment visualizes the external influence on the learners process.
The derived obstacle dimensions are assigned to the matching learning dimensions. The obstacles are derived partially from CLT and partially from the learning strategy classification as described in 2.6.

2.8 Discussion

Our research up to now gives just first new key insights to the whole topic of learning obstacles, that has to be investigated much wider. In this Section, we want to discuss further issues concerning causes and effects of learning obstacles and whether learning obstacles might be structured as category, dimension or scale.

A classification as dimension or scale includes a multidimensionality and the option that an obstacle can be of different manifestations. Currently we structure learning obstacles in dimensions, we do not classify them as pure categories in order to avoid that an obstacle is only classified to one category exclusively.

A learning obstacle could also be considered to be a cause for other new learning obstacles such as a misconception. In the moment, this paper considers just a learning obstacle as existing and implies neither related causes, nor possible effects an obstacle. Exemplarily, if you consider stress as a negative emotion this could be a cause for a learning obstacle as well as a learning obstacle as is and also a possible effect because of another learning obstacle.

Apart from this, a learning obstacle could also be a part of a superordinate one.

3 CONCLUSION & OUTLOOK

Within this publication, we aimed to derive a working definition of learning obstacles and give a first approach in identifying dimensions of learning obstacles. Therefore, we presented necessary theoretical foundations and our big picture as a result. All in all, we encountered six – or rather five – dimensions of learning obstacles from the CLT and from learning strategies. Currently, we do not claim them to be exhaustive; we have to evaluate them in our future work.

Our first steps regarding the identification of specific existing obstacles in higher software engineering education have been conducted in different pre-studies mainly using questionnaires. The first study was conducted in a classical module consisting of a lecture and a practice lesson. The second one was conducted during a five-day block course, whereby the participants answered a questionnaire each day. Both questionnaires examined existing problems and difficulties addressed in course content as well as external influences such as group discrepancies. We assign our preliminary results to epistemological and didactical obstacle dimensions, since they are obstacle of content-related nature and in our view this is on the one hand influenced from “outside” the individual, exemplary by the teacher, or from “inside” the learner because of misunderstandings/misconceptions or the abstractness of the subject. In an eye tracking study, we examined the most common errors in programming in C and extracted students’ difficulties during source code reading. We suppose that there are mainly epistemological learning obstacles [26].

For further data collection, we also plan to use augmented reality experiments and hope to overcome specific existing obstacles by offering new learning settings using augmented reality and online learning journals. These two techniques have a double function since they act as technologies to overcome and to collect learning obstacles. Furthermore, we would like to investigate students’ preconceptions and misconceptions in software engineering (as described in [27]) in an exploratory research work; as this seems to be a gap in scientific research due to the small amount of literature on the topic. Consequently, a predominantly qualitative research method seems to be appropriate to get a deeper understanding.

Our research up to now gives just first new key insights to the whole topic of learning obstacles, that has to be investigated much wider and deeper.

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