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Optimizing the Learning Process in Higher Education: The Six Process Features of Learning

Human learning is characterised by six process features: learning is active, constructive, emotional, self-regulated, situated, and social. However, teaching often fails to adequately honour these features, particularly within higher education. To address this issue, we explain the six process features of learning and present examples of how to integrate them in class. As this article is intended for lecturers teaching at higher education institutions, we offer methodological guidance by providing additional material including visualizations, a didactic self-assessment tool, and posters that can be applied in diverse classroom settings, aiming to enhance teaching practices across disciplines.

Keywords

cognitive activation, situatedness, social learning, constructivism, self-regulated learning

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Optimierung des Lernprozesses in der Hochschulbildung: Die sechs Prozessmerkmale des Lernens

Zusammenfassung

Menschliches Lernen ist durch sechs Prozessmerkmale gekennzeichnet: aktiv, konstruierend, emotional, selbstgesteuert, situiert und sozial. In der (Hochschul-)Lehre werden diese Merkmale jedoch oft nicht angemessen berücksichtigt. Wir erläutern die sechs Prozessmerkmale des Lernens und stellen Beispiele vor, wie sie in den Unterricht integriert werden können. Da sich dieser Artikel an Dozierende richtet, geben wir methodische Orientierungshilfen: Wir stellen zusätzliches Material zur Verfügung, darunter Visualisierungen, ein didaktisches Selbstbewertungsinstrument und Poster, die in verschiedenen Unterrichtssituationen eingesetzt werden können, um den Unterricht fächerübergreifend weiterzuentwickeln.

Schlüsselwörter

Kognitive Aktivierung, Situiertheit, soziales Lernen, Konstruktivismus, selbstreguliertes Lernen

1 Introduction

A solid understanding of the fundamental principles governing human learning can enhance the efficacy of teaching in higher education (e.g., Ulferts, 2019). In this article we discuss six features that describe the process of learning, hence they are called ‘process features’. Learning is an active, constructive, emotional, self-regulated, situated, and social process. Reinmann-Rothmeier & Mandl (1997) outlined these process features, with the addition of the ‘emotional’ learning feature in a subsequent publication from 2001. We aim at facilitating an understanding of these factors for lecturers across all disciplines.

The focus of this article is on the side of the learners (as opposed to the side of the teachers or the side of instructional material). We acknowledge that there are other factors contributing to the effectiveness of teaching, such as instructional techniques, performance assessment, and the microstructure of a course (Schneider & Preckel, 2017). With regard to learning, however, the six process features are robustly demonstrated to be important features in a multitude of studies (see Bransford et al., 2000) or the APA Top 20 principles from psychology for PreK-12 Teaching and Learning (Coalition for Psychology in Schools and Education, 2015).

We refer to the teacher education programme for secondary schools at ETH Zürich. In this programme the challenge is to build up pre-service teachers’ pedagogical knowledge within a relatively limited timeframe. A total of 15 ECTS are allocated to the teaching of educational and psychological foundations of learning and classroom management. This necessitates an emphasis on the most crucial features of learning. Consequently, the six process features constitute a pivotal element of our teacher education programme. In our experience, some pre-service teachers encounter difficulties in grasping the features and applying them in the classroom. This observation is in line with studies showing that pre-service teachers frequently hold myths or assumptions about the principles of learning (Krammer et al., 2021) and that intuitive beliefs about how learning is supposed to work can impede teaching (e.g., Trautwein, 2013). We therefore identified the need to explore how we can ensure that the six process features of learning are understood in a meaningful and lasting way. In the subsequent sections we propose answers to this question and dispute inaccurate beliefs with respect to each feature.

The remainder of the article is structured as follows: In the second section we provide a detailed account of the six process features of learning and discuss inaccurate assumptions or beliefs commonly held by instructors. Afterwards, we describe how we integrate the process features into our teacher education programme at ETH Zürich. We thereby discuss concrete examples showing how lecturers in higher education can incorporate the process features in their teaching.

2 The six process features of human learning

The process of learning can be described as active, constructive, emotional, self-regulated, situated, and social. Figure 1 shows visualizations for all features. Note that 'situated' is depicted with two visualizations, as it has two dimensions (see 2.5 Situated). Reinmann-Rothmeier & Mandl discussed these features in a book chapter in 1997 and referred to them as process features of learning. These features have not lost their relevance, but in the past they have often been discussed independently of each other. We therefore aim to bring the focus back on this core set of process features of human learning, discussing them in conjunction with each other.

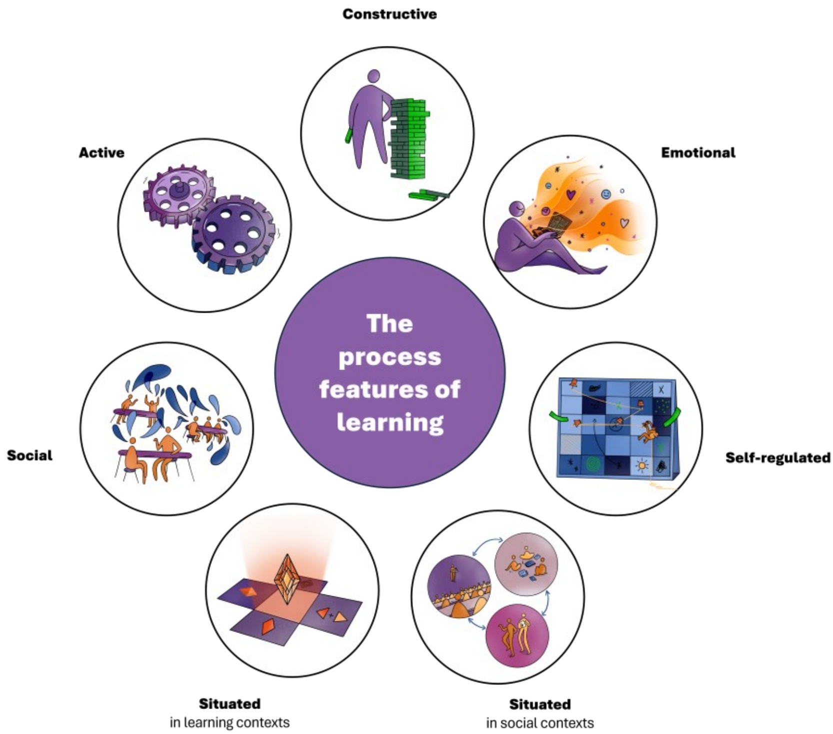

Fig. 1: The six process features of human learning

2.1 Active

Learning is an active process: receiving, interpreting, manipulating, relating, and storing new information cannot be accomplished by a passive recipient. Active learning, however, has become a variably interpreted umbrella term (Lombardi et al., 2021). The requirement for actively processing the learning content is often misunderstood as a requirement for (physical) activity during learning. For example, educators might be pleased that students are experimenting with different substances in the chemistry lab following the instruction, or that students are highlighting phrases in a textbook. However, overt behavior cannot be equated with covert behavior (see Thurn et al., 2023). We thus prefer to use the term *cognitive* activation, which means that the students process the learning content more deeply to build conceptual understanding (see Fauth & Leuders, 2018). This can be supported by cognitively activating instruction methods (Schumacher & Stern, 2023), such as self-explanation prompts or comparing and contrasting activities. As cognitive activation is a latent, unobservable construct, the visualization of 'active' in Figure 1 employs the cogwheel icon, which is often used to represent thinking.

2.2 Constructive

To make sense of new knowledge, one needs to relate it to existing knowledge (Driver et al., 1994). For example, try to remember the following words: 'Yachanim mana yachasqayta'. Unless you are one of the 7 million people in the Andes speaking Quechua, these words will probably not be easy to remember. In contrast, it will be easier to remember the preceding sentence ("Unless …"), because it matches your English vocabulary and you can relate its meaning to your prior knowledge stored in long-term memory (e.g., that the Andes are the longest continental mountain range in the world).

Concepts in long-term memory are relational, that is, they refer to each other and are linked to each other (cf. Goldwater & Schalk 2016). These relations can be conceptualized as links between knowledge elements in a network. Such knowledge networks change during instruction (e.g., Thurn et al., 2020), as our brain relates new information to already-known knowledge elements in the network. Many teachers, however, still follow so-called transmissive beliefs (Trautwein, 2013), in which knowledge is assumed to be directly transferred from teacher to students. Instead, students need to construct their knowledge themselves, and teachers are best suited to monitor this process.

Another implication of constructive learning is that each student interprets new information differently, based on their (individual) knowledge network. However, these "private universes" do not imply that students' conceptions are entirely unique or idiosyncratic. In fact, it is possible to identify and cluster students' conceptions toward topics (see decoding the disciplines, e.g., McBrady, 2022).

A common challenge in teaching is that the content to be learned is at odds with learners' prior conceptions (diSessa & Sherin, 1998; Thurn, 2024; Vosniadou, 2013). An important aspect of teaching is therefore the assessment of students' prior knowledge, e.g., by means of formative assessment techniques (Black & Wiliam, 2009; Sippel, 2011). To illustrate the constructive nature of learning, the visualization in Figure 1 refers to building blocks, where lower blocks form the basis for adding higher ones, but some structures can also be destructed and changed during the building process.

2.3 Emotional

Emotions can influence learning processes, as some learning contents (such as the climate crisis, vaccinations, or social issues) will likely evoke strong emotional reactions (Thurn, 2024). Whereas positive emotions such as enjoyment can foster learning (Camacho-Morles et al., 2021), negative emotions such as anger, anxiety, and boredom may impede learning (Pekrun et al., 2002).

The influence of emotions on learning is intertwined with motivation: Emotion and motivation "both seem to result from an appraisal of the situation, and both energize or de-energize certain behaviors" (Vu et al., 2021, p. 43). The relation between motivation and achievement is reciprocal (Gardiner, 2011; Vu et al., 2022), meaning that higher achievement leads to greater motivation, which in turn leads to higher achievement, etc. In teaching, motivation for a certain topic can be elicited by questions such as "Why is this interesting and relevant? What is it useful for?".

The visualization of 'emotional' in Figure 1 refers to a constant stream of emotional and motivational events that arises from the learner when interacting with the learning material. This process feature, however, is less tangible and elaborated in Reinmann-Rothmeier & Mandl's work, and even though they introduced it in 2001, in some later publications they only mentioned the other five process features (e.g., Mandl & Krause, 2003).

2.4 Self-regulated

Students who learn in a self-regulated manner achieve better learning outcomes (Theobald, 2021). What do students need to self-regulate? They must set goals, plan how to achieve them, monitor their progress, and evaluate the outcomes (Zepeda et al., 2015). These steps fall under the concept of metacognition (i.e., attending to and analyzing one's own thought processes). The visualization of 'self-regulated' in Figure 1 refers to agendas and planning wherein the learner as a metaphorical climber can see the different tasks and goals, observe their position in relation to them, and decide on the route to take.

Clearly, in formal instruction, some boundary conditions are given and cannot be freely chosen by the students. However, the instructor can provide scaffolding and guidance to the students to enable self-regulated learning. This entails communicating the learning goals, assessing students' learning progression, and giving constructive feedback to the students. To increase self-regulation in higher education, one could for example let students decide on a topic on which to write about, such as a blog post about gender effects (e.g., Berkowitz et al., 2022).

2.5 Situated

The concept of situated learning suggests that learning is influenced by the context in which it occurs (e.g., Stark, 2003). It is a common adage that learning at university is too theoretical, and students frequently express a preference for learning more about applications. Such a preference, however, would be ultimately misguided. Theory is an indispensable component of scientific discourse, as theories, and not the applications, provide a framework for understanding and explaining phenomena.

An important challenge is to address the discrepancy between having theoretical knowledge and being able to apply it. For example, merely acquiring the knowledge that $f = m*a$ (the theory) is insufficient for human brains to process its meaning and applying the knowledge. The "abstract characterization of concepts misses the reality of their grounding in multiple experiential intuitions" (Amin, 2009, p. 192). Human learning is grounded in experiences, and embodied (i.e., shaped by and inseparable from our physical bodies and sensory experiences). Students are thus often unable to grasp concepts that fall outside the scope of their everyday experiences without appropriate analogies that connect abstract concepts to their experiences and embodied understanding (Niebert & Gropengiesser, 2018). Besides a right way of abstraction, the brain requires a multitude of examples to facilitate comprehension of the underlying pattern.

Thus, theories need to be embedded in contexts with variations at two dimensions to enable successful transfer: the learning context and the social situation (e.g., Engle et al., 2012). The learning context relates to the examples, the problems, or the cover-stories which are discussed. The social context relates to the "who, when, where, how, and why of a learning or transfer situation" (Engle et al., 2012, p. 216). For situated learning, we thus created two visualizations (see Figure 1): the visualization for the learning context depicts a multifaceted rhombus with underlying illustrations that highlight different perspectives, e.g. two-dimensional, three-dimensional, or additive. This relates to the embedding of a concept in multiple learning examples, that can shed light on different aspects of the concept. The visualization for the social context depicts three different social situations in which a concept can be activated.

To capitalize on situated learning and enable transfer, it can help to use concreteness fading (Kokkonen & Schalk, 2021). Concreteness fading involves embedding concepts in multiple examples following a sequence from concrete to abstract contexts. This technique supports learners comprehending the underlying concepts by distilling them from the examples. Problem-based learning activities are also an effective method for supporting students in acquiring concepts (e.g., Thurn et al., forthcoming), when the problems are embedded in multiple contexts.

2.6 Social

As each learner constructs their own understanding, it becomes important to exchange these understandings through social interaction and discussion. Students may compare their individual interpretations, which could facilitate a more nuanced and comprehensive understanding of the subject matter. Research typically distinguishes between teacher-student interaction and student-student interactions. Prompting by an instructor can thus already constitute social learning, albeit likely of a lesser degree than students working as a group. The visualization of 'social' in Figure 1 therefore refers to the exchange between people. However, social interaction alone is neither sufficient nor conducive for meaningful learning (see Thurn et al., 2023). In collaborative learning, students exhibit knowledge interdependence (Deiglmayr & Schalk, 2015). For example, when completing a jigsaw method on stochastics and urn models, students rely on their co-students' understanding and ability to explain the expert group's urn model adequately. Thus, reducing the knowledge interdependence by providing all urn models embedded in different contexts by group can provide all learners with an equal opportunity to learn (Deiglmayr & Schalk, 2015).

2.7 Coordinating the process features

To relate the process features to each other, we first categorize them according to an internal-external perspective. Whereas social and situated process features concern external factors (e.g., information from the environment that is embedded in a context or listening to a discussion with peers), the features emotional, active, constructive, and self-regulated concern internal factors.

On this line, the features interact with each other: As the brain identifies and interprets new information based on prior experience (i.e., constructive), it is helpful to activate prior knowledge. Deeper mental processing (i.e., cognitive activation) requires strong self-regulation from the students. A motivated student, who experiences positive emotions, is likely to self-regulate with greater success. The other way around, motivation can stem from autonomy, which can be experienced in self-regulated learning opportunities, from competence, and from relatedness (self-determination theory, Deci & Ryan, 2012), which is facilitated through social learning.

3 Implementing the six process features in teacher-education—Didactic tools

In the teacher education programme at ETH Zürich, we are faced with the challenge of teaching educational and psychological foundations of learning in a relatively limited amount of time (15 ECTS, i.e., 375–450 hours are allocated to it). See Greutmann et al. (2020) for an overview of the topics covered in the teacher-education programme at ETH.

We thus make the six process features a central part in our teacher education programme, embedding and referring to them in multiple courses so that our students can create meaningful connections. However, our students sometimes have difficulties in understanding the features and in transferring them to the classroom. We therefore designed materials to support our students' learning progress in a sustainable way. These materials target science-practice communication and can be used for instructors across institutions and fields. They comprise visualizations, posters, and a heuristic self-assessment tool, which we describe in the following.

As discussed in Section 2, Figure 1 shows the visualizations of the six process features of learning. The internet and the resulting faster exchange of information creates a need for more visual communication (Vaillant & Castaing, 2003). As expressed by the theory of multimedia-learning, the combination of text and images is conducive to learning (Mayer, 2009). Visual information can be conveyed efficiently in the form of recognizable icons. In the absence of a precise convention for depicting the process features of learning, we chose to use visualizations of iconified images (e.g., the cogwheel). These visualizations provide an alternative mode of representing and connecting ideas, in addition to the verbal explanations in the paper, thereby leveraging the potential of multimodal learning.

We created the visualizations together with a team of educational media developers at ETH Zürich. The visualizations are open educational resources (OER) licensed under a CC-BY license, so any instructor around the world can use them in their work and teaching at no financial cost. Additionally, we have designed posters in both landscape and portrait formats, featuring the visualizations, for display in university corridors or lectures. The resources are available at:

http://hdl.handle.net/20.500.11850/714349.

To enable students to establish a connection between the visualizations and the respective concepts, we embed the visualizations when discussing the process features in our courses. Furthermore, we supplement the discussion of empirical studies with them, so that students can rapidly ascertain which process feature(s) the studies relate to.

When we prompt our students to reflect on the extent to which a specific method fulfills the process features, they often answer “not at all” or “very much”. However, the extent to which a method fulfills the process features is not a dichotomous decision but a continuous one. To reflect about this continuous extent, a group of students came up with the idea to use a radar chart as a heuristic tool, which we present here. Radar charts are an effective tool for self-assessment and a method to minimize dichotomous thinking. They are therefore frequently used in evaluation research and organizational development, but also in higher education (Kaczynski et al., 2008; Lübke et al., 2017).

The radar charts support lecturers to self-assess their teaching method(s). Self-assessment can improve teaching and self-efficacy for three reasons (e.g., Ross & Bruce, 2007): Assessment helps in defining the target concept and facilitates communicating about it. It also helps in selecting those domains where one wants to install change. Finally, self-assessment helps setting clear goals. The radar chart thus can help lecturers through visualizing which process features are currently prevalent in their teaching and in selecting goals for how the process features should be distributed across various instruction techniques.

To provide an example, consider the following instructional sequence related to sustainability and climate change: At first, the lecturer asks their students to individually reflect on the question "How many countries are currently on track to meet their 1.5-degree goal?" and to answer it individually via an online tool. Then the lecturer shows them the answer (no country) and asks them to discuss their reactions with their neighbors. This instructional sequence corresponds to the idea of peer instruction (Mazur, 1997). Figure 2 depicts the radar chart profile for this instruction. The blue line represents the range of extent for the process features. We chose a rather thick line, as the tool should serve as heuristic, not as an exact measure. The activity activates prior knowledge and lets the students process the concepts of the 1.5-degree goal and respective measures that mitigate climate change. The activity is constructive in that the students can retrieve relevant prior knowledge, especially as they are likely to be confronted with an unexpected answer. Furthermore, this topic will probably elicit emotions. As the lecturer asks about a worldwide phenomenon, the question is general, but students might think of specific examples of countries, wherefore the instruction is partly situated. In terms of self-regulated learning, the instruction does not leave a lot of room for the students to select and monitor the process. The social feature is integrated through the exchange with the neighbor but could be increased by further prompts encouraging discussion.

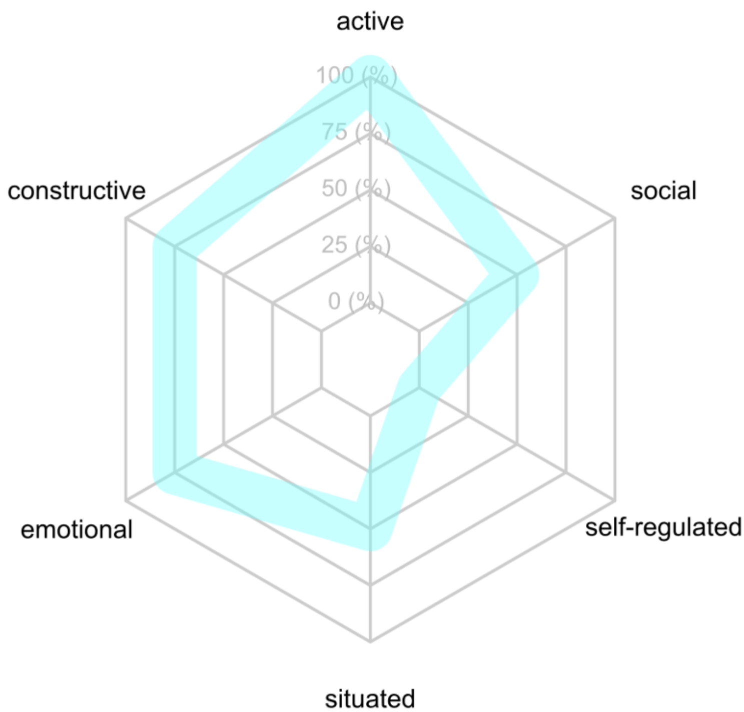

Fig. 2: Radar chart for assessing the profile of an instructional method

To try out this heuristic didactical self-assessment tool yourselves, we would like to encourage you to think about an instructional method that you use in your classroom, and to assess its profile by using the radar chart depicted in Figure 3:

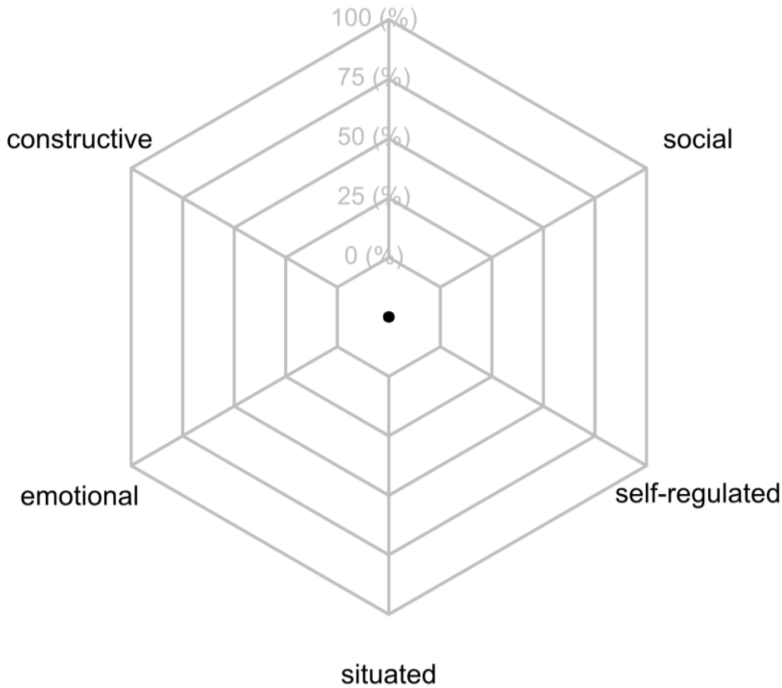

Fig. 3: Assess the profile of your instructional method

4 Research desiderata

The compendium of the six process features does not lay a claim to be complete, but notably, it is often possible to classify stories from learning biographies, findings from educational psychological studies, and theories under these six features. For example, studies show that asking students questions such as “what is the biggest moon of Saturn?” before instructing them about the moons of Saturn not only leads to better performance on this specific question, but also on other questions on the topic (Little & Bjork, 2016). This phenomenon is known as pretesting (Pan & Carpenter, 2023). Using the six process features, pretesting activates prior knowledge, such as knowledge about planets and moons, prompts metacognitive awareness by highlighting gaps in knowledge (which is conducive to self-regulation), and triggers curiosity and thereby motivation. Together with the example on the 1.5-degree goal discussed in the previous section, this example of classifying research observations according to the six process features demonstrates the application of this framework. The features strike a balance between breadth and specificity: they are broad enough to capture key aspects of human learning, yet distinct enough that they form separate categories.

Finally, as psychological and educational research can be said to be in a theory crisis (e.g. Mutukrishna & Henrich, 2019), we strongly advise that future research on the field of human learning prioritizes formulating a cumulative theory of human learning. Successful learning encompasses more than the abovementioned features, such as motivation (Schneider & Preckel, 2017), socioeconomic status (Schneider & Preckel, 2017), and the interplay of knowledge and intelligence (Thurn et al., 2022). The six process features will thus not lead to a complete understanding of human learning in its broadness and variety[3]. They can, however, help identifying factors that should be considered in a cumulative theory. Insofar, the six process features represent a promising starting point.

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