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Conceptual approach to problem-oriented teaching in the subject sciences

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Abstract

In order to increase the coherence between the specialist sciences and the relevant vocational didactics, this article presents the first cycle of a design-based research approach in which a lecture series on building physics was conceptually reorganized in such a way that the relevance of the lecture content becomes clearer to students. A key aspect of this is problem orientation, in which the phases of the problem-solving process are made transparent to students and the content to be considered is categorized and made explicit. The analyses of the lecture materials show that the cognitive activation potential was significantly increased by the problem orientation. However, the increased number of slides is problematic. It is therefore necessary to decide which lecture content can be dispensed with or made accessible to students in another form.

Zur Erhöhung der Kohärenz zwischen den Fachwissenschaften und den einschlägigen Berufsdidaktiken wird im vorliegenden Beitrag der erste Zyklus eines Design-based Research-Ansatzes vorgestellt, bei dem eine Vorlesungsreihe zur Bauphysik konzeptionell so umgestellt wurde, dass Studierenden die Relevanz der Vorlesungsinhalte deutlicher wird. Ein wesentlicher Aspekt ist dabei die Problemorientierung, bei der Studierenden die Phasen des Problemlöseprozesses transparent und die dabei zu durchdenkenden Inhalte eingeordnet und expliziert werden. Die Analysen der Vorlesungsmaterialien zeigen, dass das kognitive Aktivierungspotenzial durch den Problembezug deutlich erhöht wurde. Problematisch ist allerdings die erhöhte Anzahl der Folien. Daher ist zu entscheiden, welche Vorlesungsinhalte verzichtbar bzw. in anderer Form Studierenden zugänglich gemacht werden können.

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1. Problem background

In many engineering degree programs and vocational and general education teacher training programs, students are faced with the challenge of having to deal with abstract technical and scientific contexts. The fact that this content is often taught in undergraduate courses without any reference to later professional activity makes it difficult for students to deal with the content [1]. For teacher training students, there is also little or no coherence between the engineering and natural sciences and the educational sciences. This inhibits the development and use of specialist knowledge. The lack of reference to later professional activities is seen as a reason for students dropping out in the first semesters [2].

As part of the Quality Campaign for Teacher Education (QLB), sub-project 3 of the TUD-SYLBER BBS project, approaches are therefore being developed to analyze and improve the coherence of content between subject-specific sciences and subject-specific didactics. These approaches are based on the assumption that problem-oriented teaching makes the links between the content clear both within a course and across disciplines and courses [3]. In terms of research methodology, the design-based research approach (see Fig. 1) is followed.

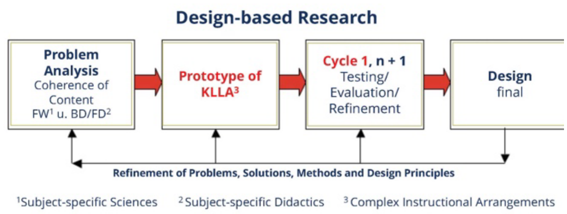


Fig. 1: Design-based research approach for the development and evaluation of complex instructional arrangements (KLLA); own illustration based on Reeves (2006) [4].

To this end, lectures in building physics and physical chemistry were observed and analyzed according to the chosen structure of the content. The results of the current state analysis showed that the lectures and the associated scripts tend to follow a subject-systematic sorting of the content, whose significance for the world of work and life is often subordinated [5]. However, teaching approaches are more cognitively activating if they place the problem at the beginning and derive learning steps logically from this in order to motivate students and set goals [6]. The less problem-oriented the content is in subject-specific courses, the more challenging it is for students to gain an in-depth understanding of the issues addressed in the course. A stronger practical orientation may also increase students' motivation to learn.

The question is to what extent it is possible for the subject sciences to restructure their content for a more problem-oriented teaching approach.

2. First cycle of problem-oriented teaching of building physics

The aim is to make the courses in the specialist sciences more problem-oriented. To this end, lectures in building physics were observed in two consecutive winter semesters (2021/22 and 2022/23) and regularly evaluated with the lecturer. In addition, working meetings were held at which professional and didactic approaches for a stronger problem orientation were presented. On this basis, the lecture content in building physics was restructured for winter semester 2022/23. For this purpose, a renovation project of a villa was placed at the center, which was suitable for sorting the lecture content along the renovation requirements of the villa.

Fig. 2 shows the number of slides that refer to the villa for the respective topics in building physics. A central problem in the renovation of the villa is the formation of mold on the walls, which must be remedied. To this end, the causes must be identified in order to derive appropriate measures for remedying the damage. Fig. 3 shows the relationships to be discussed in abbreviated form in a concept map.

One factor that promotes mold growth is moisture on the surface of the building component. This in turn is caused by condensation water, which forms on the surface of the building component when the temperature falls below the limit temperature. On the construction side, falling below the limit temperature can be prevented by thermal insulation measures. In order to select suitable measures, the conditions of the outdoor and indoor climate must be taken into account.

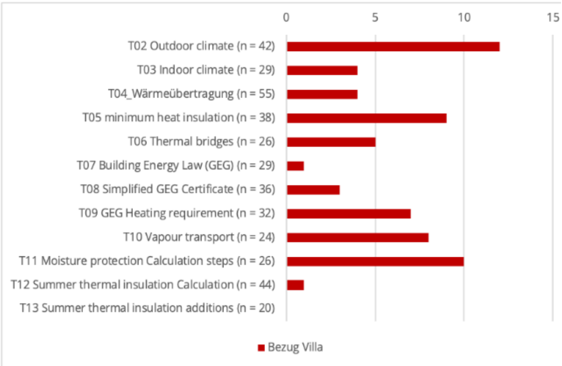


Fig. 2: Number of lecture slides with problem reference Villa in winter semester 2022/23 [2]

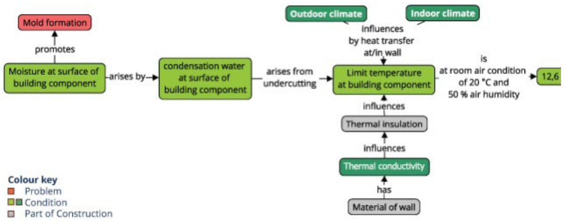
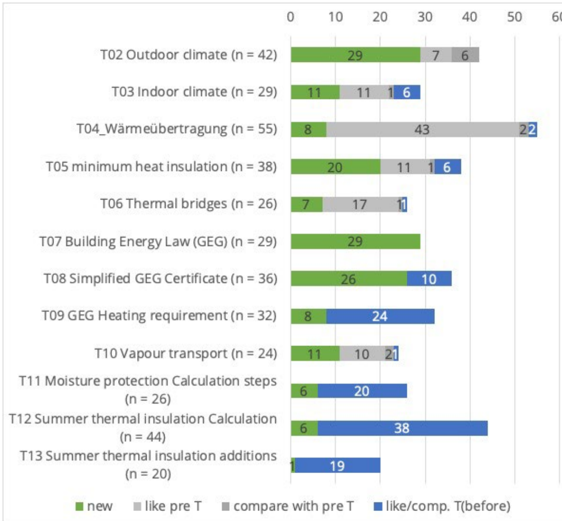


Fig. 3: Concept map of the logical relationships of mold growth in buildings [3]

3. First results of the evaluation

A total of 718 lecture slides were analyzed in the pre-post comparison of the winter semesters mentioned (n(pre) = 317; n(post) = 401). The problem reference to the villa led to the creation of new slides (n = 162), all other slides from winter semester 2022/23 (n = 239) were taken from the previous semester (*as pre T*), partly adapted (*cf. m. pre T*, see Fig. 4). Even if slides from winter semester 2021/22 were not adopted, the total number of slides in winter semester 2022/23 increased significantly (n = 84). It is noticeable that as the topics progress, reference is made to slides from previous topics (*like/comp. T(before)*; see Fig. 4).

In the newly designed slides, aspects relating to the villa in particular have been illustrated. In the revised slides (*cf. with pre T* and *T(previously)*, see Fig. 4), headings were optimized and formulas were supplemented with corresponding illustrations. In some cases, logical breaks were identified in the sequence of the sub-goals associated with the problem.



Legend: T = Topic

Fig. 4: Number of unmodified to slightly modified slides for the building physics lecture in a pre-post comparison [3]

4. Conclusion and outlook

The contents to be worked on in the lecture were well contextualized by the problem reference to the villa. In connection with this, subgoals for solving the problem were formulated (mostly in the form of questions). In winter semester 2022/23, significantly more reference was made to the content of previous lectures than in winter semester 2021/22, so that the lecture topics were better related to each other. Qualitative correlations were better illustrated with figures.

From these findings, it can be concluded that the cognitive activation potential of the lecture topics was significantly increased by the reference to the problem. The increased number of slides that could not be fully covered in the respective lectures is problematic. Therefore, for the second cycle, revision proposals are to be developed as to which lecture content can be dispensed with or made accessible to students in a different form. The contents of the lecture are to be analyzed according to the given subobjectives/learning tasks, the (non-) recurring aspects and routine aspects in order to derive which changes to the sequence of sub-objectives/learning tasks are necessary and which forms of learning support are suitable and possible for the respective sub-objectives/learning tasks. The basis for this revision is the 4C/ID model. This model describes an instructional design that consists of four components: learning tasks, supporting information, procedural information and exercises [7].

- Learning tasks are derived from the subgoals.
- Supporting information refers to the non-recurring aspects of a learning task so that it can be successfully completed by explaining to learners how a *domain* is structured and how to approach the problem solving of a domain. In this way, the process of schema formation is supported so that students can process the new information/learning content more deeply.
- Procedural information specifies how routine aspects of the learning task are to be implemented, preferably in the form of direct, step-by-step instructions.
- Exercises are used to automate recurring aspects of a learning task.

Sorting lecture content according to these four aspects also has implications for the way content is provided in digital formats, which have become particularly important during and after the pandemic. The decisive factor is how sub-objectives/learning tasks are linked to the information required (for processing). With the current version of the lecture slides and the accompanying script, the necessary material basis for a conversion of the content according to the 4C/ID model has already been created.

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