Instructional Design of Conceptual Online Physics Instruction Modules - Bridging the Gap between Instruction and Problem Solving

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Abstract. Physics education research (PER) delivered evidence that traditional instruction and traditional problems are too inefficient regarding the development of students' conceptual understanding in on-campus undergraduate calculus-based experimental physics courses. Simply copying parts for distance education (e. g. video-recorded live lecture) is therefore not the best option.

Based on PER about conceptions/misconceptions we develop and test Conceptual Online Physics Instruction Modules (COPhIMs), which consist of a theoretical and two self-assessment parts (one with experiments). The self-assessment parts build a "smooth" transition between instruction and problem solving and the whole modules should increase students' prior conceptual knowledge for successful problem solving.

1 Theoretical background

Research has shown that students in on-campus undergraduate calculus-based experimental physics courses do not develop a sufficient understanding of concepts when lectures are taught in the traditional format and moreover when in the separated weekly recitation sessions only traditional quantitative problems are used. The majority of students do not acquire enough conceptual knowledge from textbook- and content-based lectures for successful and effective problem solving [1-4].

With regard to cognitive load theory [5,6] it is necessary to emphasize more on scaffolding conceptual learning [7] before problem solving to overcome the described conceptual gap between instruction and problem solving: Timely conceptual instruction guides students better in the construction of schemes and development from novices to experts, because they have the opportunity to deal with the same concepts twice - during instruction and problem solving. More prior conceptual knowledge before problem solving reduce indirectly the intrinsic cognitive load, because it can be applied to develop a sufficient problem representation. The risk to use means-ends analysis is reduced, because students are not overburden to recognize relevant concepts for solving a problem. Therefore we develop COPhIMs for direct instruction of conceptual knowledge in distance learning or hybrid presence learning.

2 Instructional design of Conceptual Online Instruction Modules

COPhIMs deal with one theme (e. g. dynamics of rigid bodies) and are structured by subthemes (e. g. properties of rigid bodies) of the theme´s central law/principle (e. g. Newton´s law for rotating bodies) to foster the application of central laws/principles during problem solving (Fig. 1). The parts "Theory", "Exercise" and "Experiment" of a module comprise well-known conceptions/misconceptions from PER literature (e. g. [8]).

Stronger guided instruction of quantitative theoretical information (handwritten formulas, hand drawn sketches on a whiteboard and instructors voice in synchronous mode) in "Theory" is combined with less guided qualitative tasks in "Exercise" and "Experiment" [9,10]. In "Exercise" formative self-assessment tasks are directly related to the subthemes in "Theory" and cover in

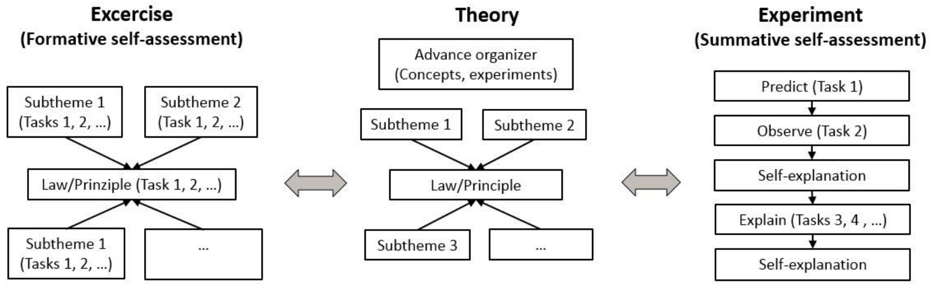

Fig. 1 Instructional Design of COPhIMs

small steps a wide range of level of difficulty (definitions, terms, laws, concepts). Experiments in "Experiment" (e. g. Maxwell´s wheel) acquire for their understanding the simultaneously application of several concepts and use the predict-observe-explain principle [11] combined with self-explanations for summative self-assessment. When students perform tasks they can request a conceptual feedback about the correctness of their answer together with an explanation why the answer is correct or false.

The modules are implemented in HTML5 and JavaScript without additional requirement of a video player or applet and are running on browsers of every end device.

3 Prototyping and study design

A pilot study (7 presence students in third term, no prior knowledge about challenging theme "motion of variable mass bodies") with a prototype of COPhIMs (live lecture with emphasize on concepts, conceptual tasks about theory and experiments) and subsequent solving of problems were conducted in 2017. An identical concept test before and after the lecture and after problem solving yields that the students test result increased from 0,51 ± 0,21 before the lecture, 0,71 ± 0,17 after the lecture to 0,77 ± 0,19 after problem solving.

We present the COPhIM "Dynamics of rigid bodies" together with test results of a study in distance education with a similar study design. Additionally, during students had access to the module, we tracked their activities on click level to gain insight how they interact with parts of the module. This allows also to correlate the amount of activities with test results.

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