Facilitating Knowledge Acquisition in Remote Labs: Levels of Inquiry and Types of Information

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Abstract. Discovery and inquiry learning are ideal approaches to foster experimental skills as well as knowledge acquisition by remote experimentation. However, since students have to self-regulate their learning process and the success of self-regulated learning is highly dependent on prior knowledge, learners usually need additional information, e.g. about the experimental setup. When and how should this information be presented? Under what conditions can students independently acquire knowledge in a remote lab? Results show that a) a setting of inquiry-based learning in which students develop both the solution and the approach itself (Guided Inquiry) is most appropriate for ninth-graders, and b) that information that describes the structural characteristics of a system is less supportive than information that links entities with each other.

1 Introduction and Theory

Spectroscopy is a central topic that also opens excellent starting points for inquiry and discovery learning in various facets. The design of the information offered on the experimental fundamentals and the possible ways of working is an important factor for effective learning processes and should be examined more closely in this paper after a brief theoretical outline.

Since Bohr discovered the relationship between optical spectra and the structure of atoms, spectrometry has served an important role in physics and chemistry. The analysis of spectra is a fundamental component for the understanding of wave optics and colour perception. Every student should have the opportunity to conduct his or her own optical emission experiments. Since spectrometers are expensive and require accurate calibration to obtain high quality spectra, we developed a remote lab for optical spectrometry [1].

Banchi and Bell describe four levels of inquiry in activities, which are each increasingly open-ended and less reliant on predefined structure [2]. On the first level, *Confirmation Inquiry*, students confirm a principle through an activity when the results are known in advance. During *Structured Inquiry* students investigate a teacher-presented question through a prescribed procedure. The third level, *Guided Inquiry*, means that students investigate a teacher-presented question using student designed or student selected procedures. On the highest level, *Open Inquiry,* students investigate questions that are student formulated through student designed or student selected procedures.

Since the topics to be examined are new to the students, they require additional information about the basics (e.g. about the experimental setup). Thus, the question arises, which information should be offered and when? And how should it be presented? To clarify the question of how the information should be offered, the instructional material was varied according to three types of presentations of information. *Structural-attributive* information describes the structure of a system and disregards the meaning of the information for the recipient. From a student perspective, structural-attributive information helps to *orient*, e.g. when working with a complex experimental setup. *Functional-cybernetic* information conveys the function of individual parts of a system and thus incorporates the semantic meaning for the recipient. In addition, functional cybernetic information is intended to help students *link* individual aspects, e.g. how the individual elements of a test setup interact with each other. *Pragmatic* information is to be understood here in the manner represented by Morris as information that contains an implicit instruction for the recipient [3]. This should encourage students to *act*, that is, to take up work.

2 Methods

In this study, we utilize differential item functioning analysis to conduct a study of knowledge acquisition during inquiry-based learning [4]. The experiment used a 3 (inquiry level: confirmation vs. structured vs. guided) × 3 (information type: structural-attributive vs. functional-cybernetic vs. pragmatic) between-subjects design in which participants introduced themselves to atomic physics in an online learning environment in which they conduct experiments on optical spectrometry. Participants were 279 students in the 9th grade from 10 German high schools. The average age was 14.6 years (SD = 0.70, 56.6% female). The participants were randomly assigned to one of the nine treatments and worked 90 minutes with the learning environment.

The analyses are aimed at determining significant predictors of knowledge acquisition following the conceptual framework. The primary data source for the study is a 67-item single-select multiple-choice test with one key and four distractors on each item. Additionally, prior course work scores and individual covariates were matched to the survey data to create a more comprehensive database to permit multi-level analysis of knowledge acquisition. The instructional material was designed as an online learning environment.

3 Results

The answers to the knowledge test were analyzed on differntial item functioning based on a logistic model using the R package DIFtree [5]. The factor levels of the two factors were dummy coded and included as covariates in the model. Eleven items show a differential item functioning. For subjects which have been learned with Confirmation Inquiry, one item is significantly more difficult, for subjects with Structured Inquiry another item. Moreover, five more items are much easier for subjects which have received Guided Inquiry variants. Other items are more difficult with structural-attributive and pragmatic information presentation.

4 Conclusion

The online learning environment used in this study allows for an adaptive choice of the best learning path for each indiviudal student. It would be conceivable, e.g. to choose the degree to which a subject is introduced based on the student’s motivation or to adapt the information presentation type to prior knowledge. However, for ninth-grade students, under all circumstances, a setting of inquiry-based learning in which students develop both the solution and the approach itself (Guided Inquiry) is most appropriate.

References

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