From Science to School - Educational Transfer Research of Modern Science Topics in the Interplay of Curriculum Development and Empirical Research

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Abstract

At the Friedrich Schiller University Jena, as at many other universities in Germany, measures for professionalization in teacher's training have been promoted since 2015 as part of the "Qualitätsoffensive Lehrerbildung". The goal is to develop a coherent education program for teachers. Furthermore, collaboration between all players in teacher's education is intended through both cross-phase and intra-phase cooperation. A closer connection between subject and subject education is particularly important for development of modern science teaching. Within the project Learning-to-Teach Lab: Science (LTL:S), a structure will be established which translates scientific innovations into school reality through educational transfer supported by empirical research [1]. Following the presentation of the underlying project structure the development process of curriculum innovation will be shown by applying it to the topic "self-healing materials". With the help of experimental implementations school-based approaches are presented. To investigate the use of such curricular innovations, an empirical research design was developed based on the topic "drugs as a context of chemistry teaching" and put into test in fall 2020. For this purpose, a standardized observation protocol was designed which documents the way in which students deal with the topic. The article will focus on the development of the research instrument and the different steps of the observer's training. Finally, the project's previous work will be systematized regarding digital learning communities.

Keywords: *coherent teacher education, observational study, self-healing materials, professional learning communities*

1. Coherence in Teacher Education

The demand for stronger networking in teacher education, both within and across teacher education phases, has been at the center of subject education discussions for several years. Since 2015, numerous project initiatives have been founded throughout Germany within the framework of the "Qualitätsoffensive Lehrerbildung" (QLB), in which a contribution is made to the promotion of teacher professionalization through greater coherence in teacher education [2]. The concept of coherence in teacher education presents itself as a multifaceted network of numerous content-related and structure-giving measures [3]. On the conceptual side, a distinction can be made between vertical and horizontal coherence. Horizontal coherence goes hand in hand with intra-phase networking, for example when courses are jointly designed by subject and subject education. The development of a deep structure within a discipline, for example through the application of theoretical knowledge in practical situations, can be described as vertical coherence. Furthermore, networking on a temporal level is divided into synchronous and consecutive networking. Synchronous coherence is present when, for example, pre-concepts are discussed in the subject education and the constructivist foundations are discussed at the same time in the educational sciences. The construction of a spiral curriculum (cumulative learning) or also the interweaving of the respective phases of teacher education (cross-phase cooperation) can be interpreted consecutively, i.e. chronologically. Eventually, relevant subject specifics (e.g. the methods for gaining knowledge in the natural sciences) or holistic educational concepts (e.g. education for sustainable development, inclusion) can also be integrated into the discussion on coherent teacher education.

2. Self-Healing Materials – an example for Curriculum Innovation

The guiding principle of subject-subject education linkage, which is currently discussed in the subject education landscape, is accompanied by the demand for more modern science teaching. In order to develop new subject content for science teaching, current research work must be reviewed, elementarized to the fundamental contexts of meaning and implementation strategies for teaching derived. Within teacher education phase, this results in the necessity of cooperation between subject scientists and subject education experts. Within the framework of such cooperation with the Institute of Organic and Macromolecular Chemistry, the topic of "self-healing materials" was developed in student seminars in the summer term of 2020. After an introductory and educationally reduced lecture, small groups worked on partial aspects of this topic. These included self-healing in nature, self-healing polymers and self-healing concrete and asphalt. For each aspect, initial educational structuring was developed and, under the guideline of educational reduction, fundamental principles were focused on, technical terms reduced and corresponding simplifications integrated. The first results are presented here.

2.1 Self-healing polyurethane-based films

Self-healing films have been marketed for some years as paint protection for automobiles or coating for mobile phone displays. Their self-healing function is based on a network of strong covalent bonds and weaker hydrogen bonds [4]. In simple experiments, the self-healing of such films can be investigated in an everyday context and used as a motivating introduction to the topic.

2.2 Model experiment of a self-healing asphalt

Self-healing asphalt is based on a composite of bitumen and steel wool. By means of inductive heating, fine cracks in the asphalt can thus be healed by melted bitumen [5]. In a model experiment (Fig.1), a mixture of candle wax and graphite flakes is used. In an electromagnetic alternating field (microwave), the mixture begins to melt, so that cracks are healed. As a comparison, it can be shown that pure wax does not melt in the microwave.

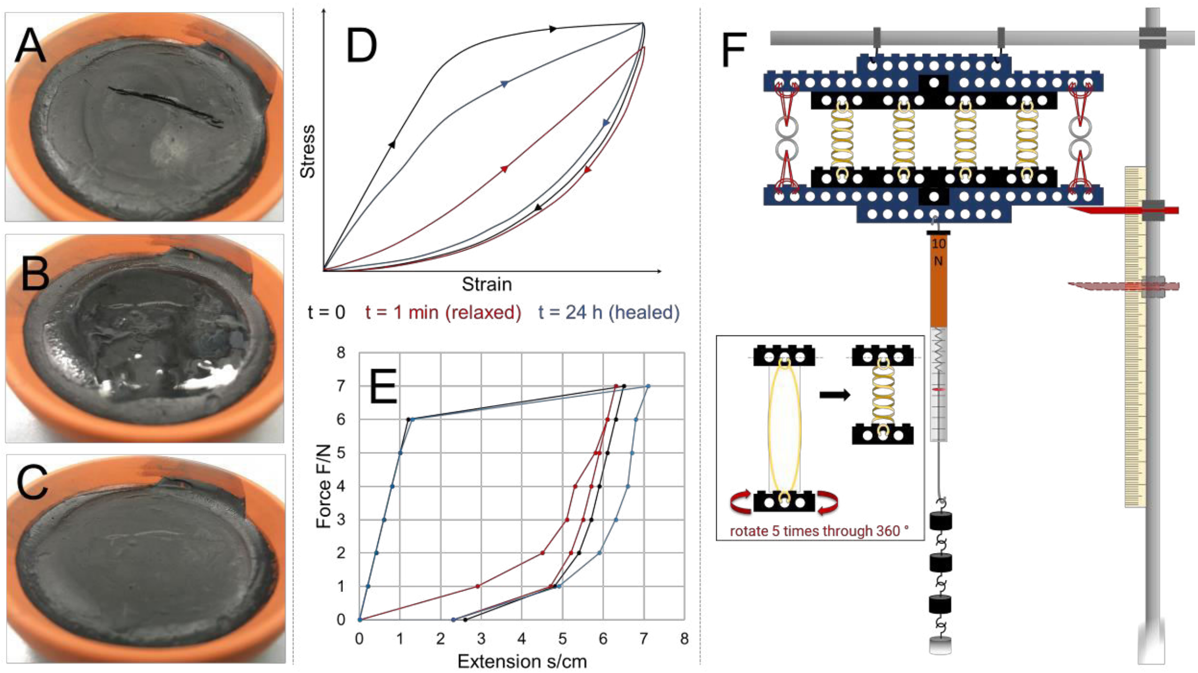

Fig.1. Experimental approaches to the topic of self-healing materials. ABC: Model experiment on self-healing asphalt after damage (A), after 10 s microwaving (B) and after curing (C). DEF: Model experiment on the self-healing of the adhesive hair of the California mussel. Ideal stress-strain diagram after three cycles (D) [6], sketch of the model experiment created (F), tensile force-strain diagram for the model experiment after three cycles (E)

2.3 Model experiment on self-healing of shell hair

The adhesive hair of the California mussel shows a self-healing mechanism in stress-strain experiments, which is due to proteins with β-sheet structure and coordinative bonds between zinc ions and histidine-rich proteins [7]. When stretched beyond the elastic range, the coordinative bonds break at the yield point. The folded sheet structures are abruptly unfolded by the acting force. When stretched again, the curve is clearly flattened, as now only the β-sheet structures contribute to the modulus of elasticity. After some time, however, the coordinative bonds are formed again. This process was simulated in a model experiment (Fig.1) in which twisted rubber bands represent the β-sheet structures and further rubber bands with magnets represent the proteins with coordinative bonds.

3. The empirical research design based on the topic "drugs as a context of chemistry teaching"

Data collection for the intervention study was conducted with students at the age of 16 and 17 (grades 10 and 11). Questionnaires in a pre-post design are designed to collect feedback on interest and prior knowledge regarding the topic as well as acceptance of the program and the individual stations. Short-term program effects on content learning gains will be asked in an open response format in the post-test. The way in which the test persons work through the stations and which process-related competences can be observed will be documented by a trained team of observers. The focus was set on observing the processing of the stations in collaborative work forms. The design and content of the measuring instrument was based on work from the fields of chemistry didactics, pedagogy, psychology, and classroom research [8-10].

3.1 Training steps of the observer training

In order to generate reliable data and objective assessments, adequate observer training was designed (Fig. 2).

Fig. 2. Sequence of training steps for observer training

The goal was to explain the developed measurement instrument with associated rating manual to the observers. In order to become familiar with the method and to gain a feeling for the sensitivity of relevant behaviours, a video simulation was planned to determine observer agreement with the measurement instrument [11]. For verification, multiple simulation videos were double-coded by two independent observers. Cohen's Kappa (κ) was chosen as the measure of observer agreement. Specific values for interrater reliability were obtained, so that the instrument can be used for the upcoming main study.

3.2 The observation protocol of the main investigation

Four main categories are defined for the documentation (Fig. 3). Each main category is broken down into three observation foci, which are assessed by four evaluation scales. In addition, a column with comments and a field for special anomalies are provided. A rating manual contains feature descriptions and scale expressions. A trained team of observers codes the measurement instrument parallel to the intervention. The observers take the role of pure observers without interacting with the research field. To ensure a laboratory study with a continuous framework, each observer acts as an expert of an assigned station for the entire phase of the main investigation [12,13].

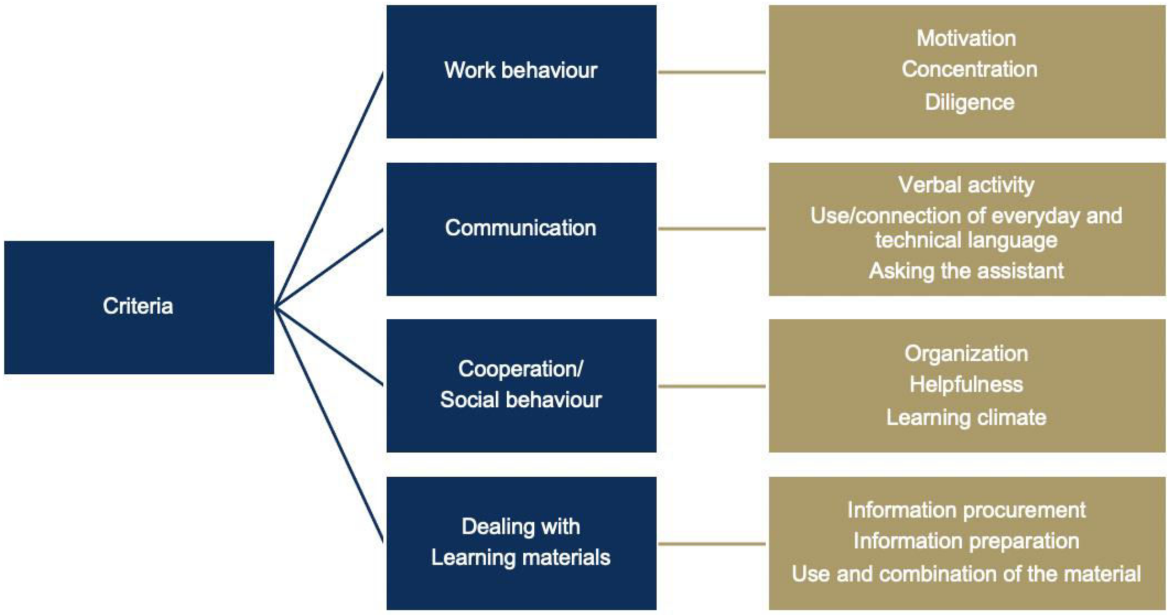

Fig. 3. Main- and subcategories of the observation protocol

4. Digital Learning Communities – a new Approach in Teacher Education?

In this article, a procedure was presented in which current subject content was developed for teaching at the interface of subject and subject education. It also showed an example of how such material developments can be evaluated and examined socio-empirically. Within the QLB, further modules were developed, tested and evaluated in chemistry education at the Friedrich Schiller University for a coherent teacher education. These include: Tandem teacher training (tandem of subject scientist and subject education expert), promotion of the professionalization process of prospective teachers through early practical experience as well as courses on inclusion, digitalization or interdisciplinary teaching as cross-cutting topics. To implement these curricular innovations, cross-phase cooperation between university and school is necessary. The project "Digitale Lerngemeinschaften zur kohärenten Lernbegleitung im Jenaer Modell der Lehrerbildung" (Digital Learning Communities for Coherent Learning Support in the Jena Model of Teacher Education) focuses on increased cooperation between teachers and the educational sciences and subject education experts of the university through digital learning formats. The cooperation of the involved actors ties in with the proven concept of professional learning communities as an effective cooperation structure for sustainable effects in school development [14]. All in all, these digital learning communities serve to translate subject education and pedagogical as well as curricular innovations into everyday school life.

5. References

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