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Context-based Science Education by Newspaper Story Problems and Other Authentic Learning Activities: a Research Program on Motivation and Learning Effects

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Abstract

Context-Based Science Education (CBSE) has a long-standing tradition and is considered as a highly promising approach in both current science education and educational psychology. Drawing on research in both areas, as well as on good practice reports from science classrooms, the present contribution reports on a research program on various forms of CBSE, ranging from paper-based to experimental approaches, such as learning tasks using newspapers (newspaper story problems, NSP) and Smartphone-based experiments. The goal is to improve both motivation, including perceived authenticity, and learning, including transfer.

For NSP and a closely related approach (advertisement story problems, ASP), several studies were carried out in a quasi-experimental repeated measures design, for several essential concepts of physics (velocity, temperature and heat, energy) and within a broad sample (N > 1600) of pupils of various ages and academic backgrounds. The results for NSP, when comparing treatment with control classes (with conventional exercises, but otherwise the same lesson plan, and the same teacher) show a significant and practically relevant positive effect for both motivation and learning, and for several age groups and learning topics (in all cases, $p < 0.01$ and Cohen $d > 1$). The results for other approaches investigated in the research program (among others, ASP, and experiment-based learning activities and tasks) also show a considerable potential. Consequences of these results for both research and classroom practice will be discussed, as well as some open problems and new ideas.

1. Introduction: Background and Research Questions

The present work sets out from a two widespread problems of physics (more generally: science) education: First, students' performance in transfer of knowledge, in particular to real-life contexts, is low ('inert knowledge'; **Error! Reference source not found.**). Second, this (and other) problems on the cognitive level of science learning are embedded in the general problem of low motivation for science throughout many countries, see e.g. **Error! Reference source not found.**.

Our investigation is based on two closely related approaches which have been proposed in order to counter these (and other) problems: on the one hand, context-based science learning, intensively discussed by current science education **Error! Reference source not found.** - **Error! Reference source not found.**; on the other hand, "Anchored Instruction" (AI) as one of the leading forms of situated learning, with its central idea of providing "situatedness" (or contextualisation) by means of authentic, affectively and cognitively engaging "anchor media" in form of multimedia video discs **Error! Reference source not found.**. In a first step inspired by these two lines of thought, as well as by good practice reports (see e.g. **Error! Reference source not found.**), we studied science problems based on newspaper stories (newspaper story problems, NSP, **Error! Reference source not found.**, **Error! Reference source not found.**; see Fig. 1 for an example) and advertisements (ASP, **Error! Reference source not found.**). These appear as a promising way of combining the authenticity and

a) 'Newspaper story problem' format	b) 'Traditional task' format
Lausanne/ngn. Another great round-a-world adventure a la Steve Fossett's solo flight last month. Now it seems the explorer Bertrand Piccard will attempt the world's first solar powered around the world flight Piccard comes from a family of explorers and made history in March of 1999 with a nonstop, around-the-world flight in a hot-air balloon, the Breitling Orbiter 3. But what about the solar power side of this? Is that really possible? Nearly the entire body of the plane will be covered by 287 square yards (240 square metres) of solar panels. Piccard estimates that enough power can be generated to sustain a flight of roughly 60 miles an hour (97 kilometres an hour). The plane's batteries are going to have to be pretty heavy, capable of storing 200 watts per kilogram, so that the plane can run at night. *Gadling*, 2005-04-13	In 2007 the explorer Bertrand Piccard will attempt the world's first solar powered around the world flight. He estimates that the solar panels of the plane can generated enough power to sustain a flight of roughly 60 miles an hour (97 kilometres an hour). The plane's batteries are going to have to be pretty heavy, capable of storing 200 watts per kilogram, so that the plane can run at night.
1. How long will Bertrand Piccard be on his way around the world? 2. How much electrical energy per kilogram and how much power per kilogram has to be produced at least? 3. How much electrical energy per kilogram and how much power per kilogram has to be produced at least by the solar panels, if Piccard will drive ca. 75% of the flight by day? 4. How much electrical energy per kilogram has to be produced at least by the batteries? 5. Discuss your results critically, e.g. with respect to the energy transformation process, and use physical arguments thereto.	

Fig. 1: Newspaper-task' format (a) and ‚traditional task' format (v) for the topic 'velocity'. Tasks are identical in both cases (lower part)

the "story character" of the original AI approach with the practicability and flexibility offered by the easy-to-have and easy-to-deal-with medium "newspaper". Research questions are as follows (among others)

- Are NSPs/ASPs perceived as authentic and motivating?
- What are the effects on learning?

If there are positive effects on motivation and/or learning,

- are they robust with respect to pertinent learner and classroom characteristics (gender, physics/math/reading competence, cognitive ability, class and school characteristics
- are they temporally stable (at least at a mid-term range).

In a second step, this approach of "contextualized" embedding was enlarged to decorative pictures, providing a visual, surprising an aesthetically pleasing context **Error! Reference source not found.**, and recently to experimental contexts provided by mobile, everyday life communication devices such as smartphones and tablet computers used as portable physics sensors (project iPhysicsLabs, see **Error! Reference source not found.**). In the following, we the present the NSP study in some detail, and give an overview over the other approaches.

2. Methodology

Study Sample and Procedure. The study was conducted in a cooperation network for physics education, covering a broad sample of age groups and academic levels (see Tab. 1).

Within a quasi-experimental pre-post-test study with repeated measure design, control group classes (CG), working on traditional problems, were compared to treatment group classes (TG) working with

N pupils	> 1600*
N classes	> 40*
N teachers	> 20*
N schools	15
N school types	6**

Tab. 1: research-practice cooperation network for physics education **Error! Reference source not found.**
*exact numbers depend weakly on details of research question considered (e.g. final dates of data collection etc.)
all regular school types of secondary level I of Rheinland-Pfalz (federal district where the studies took place), distinguished mainly by academic level (see **Error! Reference source not found.).

NSP (of exactly the same content, see Figure 1a). The TG and CG tasks differed only in language style (newspaper vs. textbook) and in their layout, but were identical in the basis information, and the questions related to it (see Figure 1). Subject matters were energy and energy transformations (grades 9/10) and elementary kinematics (grades 7/8). Instruction and testing followed the design presented in
Tab. 2. Work on each worksheet lasted about two school lessons (45' each). In order to control for teacher influence, a pair of TG and CG classes was taught by the same teacher.

Materials and Instruments. Repeated measures of motivation (before, immediately after and seven weeks after treatment) were carried out with an instrument well established in the literature on science motivation (adapted from **Error! Reference source not found.**; total 26 items, Cronbach α = .93) with the following subscales: Intrinsic motivation, reality connection/authenticity, self efficacy/self concept (Cronbach α around .9 for all subscales). For details see **Error! Reference source not found.**.

Achievement was tested with a written test with five items, with difficulties similar to those of the worksheets of the training period. Three of these five tasks corresponded to the PISA competence levels III and IV (transfer level), the other two tasks to the level I and II. The competence levels were assessed by an expert rating (Cohen's Kappa κ > .78).

Covariate measures. Prior achievement in physics was assessed as average grade level of students in the six months prior to intervention. Reading comprehension and non-verbal intelligence were assessed by standardized measures and taken into consideration as covariates, too (see **Error! Reference source not found.** for details).

Analysis method. According to the variable plan, the hierarchical sample structure and design described above, a 3-level-Hierarchical Linear Modeling was applied **Error! Reference source not found.**, with level 1 through 3 given by measuring times, learners (and their characteristics) and classes, respectively (the latter comprising in particular the treatment forms CG/TG).

Week	Control Group (CG)	Treatment group (TG)
1	tests of non-verbal intelligence and reading comprehension	
	motivation pre-test	
4	traditional problems Worksheet 1 – 3	newspaper story problems Worksheet 1 – 3
5	achievement post-test	
	motivation post-test	
6…13	traditional education of a new topic	
14	follow-up motivation test	

Tab. 2: Quasi-experimental repeated measures design

3. Results

Due to restrictions of space, only a selection of relevant results can be presented here (for a complete treatment see **Error! Reference source not found.**). Effect sizes reported below are Cohen's *d* **Error! Reference source not found.**: small, medium and large effects are $0.2 < d < 0.5$, $0.5 \leq d < 0.8$ and $0.8 \leq d$, respectively. Compared to conventional problems, one finds:

- *Motivation*: statistically highly significant and practically highly relevant improvements ($p < 0.001$; $d = 1.66$)
- *Motivation subscale reality connection/authenticity (RA*): as above ($p < 0.001$, $d = 2.03$)
- *Achievement*: as above ($p < 0.001$; $d = 1.18$ (overall) and $p < 0.001$; $d = 1.31$ (transfer)
- *(Temporal) stability*: improvements last at least for several months (motivation: $p < 0.001$; $d = 1.04$ after 3½ months, achievement: $p < 0.001$; $d = 2.15$ after 2½ months)
- *Robustness*: no (or weak) dependence on gender, reading competence, cognitive ability, class and school characteristics

– *Other approaches*: For ASP **Error! Reference source not found.**, learning effects were weaker

and less consistent across study groups than for NSP. Motivation effects were also weaker, but still approached d = 1; moreover, in this study relationship of the (motivation) effect on the "dose" (number of learning tasks) was investigated (dose-effect-relationship, DER), yielding with considerable precision the sigmoid functions known for DERs in other areas (chemical kinetics, pharmacology) **Error! Reference source not found.**. For the DP study **Error! Reference source not found.**, large effects (up to d ≈ 2) could be found for mood, but only weak and inconsistent effects for motivation and learning (somehow surprisingly, see discussion below). For iPhysicsLabs first results from a study among university students (with a somewhat different design) show positive effects on motivation **Error! Reference source not found.**, and investigations among secondary level pupils are under way.

4. Discussion and outlook

The results for NSP show strong support for motivation and learning, in particular transfer. Moreover, all positive effects are stable at least for several months, and they are robust with respect to relevant covariates. Together with its practicability and flexibility, this implies a desirable degree of "classroom usability". Moreover, the instructional and study design offer a promising framework for research on further variants of and more detailed hypotheses about CBSE. Eg. for the weaker effects of ASP **Error! Reference source not found.**, a possible explanation could be that pupils take less seriously advertisement than newspapers (rightly so!), and that this evaluation influences the effort investment (a similar process is known from television compared to print information, **Error! Reference source not found.**). For the still weaker effects of DP **Error! Reference source not found.**, an explanation could be that the tasks pupils had to work with were not directly related to the pictures (which was the case for NSP and ASP), so that their effects are rather that of a seductive detail than of a motivating and activating anchor. Investigation of these hypotheses is possible in the framework described here, with a suitable modification of the learning material. Another application of the present work is by use of the motivation/authenticity instrument for an assessment of these features for the PISA items **Error! Reference source not found.**. Finally, a form of *experimental* context-based physics learning is currently developed and investigated in a similar framework, with a series of activities using smartphones and tablet computers as portable physics sensors **Error! Reference source not found.**; the idea is to establish real life connections by a kind of *material* context, using familiar devices playing a large role in the everyday life of youths, but in an unexpected, and hopefully interesting way.

Thus, CBSE approaches with the instructional setting and design principles outlined in this contribution have been empirically shown, for some variants (NSP, and to some extend ASP), to be effective elements or "building blocks" for physics education, and they show considerable potential for further development.

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