Res Sci Educ (2017) 47:237–255
DOI 10.1007/s11165-015-9497-3

Constructivism in Practice: an Exploratory Study of Teaching Patterns and Student Motivation in Physics Classrooms in Finland, Germany and Switzerland

Anne Beerenwinkel[1] **· Matthias von Arx**[1]

Published online: 26 January 2016

Abstract For the last three decades, moderate constructivism has become an increasingly prominent perspective in science education. Researchers have defined characteristics of constructivist-oriented science classrooms, but the implementation of such science teaching in daily classroom practice seems difficult. Against this background, we conducted a sub-study within the tri-national research project Quality of Instruction in Physics (QuIP) analysing 60 videotaped physics classes involving a large sample of students ($N=1192$) from Finland, Germany and Switzerland in order to investigate the kinds of constructivist components and teaching patterns that can be found in regular classrooms without any intervention. We applied a newly developed coding scheme to capture constructivist facets of science teaching and conducted principal component and cluster analyses to explore which components and patterns were most prominent in the classes observed. Two underlying components were found, resulting in two scales—Structured Knowledge Acquisition and Fostering Autonomy—which describe key aspects of constructivist teaching. Only the first scale was rather well established in the lessons investigated. Classes were clustered based on these scales. The analysis of the different clusters suggested that teaching physics in a structured way combined with fostering students' autonomy contributes to students' motivation. However, our regression models indicated that content knowledge is a more important predictor for students' motivation, and there was no homogeneous pattern for all gender- and country-specific subgroups investigated. The results are discussed in light of recent discussions on the feasibility of constructivism in practice.

Keywords Constructivism · Students' motivation · Physics instruction · Video analysis

✉ Anne Beerenwinkel
anne.beerenwinkel@fhnw.ch

Matthias von Arx
matthias.vonarx@fhnw.ch

[1] School for Teacher Education, Centre for Science and Technology Education, University of Applied Sciences and Arts Northwestern Switzerland (FHNW), Steinentorstrasse 30, 4051 Basel, Switzerland

Introduction

Constructivism in Practice

Although a constructivist perspective of learning is at the heart of a high number of innovations and reforms in science education around the world, there is no such thing as *the constructivist theory*. Rather, it is a comprehensive framework integrating different theories relating to how various cognitive, affective and social factors influence learning in contrast to the more traditional information processing view. Within this framework, learning is understood as an active, highly individual construction process building on pre-knowledge and personal experience, and taking place in a specific social and historical context and in distinctive classroom settings. This very short, general description points to a crucial problem for teachers. They see themselves confronted with the question of how to make personal sense of constructivism as a basis for instruction. This is both a conceptual problem (understanding the multiple philosophical, psychological and epistemological underpinnings) and a pedagogical one (how to design learning environments that the constructivist perspective demands) (Windschitl 2002). In the last two decades, there have been several theoretical and practical attempts to identify key features of constructivist-oriented instruction. For example, Green and Gredler (2002) described and analysed various implementation requirements for constructivist teaching practices such as goal orientation, assumptions about learners as being self-aware and self-directed, and expertise in negotiating discourse communities. Baviskar et al. (2009) suggested four essential features for constructivist teaching: eliciting prior knowledge, creating cognitive dissonance, reflection on learning and the role of feedback. Taylor et al. (1997) developed the Constructivist Learning Environment Survey (CLES) questionnaire—a tool that enables teachers and researchers to monitor and develop constructivist teaching approaches. Windschitl et al. (2012) recently specified, in an evolutionary development process, a core set of instructional practices and the corresponding tools for teachers. Their work was based on the theoretical assumptions of constructivism on the one hand and observations of the teaching practices of beginning science teachers on the other.

At the same time, specific instructional methods that implement crucial aspects of the constructivist framework have gained greater theoretical foundation and conceptual precision, for example, inquiry-based learning (Bell et al. 2010), problem-based learning (Hmelo-Silver 2004) and discovery learning (Hammer 1997). There is a broad literature on the effectiveness of such approaches (e.g., Alfieri et al. 2011; Hmelo-Silver 2004). The implementation of these approaches typically comprises less instructional guidance than traditional methods of science teaching. Against this background, Kirschner et al. (2006) argued that minimally guided instruction is less effective and less efficient than guided instruction because it contradicts the current "knowledge of human cognitive architecture, expert-novice differences, and cognitive load" (p. 75). This criticism triggered a fruitful discussion in the research community. Tobias and Duffy (2009) summarised and discussed this controversy and identified two main lines of argumentation: the often neglected role of guidance and scaffolding during constructivist-oriented instruction, and the gap between research initiatives and school practice. Accordingly, Duffy (2009) emphasised these two issues as follows:

1. Neglected role of guidance and scaffolding

> The rationale for guidance and prescription for guidance remains ill-defined. . . . Indeed, perhaps the constructivists should design a learning environment to support learning about the instructional implications of constructivism—certainly an ill-structured problem. (p. 352).

2. Research initiative versus school practice

> The issue is the feasibility of implementing the constructivist instruction in the schools, beyond the research initiative where teachers are funded and experts are near at hand to lend support. … I think scaling up and sustainability are critical issues for the constructivist debate that have not been adequately addressed. (p. 362)

The role of guidance and scaffolding has also been reviewed in a meta-analysis by Alfieri et al. (2011). The analysis empirically confirmed the importance of guidance and scaffolding: the outcomes of unassisted discovery learning were inferior to those of explicit instruction, but the results were opposite if discovery learning was enhanced and/or assisted adequately. Regarding the gap between research and practice, Duit et al. (2008) identified very similar problems in their review on the role of conceptual change in science teaching: "a gap between what is known about effective teaching and learning science from conceptual change perspectives and the reality of instructional practice" (p. 629).

The above review of the literature was the starting point for our present study. We wanted to investigate to what extent features that are characteristic of learning and instruction within the constructivist framework are integrated into everyday school practice in the absence of any given intervention or support for the teachers by experts. Since students' affective characteristics are seen as important aspects both within the constructivist framework and in the light of triggering deep-learning processes, we were interested in the relationship between constructivist teaching and motivation. In the following, we outline a selection of aspects on the construct of *motivation* which were of importance to this study.

Motivation

Motivation is seen as an essential construct with regard to learning science and pursuing a science career (e.g., Bransford et al. 2000; OECD 2007), and positive relations between motivation and variables relevant to school learning—such as cognitive engagement, effort or achievement—have been found (Bryan et al. 2011; Kuyper et al. 2000; Wolters 1999). There are different theories and research concepts regarding the investigation of motivation in the classroom (Pintrich 2003; Urdan and Turner 2005). *Self-determination theory* (SDT) is one of the most prominent theories, representing a strong theoretical framework with a broad empirical validation. Since constructivist learning environments embrace self-regulated learning, SDT formed the theoretical basis for the present study. The core aspects of SDT are discussed in the following.

Self-determination theory is a comprehensive framework that assumes, besides other things, that human beings are inclined to engage in interesting activities (Deci and Ryan 2000). Accordingly, it distinguishes between intrinsically and extrinsically motivated behaviour; whereas the former refers to doing something because it is perceived as enjoyable and interesting by itself, the latter refers to doing something in order to obtain a separate outcome. The dichotomy of intrinsic versus extrinsic motivation has been elaborated within SDT based on the assumption that humans tend to internalise socially-given values or requests into personal ones. To model this process, a continuum of motivational facets has been proposed which covers a range from amotivation through different types of extrinsic motivation to intrinsically motivated behaviour (Deci and Ryan 2000). Within this model, extrinsic motivation is differentiated into four different types of motivation ranging from external regulation, which refers to the classical definition of behaviour motivated by external outcomes, to integrated regulation, a state where external values are not only accepted by the individual but also put into coherence with the self. The continuum of different facets of motivation can be characterised as a "continuum of relative autonomy" (Ryan and Deci 2000, p. 63). The most autonomous type of motivation, intrinsically motivated behaviour, is seen as the most preferable thriving force for students' learning because it is connected with better learning and performance. When compared to less autonomous types of extrinsic motivation within the model, the more autonomous types have also been positively associated with different factors that are important for students' learning, such as engagement, performance or the quality of learning. To foster students' motivation in the direction of the more autonomous types of extrinsic or even intrinsic motivation, SDT stresses the importance of creating learning environments that meet three basic needs presumed to be innate to all human beings: the need for relatedness, competence and autonomy (Niemiec and Ryan 2009). This means that students "feel connected to others within the setting, … function effectively in it, and … feel a sense of personal initiative while doing so" (Brophy 2004, p. 189).

Translated into classroom practice, SDT proposes that teachers need to create autonomy-supportive, caring learning environments with activities that match the students' levels of knowledge and skills. There need to be choices for the students concerning what they want to work on and how they want to work on what they have chosen so that they have the opportunity to take ownership of their work. The teacher further provides plenty of opportunities for the students to work collaboratively, gives formative feedback on a regular basis and cares for a supportive learning climate (Brophy 2004; Urdan and Schoenfelder 2006). These elements, fostering students' autonomy in the classroom, should be combined with scaffolded instruction in order to create a safe learning environment that encourages students to take on challenges in their learning process (Urdan and Schoenfelder 2006). The need for a balance between autonomy and support was also stressed by Andersen and Nielsen (2013), who carried out a video-based analysis for students' motivation in the science classroom. In other words, instruction that integrates elements of autonomous learning combined with scaffolding seems to be an approach that might positively influence students' motivation.

That instructional features can predict situational motivation has also been shown by Jurik et al. (2014), who investigated teacher-student interactions using data from a video study of physics classrooms. It was found that behavioural features of the teacher, concretely deep-reasoning questions and feedback that supports students to solve challenging problems, predicted students' self-reported intrinsic motivation in reference to the experienced teaching unit. Intrinsic motivation as a dependent variable was also investigated by Grouzet et al. (2004), who studied the influence of success versus failure feedback with an experimental design and found that success feedback led to increased intrinsic motivation, mediated by the perceptions of competence. Taken together, it seems that important features of constructivist learning environments may positively predict students' situational motivation regarding lessons that implement these features.

Research Questions

For this study, we had access to a large sample of videotaped Finnish, German and Swiss physics classes of grades 9 and 10 within the Quality of Instruction in Physics (QuIP) project (Fischer et al. 2014). A subsample of these videos was analysed to answer the following three research questions:

1. What components of constructivist teaching can be found in physics classes across the three countries?
2. What kinds of constructivist teaching patterns can be found?
3. Is there a higher degree of students' motivation in classes where the components of constructivist teaching are more prominent?

Methodology

Instruments

Background of the Study Our investigation is a secondary analysis and part of the tri-national research project QuIP, which aimed at identifying features and patterns of physics instruction that have the potential to explain differences in student achievement. Within the project, double lessons on the topic of "The Relation between Electrical Energy and Power" were videotaped in 103 Finnish, German (North Rhine-Westphalia state) and Swiss (German-speaking part of Switzerland) classes (9th and 10th grades) for subsequent analyses. Pretests and posttests were administered to students and teachers to collect a wide range of background information, such as students' motivation and interest and teachers' pedagogical content knowledge (Neumann et al. 2014). It was assumed and found in the QuIP project that classes from these three countries showed a broader spectrum of teaching patterns than did classes from only one country (Fischer et al. 2014). For a detailed description of the data collection process, the sample, the instruments and primary analyses, see Fischer et al. (2014).

Instrument to Measure Students' Motivation Within the QuIP project, a paper-and-pencil test to measure students' situational motivation at lesson level was developed and administered to the students just after the recorded double lesson. The instrument included scales based on *self-determination theory* and described the range from amotivation (e.g., "During the video-taped double lesson … I attended instruction, although I definitely knew that it was not worth it"; item texts translated by the authors) through different types of extrinsic motivation (e.g., "During the video-taped double lesson … I participated only because it was expected of me") to intrinsic motivation (e.g., "During the video-taped double lesson … I participated avidly because I really liked the lessons"). Altogether, there were five subscales, one for amotivation, three for extrinsic motivation (describing the range from external to partially internal motivation—external regulation, introjection, identification) and one for intrinsic motivation (Helaakoski and Viiri 2012).

These scales were combined into the Relative Autonomy Index (RAI) to get an overall measure for students' motivation. The less autonomous and more extrinsic scales got negative weightings, whereas the scales on the more autonomous and intrinsic end of the spectrum got positive weightings (unpublished coding manual). High values of RAI thus indicate more intrinsic and autonomous states of motivation in contrast to low RAI values, which are related to less autonomous and more extrinsic states of motivation or amotivation.

Additionally, the instrument contained items asking students about their attitude with regard to the lessons as a whole (e.g., "Overall, I really liked these lessons"). These items were combined into a scale called Attitude (ATT) by calculating the mean (Helaakoski and Viiri 2012; Keller 2011; unpublished coding manual). A detailed description of the instrument and its validation is given in Helaakoski and Viiri (2012).

Instrument to Measure Students' Physics Knowledge A paper-and-pencil test to assess students' physics knowledge was developed within the QuIP project and administrated as a pretest and posttest before and after the unit on electricity, which included the videotaped double lesson on the topic of "The Relation between Electrical Energy and Power". The test included multiple choice and open-ended items and focused on the topic of electrical energy (for a detailed description of the instrument and its validation, see Spoden and Geller 2014).

Coding Scheme for Constructivist Teaching Another part of the QuIP project was the development of a coding scheme to explore how aligned the videotaped lessons were with the constructivist framework for teaching. For this purpose, the methodological approaches of Rakoczy and Pauli (2006) and Kobarg and Seidel (2005) for the event-based, high-inference rating of deep-structure elements in videotaped lessons were adapted to the four categories from the theoretical framework by Widodo and Duit (2004): Construction of Knowledge (CK), Personal Relevance (PR), Social Interaction (SI) and Independent Learning (IL). Each category was composed of different facets describing key elements and possible observables. The analysis unit was the full double lesson, i.e., there was one overall rating for each facet over the full double lesson on a four-point Likert scale (from 0=does not apply, up to 3=fully applies).[1]

The following example ("Activation of pre-knowledge") illustrates the typical rating procedure. The coding manual for this facet states that students' knowledge on the topic/subject under discussion should be activated. For a high rating (3), this activation has to purposefully take place (not just accidentally), it has to include a large majority or all students and it has to become clear to the students why this knowledge is considered to be "pre-knowledge" and in what sense it is relevant for the topic of the lesson and the acquisition of new knowledge or the further development of (individual) students' knowledge structures. In other words, the rating of this facet is a measure of the extent to which knowledge and knowledge structures of the students are activated and made explicit, and serve as a starting point for the acquisition of new or the revision of existing knowledge. All information available from the videotape (verbal, non-verbal, written, by students and teacher) was taken into account for the rating. Altogether, there were 19 different facets, covering cognitive, metacognitive, motivational and social aspects of learning and focusing on latent or deep-structure elements rather than on surface elements. Each facet was described in the coding manual and rated in a similar way as exemplified above. A short description of all facets is given in Appendix 1.

[1] Please note that we interpreted these variables as interval variables for the statistical analyses.

From the initial sample of 103 classes of the QuIP project, three stratified subsamples were selected based on the variables country and school type (n_{Finland}=20, n_{Germany}=20 and $n_{\text{Switzerland}}$= 20). The 60 classes were then rated according to the coding scheme by two independent raters. The interrater reliability was between 0.65 and 0.96 for 17 of the 19 facets. One additional facet had to be omitted from further analyses due to insufficient coding, yielding a final sample of 16 variables. For a detailed description of the coding scheme and its reliability, see von Arx (2014).

Statistical Methods

To investigate the three research questions, different statistical models were applied to analyse the data collected from this subsample of classes using the statistical software R. Analyses were conducted on both the class level with the sample of 60 classes and on the student level with the sample of 1192 students depending on the variables under consideration.

Principal Component Analysis An exploratory principal component analysis (PCA) on the class level with a subsequent analysis of reliability was conducted on the variables of the coding scheme about constructivist teaching. The adequacy of the sample of variables for conducting a PCA was evaluated using the Kaiser-Meyer-Olkin measure (KMO), individual measures of sampling adequacy (MSA) and Bartlett's test of sphericity. In order to determine the number of components, we consulted the screeplot, model fit and content validity. Reliability of the scales was estimated by determining the Cronbach's alpha values.

Cluster Analysis A cluster analysis on the class level was conducted for the two *N*(0,1)-standardised constructivist scales that emerged as a result of the principal component analysis—Fostering Autonomy and Structured Knowledge Acquisition—using hierarchical clustering with Ward's method and Euclidian distance to determine the number of clusters. The criteria for the number of clusters were a strong increase of heterogeneity within the clusters with a decreasing number of clusters and sufficient cluster size. *K*-means was used for clustering the data based on the number of clusters determined with the hierarchical clustering method. We wrote an R script to implement an algorithm that used *K*-means to compute cluster solutions based on random data permutations and randomly selected initial centres (see Appendix 2 for details). Homogeneity was tested by calculating the ratio of the variance of each variable within a particular cluster to the variance of the entire sample. The stability was evaluated by running the algorithm several times and comparing the cluster solutions.

The clusters were compared descriptively on the student level for differences on the two *N*(0,1)-standardised motivational scales ATT and RAI. Whether possible differences were statistically significant was tested by running an ANOVA with a subsequent post hoc test (Bonferroni method). The premise of homogeneity of variances was checked for with Levene's test.

Regression Analysis Multiple regressions were run on the student level with the *N*(0,1)-standardised motivational scales RAI and ATT as dependent variables, respectively. Predictors were the two constructivist scales Fostering Autonomy and Structured Knowledge Acquisition, which emerged as a result of the principal component analysis. Since competence is seen as one crucial component of self-determination theory, we included the knowledge scale posttest to control for the influence of students' physics knowledge. All predictors were *N*(0,1)-standardised. In the QuIP project, large between-country differences were found for students' posttest results (Spoden and Geller 2014). To account for this, regression models were run separately for each country. In addition, the models were specified for female and male students separately because gender segregation in the science, technology, engineering and mathematics (STEM) sector is still an issue in Germany and Switzerland. Furthermore, gender differences are prominent for motivation-related variables such as interest or self-concept (for an overview, see, for example, Börlin et al. 2014). Thus, the models were specified for six different subgroups: Finnish male/female, German male/female and Swiss male/female students. Model assumptions were tested with different methods. Multicollinearity was checked for with the variance inflation factor (VIF), and the Durbin-Watson test was used to test for autocorrelation of residuals. Goldfeld-Quandt tests were run to test for residual homogeneity of variance, and the normal Q-Q plots of the models were examined for normal distribution of residuals. Model fit was evaluated with *F*-statistics.

Results

What Components of Constructivist Teaching Can Be Found in Physics Classes Across the Three Countries?

For the 16 variables of the coding scheme for constructivist teaching, the Kaiser-Meyer-Olkin measure (KMO) and measures of the sampling adequacy (MSA) were calculated. Based on these measures, inadequate items were excluded, yielding a final sample of 11 variables with satisfying KMO and MSA values. Bartlett's test of sphericity, χ (55)=254.7, $p<0.001$, gave further indication for sufficient variable correlation to conduct a principal component analysis (PCA) on these 11 variables. An initial PCA was conducted in order to determine the number of underlying components. The analyses of eigenvalues (Kaiser's criterion), screeplot, proportion of high residuals, model fit measured by the sum of the squared residuals divided by the sum of the squared correlations and content validity suggested a two-component solution, which explained 51 % of the common variance.

Two scales were therefore calculated based on the mean values of the according variables. The analysis of reliability showed that the second scale, which was comprised of variables with high loadings on the second component, became more reliable when two variables were excluded. The two final scales are presented in Table 1. As can be seen, the first scale consists of seven facets. The first facet, student-teacher interaction, indicates the intensity, diversity and reciprocity of discussions. The following three variables describe, respectively, periods of a lesson during which (1) students get the opportunity to organise their learning, (2) they are challenged to rethink and to examine their answers to questions from different perspectives and (3) they are encouraged to reflect on their learning process. The first scale further includes the facet which estimates the benefit from independent learning by rating how engaged students are while working on a problem and whether they develop relevant questions or ideas from this work that advance their understanding or skills. Opportunities for students to externalise their thoughts on their thinking and learning are also part of this scale as well as the last facet, "providing problems", which refers to teachers giving problems that support students in realising the need to change their current status of knowledge. In general, the first scale indicates the degree to which the teacher supports students in developing an independent—or in terms of self-determination theory, an autonomous, reflective learning style. It was thus labelled Fostering Autonomy. The scale showed a mean value of 0.71 (±0.52) on the Likert scale (range 0–3) used for rating the videotaped double lessons.

Table 1 Two-component solution of the principal component analysis with oblimin rotation

Facets	Fostering Autonomy	Structured Knowledge Acquisition
Student-teacher interaction	*0.75*	
Space for independent learning	*0.60*	
Encourage rethinking	*0.68*	0.38
Foster metacognition	*0.74*	−0.50
Benefit from independent learning	*0.71*	0.35
Metacognitive abilities	*0.75*	
Providing problems	*0.46*	0.30
Demonstration of scientific approach to knowledge generation		*0.83*
Evolutionary development of knowledge		*0.74*
Activation of pre-knowledge		0.39
Everyday-life context		−0.39
Reliability of scale (Cronbach's alpha)	0.80	0.75

Italicised factor loadings indicate which facets were included into the final scales Fostering Autonomy and Structured Knowledge Acquisition; factor loadings below 0.30 are suppressed

The second scale includes two facets. The first facet describes learning environments in which students get the opportunity to become familiar with the typical mechanisms of knowledge generation in science such as generating a hypothesis, planning an experiment, analysing data and drawing conclusions. The second facet of this scale refers to a teaching style in which the teacher guides students in modifying their existing knowledge by a stepwise integration of new concepts or reinterpretation of their existing knowledge structures. The scale thus describes how the teacher provides structured opportunities for students to conceptually grow and to become familiar with scientific working methods. It was thus labelled Structured Knowledge Acquisition. The scale showed a mean value of 1.70 (±0.78) on the Likert scale (range 0–3) and correlated moderately but significantly with the first scale Fostering Autonomy ($r=0.34$, $p<0.01$).

What Kinds of Constructivist Teaching Patterns Can Be Found?

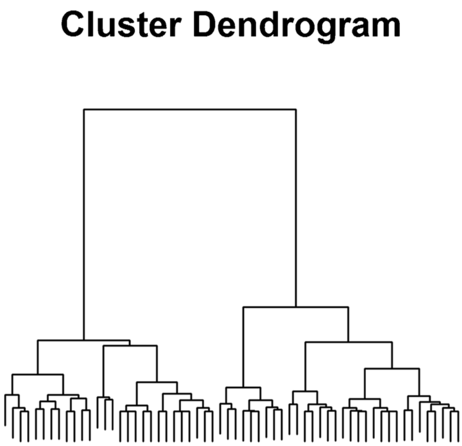
The dendrogram of Ward's method gave no clear-cut solution (see Fig. 1). Based on the increase of heterogeneity and cluster sizes, a four-cluster solution was specified for the K-means algorithm ($K=4$). To check for the stability of the solution, the algorithm was repeated three times, yielding the same results. The homogeneity indices yielded overall good values with only one index of a value above 0.50 as shown in Table 2 (Jones et al. 2006, p. 256).

Figure 2 shows the four-cluster solution with $N(0,1)$-standardised values. Cluster centres are marked by numbers. All data points were jittered slightly by adding to each data point a random error term drawn from the (0, 0.05) normal distribution to visualise overlying points.

Cluster 1: constructivism low. Cluster 1 included 16 classes which showed comparatively low values for both Fostering Autonomy and Structured Knowledge Acquisition.

Cluster 2: autonomy high. Cluster 2 was the smallest cluster, with only three classes that differed from the rest of the sample in their focus on Fostering Autonomy.

Fig. 1 Dendrogram of the hierarchical clustering with Ward's method



Cluster 3: constructivism high. Cluster 3 contained 16 classes. The physics lessons of these classes were stamped by comparatively high values for both Fostering Autonomy and Structured Knowledge Acquisition.

Cluster 4: average. Cluster 4 was the largest cluster with 25 classes. In terms of the whole sample, these classes showed average values on the two scales describing constructivist teaching.

The four clusters were compared with respect to their mean values on the two motivational scales: Relative Autonomy Index (RAI) and Attitude (ATT). It was found that the classes of cluster 1 were characterised by relatively low values, whereas the classes of cluster 3 displayed relatively high values on both scales. The three classes of cluster 2 reached particularly high values on ATT. Cluster 4 classes showed average values for both scales. Figure 3 presents the mean values of the clusters for the standardised scales RAI and ATT. The differences between the clusters were statistically significant: for ATT, $F(3, 1063)=5.55$, $p<0.001$, and for RAI, $F(3, 1067)=5.07$, $p<0.01$. Post hoc analysis revealed that cluster 1 differed significantly from clusters 2 and 3 on ATT (cluster 1 vs. cluster 2: $p<0.05$, cluster 1 vs. cluster 3: $p<0.01$) and cluster 1 from cluster 3 on RAI ($p<0.001$).

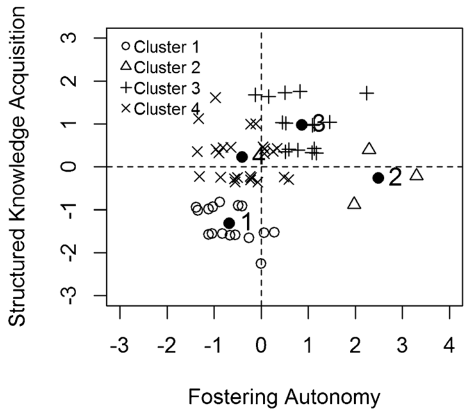
Is There a Higher Degree of Students' Motivation in Classes Where the Components of Constructivist Teaching Are More Prominent?

Model Fit The evaluation of model fits was overall satisfactory. However, some of the data showed minor correlation of residuals and homogeneity of variance so that the regression results shown in Table 3 have to be interpreted with caution. The F-statistics for the different models were all significant with the exception of the two models for the female German subgroup, which means that these two models did not fit the data appropriately. The results of the regression analyses are presented in Table 3.

Table 2 Homogeneity indices for the four-cluster solution

Cluster	1	2	3	4
Fostering Autonomy	0.25	0.53	0.28	0.33
Structured Knowledge Acquisition	0.16	0.41	0.30	0.29

Fig. 2 Clustering and the cluster centres for the four-cluster solution



RAI All the regression models showed a significant positive influence of students' knowledge, indicated by the variable posttest, on students' motivation as measured by RAI. The only exceptions were the groups of German girls and Swiss boys. Only in two cases did the models show a significant influence of the two constructivist scales: the motivation of the male German students of the sample seemed to be positively influenced by Fostering Autonomy, whereas the model for the male Swiss students indicated that this subgroup preferred Structured Knowledge Acquisition. For German girls, the model was not significant.

ATT Here again, all the regression models showed a significant positive influence of students' knowledge on how students liked the lessons as a whole, as measured by the scale ATT. The only exceptions were again the groups of German girls and Swiss boys. Only one model showed a significant influence of one of the two constructivist scales: Fostering Autonomy seemed to positively influence how the female Swiss students of the sample liked the lessons. As above, the model for the subgroup of German girls was not significant.

Fig. 3 Mean values of the $N(0,1)$-standardised motivational scales RAI and ATT by cluster

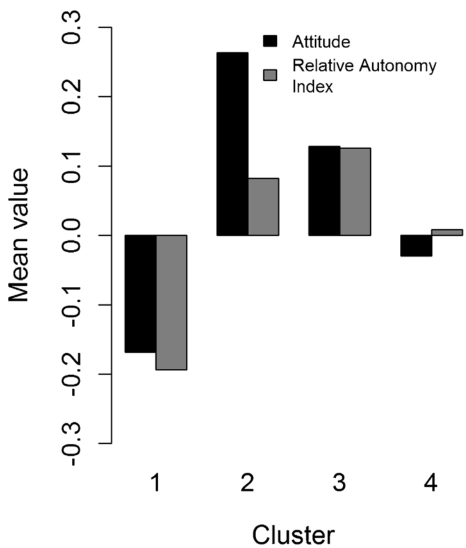


Table 3 Regression models with $N(0,1)$-standardised variables

	Posttest	Fostering Autonomy	Structured Knowledge Acquisition	Adjusted R^2	Model fit (p value)
RAI					
Finland female	*0.43*	0.04	−0.04	0.16	0.00
Finland male	*0.44*	0.04	0.15	0.19	0.00
Germany female	0.04	0.01	0.15	0.01	0.24
Germany male	*0.42*	*0.21*	0.00	0.22	0.00
Switzerland female	*0.29*	0.14	0.09	0.13	0.00
Switzerland male	0.06	−0.15	*0.29*	0.09	0.00
ATT					
Finland female	*0.39*	−0.08	0.14	0.14	0.00
Finland male	*0.27*	0.01	0.15	0.07	0.01
Germany female	0.02	0.10	0.11	0.01	0.17
Germany male	*0.29*	0.07	−0.03	0.07	0.00
Switzerland female	*0.28*	*0.20*	0.07	0.14	0.00
Switzerland male	−0.07	0.12	0.17	0.04	0.04

Italicised numbers indicate significant regression weights ($p<0.05$)

Summary and Discussion

This study was part of the tri-national research project Quality of Instruction in Physics (QuIP), which compared physics teaching in Finland, Germany and Switzerland (Fischer et al. 2014). Sixty videotaped double lessons on the topic of "The relation between electrical energy and power" ($n_{\text{Finland}}=20$, $n_{\text{Germany}}=20$, $n_{\text{Switzerland}}=20$) were rated according to a newly developed coding scheme to explore to what extent the videotaped lessons were aligned with a constructivist approach to teaching. Students' motivation was measured after the lessons with a motivational questionnaire developed by Helaakoski and Viiri (2012). The following discussion is structured around the three research questions.

What Components of Constructivist Teaching Can Be Found in Physics Classes Across the Three Countries?

The exploratory principal component analysis (PCA), followed by an analysis of reliability, led to a reduction of items. This is not surprising since the coding scheme was developed on a theoretical and normative basis. The rating of the 60 physics classes was the first empirical validation of this newly designed instrument.

Despite these limitations, the exploratory PCA revealed two underlying components resulting in the scales Fostering Autonomy and Structured Knowledge Acquisition, which describe key aspects of constructivist teaching. By looking at the mean rating values of the scales, it was found that Structured Knowledge Acquisition showed an average value of 1.70. The scale Fostering Autonomy, in contrast, displayed a very low mean value of 0.71, which suggested that this component was not a common feature of the observed physics lessons. The relatively high standard deviation of 0.52 indicated a distinct heterogeneity among the teachers with respect to how strongly they integrated different aspects of the scale Fostering Autonomy, such as providing space for independent learning or fostering students' metacognitive abilities. This finding matches those of other studies that involved observations of regular science classrooms and found that there is still a gap between instructional designs based on research and regular classroom practice. The transmissive view of teaching and learning is still more prominent in the science classroom than the constructivist view (e.g., Duit et al. 2008).

The results of the PCA suggested that the newly developed rating scheme is capable of capturing core aspects of constructivist teaching when analysing regular physics classes without any intervention. However, there is also room for improvement. For example, the coding scheme should focus more on the two components Fostering Autonomy and Structured Knowledge Acquisition, which emerged from the PCA and the number of items describing the dimension of Structured Knowledge Acquisition should be augmented.

What Kinds of Constructivist Teaching Patterns Can Be Found?

The cluster analysis based on the two $N(0,1)$-standardised scales, Fostering Autonomy and Structured Knowledge Acquisition, revealed four clusters. The biggest cluster (cluster 4) had 25 classes and showed average ratings for the two constructivist scales in relation to the whole sample. The smallest cluster (cluster 2), with only three classes, was characterised by a comparatively high value for Fostering Autonomy. The small size of this cluster matches the low overall mean value for the scale Fostering Autonomy as described above. The other two clusters (clusters 1 and 3) each comprised 16 classes, and they can be described as diametrically opposed. Whereas classes within cluster 3 scored comparatively high on both constructivist scales, those in cluster 1 showed comparatively low ratings.

Students' motivation, as measured by the Relative Autonomy Index (RAI) and students' attitude (ATT), was compared across the different clusters with an ANOVA. The comparison showed that the two clusters—which were characterised by comparatively low (cluster 1) and high (cluster 3) ratings for the two constructivist scales—differed significantly in students' motivation with higher values for the high-constructivist cluster (cluster 3). The small cluster with high rating values for Fostering Autonomy (cluster 2) differed positively from the low-constructivist cluster (cluster 1) only on students' ATT but not on RAI. This finding indicates that Fostering Autonomy *without* a focus on Structured Knowledge Acquisition is not sufficient to foster students' intrinsic motivation. However, it has to be taken into account that the small size of cluster 2, comprising only three classes, restricts the explanatory power of the findings related to this cluster.

Taken together, the findings suggest that teaching physics classes in a structured way combined with a relatively high amount of autonomy may contribute to students' motivation in the sense that they like the lessons better and that they feel more intrinsically motivated. These findings are in line with those of Andersen and Nielsen (2013), who concluded "that there must be a balance between support and autonomy" (p. 924) in order for students to benefit from a learning environment that focuses on supporting students' autonomy. However, it has to be taken into account that the results of our study might be confounded by country effects. For example, the low-constructivist cluster had only two German classes compared to five Finnish and nine Swiss classes. In contrast, the high-constructivist cluster had eight German classes compared to four Finnish and four Swiss classes.

Is There a Higher Degree of Students' Motivation in Classes Where the Components of Constructivist Teaching Are More Prominent?

In order to investigate more deeply whether the constructivist teaching scales, Fostering Autonomy and Structured Knowledge Acquisition, influence students' motivation, multiple regressions were run for the two motivational variables ATT and RAI, respectively. Fostering Autonomy, Structured Knowledge Acquisition and students' physics knowledge were included as predictors. The analysis of adequacy of the data for running regressions and the evaluation of model fits showed overall satisfactory results. However, some data displayed minor problems of autocorrelation or heteroscedasticity so that the results have to be interpreted with some caution.

The regression models for the subgroup of female German students proved to be non-significant for both motivational variables. Accordingly, neither one of the two constructivist teaching variables nor students' physics knowledge displayed any influence on the motivation of this subgroup. Thus, we could not explain any of the variance in the motivation of the female German students with the variables considered in the regression models. In other words, in the present study, neither content knowledge nor constructivist teaching aspects had any influence on the motivation of this subgroup. The motivation of the German boys, in contrast, seemed to be positively influenced by their physics knowledge. Fostering Autonomy may additionally raise their motivation as measured by RAI. The same pattern was found for the female Swiss subsample with the difference that high values of Fostering Autonomy appeared to positively influence how they liked the lessons as a whole. For the Swiss boys, in contrast, no effects of knowledge could be detected. However, a teaching style with emphasis on Structured Knowledge Acquisition seemed to raise their motivation significantly for RAI and almost significantly for ATT ($p=0.053$). The Finnish subgroup showed homogeneous results for both male and female students and for both motivational variables: the only significant predictor influencing the motivation of these students was their physics knowledge.

To sum up, in the regression models, content knowledge appeared to be the most prominent predictor for students' motivation. According to self-determination theory, one presumption for students to be motivated is that their need to feel competent is fulfilled. It is likely that it is easier for students with a higher level of physics content knowledge to feel competent during a physics lesson compared to those with a lower level of content knowledge. However, as Grouzet et al. (2004) showed, it is not necessarily the "objective" success on a task that is important for intrinsic motivation, but the *perceived* competence. This might be an interesting aspect to consider for further research. In contrast, a more detailed look at the influence of the two constructivist teaching components revealed no homogeneous pattern. Possible country and gender differences became apparent and physics knowledge seemed to be more important than Fostering Autonomy or Structured Knowledge Acquisition.

These exploratory results need further investigation. With a refined coding scheme, there is potential to take a closer look at possible country differences, and interviews with students may help to elicit the different results for male and female students in Germany and Switzerland. It may be helpful to consider the findings of Grouzet et al. (2004) regarding the importance of the perception of competence for intrinsic motivation, combined with those of Seidel (2006) who analysed the role of student characteristics in German and Swiss physics classrooms. She found that girls were more likely to show an "underestimating" profile that is characterised by high pre-knowledge of physics, an intermediate level of interest and low self-concept. Students with this profile perceived their learning environment as less supportive than students with the "smart" or "overestimating" profile. Thus, it would be interesting to take a closer look at a possible interplay between gender, objectively versus subjectively perceived competence, perception of learning environment and motivation.

Additionally, it has to be considered that the only topic of the lessons investigated in this study was "The relation between electrical energy and power". A different topic may have led to different results, as the motivation of students seems to be strongly dependent on the topic being taught (Bathgate et al. 2014). Topic dependency was also shown by Seidel and Prenzel (2006) who found that the instructional organisation of physics classrooms varies with the degree of teacher centredness versus student centredness depending on the topic. Thus, the implementation of constructivist teaching elements may also be different for topics other than the one in this study and we should be cautious in generalising our results to physics classes in general.

Finally, the effects found in this study were rather small. For two reasons, this is not surprising. First, there was no intervention. The teachers of our sample had no guidelines concerning the way they should plan or carry out the teaching in the videotaped double lesson. The only prerequisite was that the topic had to be "The relation between electrical energy and power". We therefore observed and analysed regular, day-to-day physics teaching. As a result, the variance observed for the variables investigated was rather large and larger than would be expected for a research setting with a specific intervention. Second, some of the characteristics for a constructivist-oriented instruction related to Fostering Autonomy were not very pronounced in the sample investigated. However, we could identify some elements of constructivist instruction in everyday school practice, and for some subgroups correlations to students' motivation were found. These findings are intriguing in the context of constructivism in practice as described in the "Introduction" of this article. It would be interesting to see whether the size of the correlations would increase if the values for Fostering Autonomy and Structured Knowledge Acquisition were larger. For this to occur, teachers need support on how to implement constructivist-oriented instruction by means of practical tools such as those referred to Duffy (2009) and Windschitl et al. (2012). Special emphasis in instruction should be on fostering students' autonomy. Compared to Structured Knowledge Acquisition, Fostering Autonomy had only low ratings in this study. In other words, in the classes investigated, a reasonable level of instructional structuring was observed on the *knowledge side* by developing knowledge in an evolutionary manner or by demonstrating the scientific approach of knowledge generation (see the facets of the scale Structured Knowledge Acquisition in Table 1). However, on the *autonomous learning side* of the observed instructional practice, there was room for improvement. The scale Fostering Autonomy included both aspects of autonomous learning activities and aspects of how the teacher supports and guides the students to become autonomous learners, such as providing feedback, metacognitive prompts and appropriate problems (see Table 1). In the present study, this component of constructivist teaching did not—with a few exceptions—reach a level where the students were supported to a level at which researchers would expect them to become autonomous, self-regulated thinkers and learners. The findings of the present study thus support the claim that more effort should be put into closing the gap between research and practice in light of constructivist teaching approaches.

Acknowledgments We would like thank Jussi Helaakoski, Jouni Viiri and Cornelia Geller, who developed instruments and collected and analysed data that were used in this study. Peter Labudde and Jouni Viiri are also thanked very much for supporting our research as critical friends.

Funding of the Swiss part of the QuIP Project by the School for Teacher Education Bern and the University of Applied Sciences and Arts Northwestern Switzerland (FHNW) is gratefully acknowledged.

Funding Bodies

School for Teacher Education Bern

School for Teacher Education, University of Applied Sciences and Arts Northwestern Switzerland (FHNW)

Appendixes

Appendix 1

Table 4 Overview of all facets of the coding scheme, as given in von Arx (2014)

Abbr.	Facet name and short description
CK 1	Status in learning process: new content is linked to previous content in order to allow meaningful learning. This is made explicit to students.
CK 2	Activation of pre-knowledge: Students' knowledge on the topic/subject under discussion is activated.
CK 3	Providing problems: If the pre-knowledge on the topic/subject is not compatible with the scientific view, the need for the student to extend (conceptual growth) or revise (conceptual change) his/her actual knowledge becomes evident by solving an appropriate problem.
CK 4	Evolutionary development of knowledge: A conceptual growth process is pursued by a stepwise integration of new concepts or reinterpretation of existing knowledge structures, leading to a modification of the knowledge.
CK 5	Revolutionary development of knowledge: The teacher or the learning environment offers the students problems provoking cognitive conflict, which is then resolved by creating a new knowledge structure.
CK 6	Thinking aloud: The teacher (expert) thinks aloud in order to make his/her thoughts accessible for students in the process of revising or expanding a knowledge structure.
CK 7	Demonstration of the scientific approach to knowledge generation: The learning environment allows the students to get insights into the typical mechanisms of knowledge generation in science (e.g., the sequence of hypothesis generation, experiment, data analysis and conclusion).
PR 1	Explore interest: At the beginning of a new topic, students' interest in and their personal attitude towards the topic are explored.
PR 2	Accounting for needs: Interest, curiosity and needs of students are considered and the learning environment is organised or adapted accordingly, in order to augment students' insights into the relevance and meaning of the content.
PR 3	Everyday-life context: The derivation or induction of the theoretical concepts discussed in the lessons, or examples and applications thereof, is oriented towards the everyday life of students.
PR 4	Transfer to other subjects: The new knowledge is transferable to other topics or subjects, and the transfer is made explicit by some examples, strengthening the insights of students into the importance and significance of what they have learned.
SI 1	Student-student interaction: The intensity, diversity and reciprocity of discussions on the topic are estimated.
SI 2	Student-teacher interaction (classroom): The intensity, diversity and reciprocity of discussions on the topic are estimated.
SI 3	Student-teacher interaction (during individual or group work): The intensity, diversity and reciprocity of discussions on the topic are estimated.
IL 1	Space for independent learning: During the lessons, students are provided with space and time for independent learning. Students get the opportunity to organise their learning considering several factors, such as the choice of a problem to solve, the choice of method, the form of collaboration or timing.
IL 2	Encourage rethinking: The teacher encourages students to check the feasibility of their thoughts and to reflect on them. Answers are challenged and examined from several perspectives.
IL 3	Foster metacognition: The teacher invites students or groups of students to reflect on their own learning strategies or their stage in the process of problem solving.
IL 4	Benefit from independent learning: Students work on a problem or task in a concentrated manner. They develop relevant questions, ideas or solutions, advancing their understanding or skills.
IL 5	Metacognitive abilities: When asked, students can explicate their thinking, learning or problem solving to others, or can make metacognitive statements spontaneously during discussions.

CK construction of knowledge, *PR* personal relevance, *SI* social interaction, *IL* independent learning

Appendix 2

R script for K-means algorithm (Beerenwinkel 2007, p. 78)

For the K-means clustering algorithm, the best solution was selected by maximising the quotient of between-cluster variation to within-cluster variation (Hand et al. 2001, p. 298):

$$\mathrm{B}: \text{set of computed cluster solutions} \rightarrow \mathbb{R}, C \rightarrow \frac{\mathrm{bc}(C)}{\mathrm{wc}(C)}$$

with K the number of clusters, $r_{k(j)}$ the cluster centre of the $k(j)$th cluster and C_k the kth cluster and where the within-cluster variation, wc, and the between-cluster variation, bc, are defined as follows:

$$\mathrm{wc}(C) = \sum_{k=1}^{K} \sum_{x \in C_k} \|x - r_k\|^2$$

$$\mathrm{bc}(C) = \sum_{1 \leq j < k \leq K}^{K} \|r_j - r_k\|^2, j \neq k$$

Homogeneity was tested by calculating the ratio of the variance of each variable i within a particular cluster C_k to the variance of the entire sample $\left(\frac{\mathrm{Var}(i, C_k)}{\mathrm{Var}(i)}\right)$.

References

Alfieri, L., Brooks, P. J., Aldrich, N. J., & Tenenbaum, H. R. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology, 103*(1), 1–18.

Andersen, H. M., & Nielsen, B. L. (2013). Video-based analyses of motivation and interaction in science classrooms. *International Journal of Science Education, 35*(6), 906–928.

Bathgate, M. E., Schunn, C. D., & Correnti, R. (2014). Children's motivation toward science across contexts, manner of interaction, and topic. *Science Education, 98*(2), 189–215.

Baviskar, S. N., Hartle, R. T., & Whitney, T. (2009). Essential criteria to characterize constructivist teaching: derived from a review of the literature and applied to five constructivist-teaching method articles. *International Journal of Science Teaching, 31*(4), 541–550.

Beerenwinkel, A. (2007). *Fostering conceptual change in chemistry classes using expository texts*. Berlin: Logos.

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: models, tools, and challenges. *International Journal of Science Teaching, 32*(3), 349–377.

Börlin, J., Beerenwinkel, A., & Labudde, P. (2014). *Bericht analyse MINT- Nachwuchsbarometer* [Technical report: STEM-survey: teenagers', university students' and adults' interest in and experiences with science, technology, engineering and mathematics]. Basel: Centre for Science and Technology Education, University of Applied Sciences and Arts Northwestern Switzerland (FHNW).

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (2000). *How people learn: brain, mind, experience, and school*. Washington: National Academy.

Brophy, J. (2004). *Motivating students to learn*. Mahawah: Lawrence Erlbaum Associates.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education, 95*(6), 1049–1065.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268.

Duffy, T. M. (2009). Building lines of communication and a research agenda. In S. Tobias & T. M. Duffy (Eds.), *Constructivist instruction: success or failure?* (pp. 351–367). New York: Routledge.

Duit, R., Treagust, D., & Widodo, A. (2008). Teaching science for conceptual change: theory and practice. In S. Vosniadou (Ed.), *International handbook of research on conceptual change* (pp. 629–646). New York: Routledge.

Fischer, H. E., Labudde, P., Neumann, K., & Viiri, J. (2014). *Quality of instruction in physics: comparing Finland, Germany and Switzerland*. Münster: Waxmann.

Green, S. K., & Gredler, M. E. (2002). A review and analysis of constructivism for school-based practice. *School Psychology Review, 31*(1), 53–70.

Grouzet, F. M. E., Vallerand, R. J., Thill, E. E., & Provencher, P. J. (2004). From environmental factors to outcomes: a test of an integrated motivational sequence. *Motivation and Emotion, 28*(4), 331–346.

Hammer, D. (1997). Discovery learning and discovery teaching. *Cognition and Instruction, 15*(4), 485–529.

Hand, D., Mannila, H., & Smyth, P. (2001). *Principles of data mining*. Cambridge: MIT.

Helaakoski, J., & Viiri, J. (2012). Developing an instrument to measure students' situational motivation. In H. Krzywacki, K. Juuti, & J. Lampiselkä (Eds.), *Matematiikan ja luonnontieteiden opetuksen ajankohtaista tutkimusta* [Current research on mathematics and science education] (Publications of the Finnish Research Association for Subject Didactics Studies in Subject Didactics, Vol. 2, pp. 147–167). Helsinki: Unigrafia.

Hmelo-Silver, C. E. (2004). Problem-based learning: what and how do students learn? *Educational Psychology Review, 16*(3), 235–266.

Jones, P. R., Laufgraben, L. J., & Morris, N. (2006). Developing an empirically based typology of attitudes of entering students toward participation in learning communities. *Assessment & Evaluation in Higher Education, 31*(3), 249–265.

Jurik, V., Gröschner, A., & Seidel, T. (2014). Predicting students' cognitive learning activity and intrinsic learning motivation: how powerful are teacher statements, student characteristics, and gender? *Learning and Individual Differences, 32*, 132–139.

Keller, M. (2011). *Teacher enthusiasm in physics instruction* (PhD thesis, University of Duisburg/Essen). Duisburg/Essen: University library of Duisburg/Essen. Retrieved May 4, 2014, from http://duepublico.uni-duisburg-essen.de/servlets/DocumentServlet?id=25993.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86.

Kobarg, M., & Seidel, T. (2005). Coding manual—process oriented teaching. In T. Seidel, M. Prenzel, & M. Kobarg (Eds.), *How to run a videostudy* (pp. 108–144). Münster: Waxmann.

Kuyper, H., von der Werf, M. P. C., & Lubbers, M. J. (2000). Motivation, meta-cognition and self-regulation as predictors of long term educational attainment. *Educational Research and Evaluation, 6*(3), 181–205.

Neumann, K., Fischer, H. E., Labudde, P., & Viiri, J. (2014). Design of the study. In H. E. Fischer, P. Labudde, K. Neumann, & J. Viiri (Eds.), *Quality of instruction in physics: comparing Finland, Germany and Switzerland* (pp. 31–48). Waxmann: Münster.

Niemiec, C. P., & Ryan, R. M. (2009). Autonomy, competence, and relatedness in the classroom: applying self-determination theory to educational practice. *Theory and Research in Education, 7*(2), 133–144.

OECD. (2007). *PISA 2006: science competencies for tomorrow's world* (volume 1: analysis). Paris: OECD.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*(4), 667–686.

Rakoczy, K., & Pauli, C. (2006). Hoch inferentes rating: beurteilung der qualität unterrichtlicher prozesse. [High-inference rating: assessing the quality of teaching processes]. In E. Klieme, C. Pauli, & K. Reusser (Eds.), *Dokumentation der Erhebungs- und Auswertungsinstrumente zur schweizerisch-deutschen Videostudie „Unterrichtsqualität, Lernverhalten und mathematisches Verständnis* [Documentation of the instruments applied in the Swiss-German video study: Teaching quality, learning behaviour and mathematics comprehension"] (Vol. 3, pp. 206–233). Frankfurt am Main: GFPF/DIPF.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: classic definitions and new directions. *Contemporary Educational Psychology, 25*, 54–67.

Seidel, T. (2006). The role of student characteristics in studying micro teaching-learning environments. *Learning Environments Research, 9*(3), 253–271.

Seidel, T., & Prenzel, M. (2006). Stability of teaching patterns in physics instruction: findings from a video study. *Learning and Instruction, 16*, 228–240.

Spoden, C., & Geller, C. (2014). Uncovering country differences in physics content knowledge and their interrelations with motivational outcomes in a latent change analysis. In H. E. Fischer, P. Labudde, K. Neumann, & J. Viiri (Eds.), *Quality of instruction in physics: comparing Finland, Germany and Switzerland* (pp. 49–63). Waxmann: Münster.

Taylor, P. C., Fraser, B. J., & Fisher, D. L. (1997). Monitoring constructivist classroom learning environments. *International Journal of Educational Research, 27*(4), 293–302.

Tobias, S., & Duffy, T. M. (Eds.). (2009). *Constructivist instruction: success or failure?* New York: Routledge.

Urdan, T., & Schoenfelder, E. (2006). Classroom effects on student motivation: goal structures, social relationships, and competence beliefs. *Journal of School Psychology, 44*, 331–349.

Urdan, T., & Turner, J. C. (2005). Competence motivation in the classroom. In A. J. Elliot & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 297–317). New York: Guilford.

von Arx, M. (2014). Constructivist approaches to teaching. In H. E. Fischer, P. Labudde, K. Neumann, & J. Viiri (Eds.), *Quality of instruction in physics: comparing Finland, Germany and Switzerland* (pp. 177–192). Waxmann: Münster.

Widodo, A., & Duit, R. (2004). Konstruktivistische sichtweisen vom lehren und lernen und die praxis des physikunterrichts [Constructivist views on teaching and learning and practice in physics classes]. *Journal of the Didactics of Science Education, 10*, 233–255.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: an analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research, 72*(2), 131–175.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education, 96*(5), 878–903.

Wolters, C. A. (1999). The relation between high school students' motivational regulation and their use of learning strategies, effort, and classroom performance. *Learning and Individual Differences, 11*(5), 281–299.