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The impact of science motivation on cognitive achievement within a 3-lesson unit about renewable energies

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ABSTRACT

Our study analyzed the influence of motivation towards science in relation individual cognitive achievement scores. 232 10th graders of college preparatory school level ('Gymnasium') completed a cognitive achievement test three times and a questionnaire quantifying motivation towards science once. A three-lesson module dealt with aspects of the topic *renewable energies*. The knowledge test was applied one week before (T-0), directly after (T-1) and six weeks after (T-2) participation in the learning module. The questionnaire on science motivation was completed at T-0 in order to receive unaffected data. A test-retest group (acting as control group) of 37 students completed the questionnaires with no intervention. Three motivational groups were selected: highly motivated, intermediate and less motivated. The intervention group showed substantial knowledge gain in short- and in long-term perspectives, almost independently of motivational levels. A positive linear relation between motivation and content knowledge was observable for each test schedule. In particular, intrinsic factors are shown to be responsible for this relationship.

We recommend implementing appropriately designed educational settings to promote intrinsic aspects in order to foster performance almost independently of pre-existing knowledge and science motivation We presume pre-existing knowledge as well as learning to be influenced by motivation towards science. Also, pre-existing knowledge may influence individual motivation towards science. Consequently, beyond scientific contents, a focus on motivation of adolescents in science may lead to a synergetic effect for life-long learning.

1. Introduction

In a world where science and technology are as present as today, we should know and understand science to live our lives appropriately. The level of scientific understanding existing in adult population can be summarized in the broad definition: *scientific literacy* (DeBoer, 2000). Laugksch (2000) described reasons for the importance of scientific literacy for the common and the individual good: for example, the benefits of a scientifically literate society may positively influence economic levels or sound decision-making. Also each individual can experience advantages of being scientifically literate by knowing about health maintenance (e.g. diet, addictions or screening programs), by finding better chances of employment and by feeling more competent and confident when dealing with science or technological-related issues in everyday life. It is not surprising that national education standards emphasize the important role of scientific literacy within the scope of science education, for instance in Germany (KMK, 2005). DeBoer (2000) described teaching science as important in raising interest effecting life-long learning: What students learn in school will influence their attitude towards science, but what makes them scientifically literate needs to grow and develop over time. A decline of interest, attitudes and motivation towards science during school careers may inevitably affect public scientific literacy (Rocard et al., 2007). To investigate scientific literacy, many potential dimensions need consideration in an educational context, like the nature of science, science content knowledge or attitudes towards the nature of science (Laugksch, 2000). As mentioned above, science knowledge can influence attitudes towards science but there is also evidence for a move in the opposite direction (Osborne, Simon, & Collins, 2003). Consequently, science knowledge may depend on certain aspects of attitudes towards science. Since attitude towards science is a construct consisting of many sub-constructs (Gardner, 1975), it is

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Abbreviations: SD, standard deviation; MD, mean difference; M, mean; SMQ-II, Science Motivation Questionnaire II; SDe, self-determination; IM, intrinsic motivation; SE, self-efficacy; CM, career motivation; GM, grand motivation.

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not holistically measurable, and hence we restricted our approach to *motivation towards science*.

1.1. Measuring science motivation

In a very general way, motivation is regarded as something that arouses, directs and sustains our actions: although motivation is not directly observable, it can be derived from observed activities or verbalizations. It is goal-oriented, requires mental or physical activity and is responsible for the maintenance of these activities (Schunk, Pintrich, & Meece, 2008). In a scholastic context, motivation influences methods of learning by leading to effort, persistence and commitment, e.g. doing homework conscientiously, paying attention during lessons, taking notes or asking questions (Zimmerman, 2000).

Motivation is a construct influenced by and consisting of many factors as steadily perceptible in daily life, e.g., do I complete something because I really like it or because somebody wants me to do it and I assume to get a positive feedback when I show the expected behavior (Ryan & Deci, 2000). Vedder-Weiss and Fortus (2012) extracted from empirical interview data four main domains of goal-setting motives in science: external and process-oriented (e.g. attendance or endeavor), internal and process oriented (e.g. fun, curiosity, personal relevance), external outcome oriented (short-term achievements like grades and long-term achievements like a career); and internal outcome oriented (e.g. knowing, understanding, and remembering). Vedder-Weiss and Fortus (2012) added the sense of autonomy as a motive.

The Science Motivation Questionnaire II (SMQ-II, Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011), based on the social-cognitive theory of human learning (Bandura, 1986), combines internal and external aspects of science motivation as an implied multi-component construct covering five sub-categories: Two external factors cover both extremes of a continuum; the drive to do something because of expected external compensation (*e.g.* a good school grade) or because the outcomes are judged valuable (*e.g.* career options) (Ryan & Deci, 2000). Three internal factors include the fields of enjoyment and interest (subscale called *intrinsic motivation*) as well as perceived self-efficacy and self-determination, meaning the perceived competence in performing a task and the autonomy felt during its performance (Ryan & Deci, 2000). The subscales *intrinsic motivation* and *self-efficacy* in our opinion focus on internal categories whereby the subscale *self-determination* focuses on achievement behavior as an external process.

1.2. Science achievement and science motivation

Whereas extrinsic factors such as grades play a prominent role in the science motivation of adolescents (Schumm & Bogner, 2016; Vedder-Weiss & Fortus, 2012), intrinsic aspects like individual feeling of autonomy (Black & Deci, 2000) or perceived self-efficacy (Pajares, 2002) are assumed to act as dominant influential factors on academic achievement. Bandura (1993) concluded that perceived self-efficacy even directly influences memory performance and indirectly cognitive effort. Simultaneously, interest (situational as well as personal) is regarded as related to positive cognitive performances such as memory capacity, understanding and achievement (Schunk et al., 2008). The Science Motivation Questionnaire includes *intrinsic motivation* by covering aspects of personal interest, as a preference for a certain topic, general liking, personal enjoyment, importance and personal significance (Schiefele, Krapp, & Winteler, 1992).

These findings imply different aspects of motivation as linked to academic performance. Empirical studies support those results also for the field of science in scholastic or university settings (e.g., Britner & Pajares, 2006; Singh, Granville, & Dika, 2002; Velayutham, Aldridge, & Fraser, 2011). Most studies examining different aspects of motivation and achievement used course grades or grade means as measures of achievement. In fact, grades, and especially final grades or grade means, are composed of many aspects that, for instance, reflect learning, positioning in class, class attendance, carefulness (for instance in doing homework, in-class work, reports and exams) or commitment for doing extra work/ extra presentation or participation in laboratory approaches (Britner & Pajares, 2006; Obrentz, 2012; Pajares, 1996). Motivation surely provokes certain behaviors like attendance and appropriate behavior in class, question-asking and help-seeking or commitment that positively influences academic performance (Schunk et al., 2008) as reflected by good grades. Despite numerous studies dealing with motivation and achievement, uncertainties remain about how achievement is influenced by science motivation of students.

In order to allocate relationships of invisible internal processes such as cognitive learning to science motivation, our study objectives were: (i) Can a three-lesson module yield persistent knowledge? (ii) If yes, can we observe a relation between science motivation and science content knowledge? (iii) Do highly motivated students learn better than rather unmotivated ones? (iv) Are certain motivational facets especially connected with science content knowledge?

2. Methods

2.1. Participants

232 10th graders (M ± SD: 16.02 ± 0.56; 50.41% female) of the college preparatory secondary school level (‘Gymnasium’) participated in our quasi-experimental study. ‘Gymnasium’ is a school of advanced secondary education. It emphasizes academic learning to prepare students for higher education at a university and it leads to the higher education entrance qualification. Pupils who perform well are permitted to move to a ‘Gymnasium’ after finishing primary education, aged between 10 and 11. Depending on the performance, students stay at the ‘Gymnasium’ until grade 12 or 13, aged between 17 and 19.

Teachers registered their classes for participation in our learning program about renewable energies and students agreed tto participation by informed consent. A test-retest group of 37 upper secondary school students (M ± SD: 15.99 ± 0.99; 67.57% female) only completed questionnaires, without taking part in the intervention (thus acting as a control group).

2.2. Learning program about renewable energies

Our three-lesson module (135 min) employed 8 hands-on workstations covering contents from the formation and use of fossil fuels to the impact of burning hydrocarbons to alternative energy supply like energy from sun, wind, water and biomass. An optional station was provided for fast-working students. Additionally, an interactive computer-based work station about energy system transformation was included (for an overview see attachment). The specific topics followed the current curriculum including sustainable development, carbon cycle and greenhouse effect or issues of energy supply and alternative energies. The learning module had been pilot-tested and examined by educational experts, instructors and students. We designed a short-term program as it reflects in our opinion a realistic everyday teaching unit.

Students worked in pairs (assembled by free choice), guided by a workbook. After a short introduction about the structure of the learning program, students chose autonomously the subsequent