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Computer-related self-concept: The impact on cognitive achievement

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ABSTRACT

Teaching and learning in outreach laboratories is suitable for completion of multiple hands-on experiences of students. Digital contents may support and further enrich individual haptic experiences. Nevertheless, individual variables such as computer-related self-concepts are supposed to intervene with the cognitive learning success within this context. This potential interrelationship was a major focus of our study completed in an outreach laboratory where an eLearning module specifically was integrated into a hands-on centered gene-technology module. By monitoring cognitive knowledge levels and simultaneously applying the computer-related self-concept of 162 German students (11th grade), an increase in knowledge became apparent independently of individual computer-related self-concepts. This missing relationship exemplarily fosters the assumption that computer-supported learning may suite every student regardless of computer-related self-concept scores.

1. Introduction

1.1. Student-centered learning at an outreach-laboratory

All of us had heard about an historic experiment: Two kittens from the same litter were placed in an experimental carousel for several hours daily. One of the kittens sat in a gondola on the one end of the carousel and the other one was free to move itself but also connected to the movable arm of the carousel. In consequence, both kittens were linked in a way that every movement from the active kitten causes equivalent movements for the kitten in the gondola (outside testing times both kittens were kept with their mother in darkness). This experiment was published by Held and Hein (1963) and is commonly known as the kitten carousel. After several weeks, both kittens were sat on a small plank which they could leave by a small jump on the one side or a frightening fall (without risk of injury) on the other side: Just the active kitten always took the easy way by using a small jump. The results showed that visual stimulation produced by others is not sufficient to develop visually-guided behavior. Applied to school contexts, a mere presentation of knowledge packages or demonstration of teacher-centered experiments is insufficient (see web reference). In out-of-school laboratories, students mostly work *actively* during the student-centered learning modules. Within this context, autonomous hands-on learning was always shown to increase knowledge and conceptual understanding as well (Langheinrich & Bogner, 2015; Scharfenberg, Bogner, & Klautke, 2007). Furthermore, newly acquired knowledge was repeatedly shown as more stable than in conventional and teacher-centered science classes (e.g., Gerstner & Bogner, 2010; Randler & Bogner, 2006). However, it needs further consolidation that hands-on learning offers a high potential to motivate students, in particular in terms of enjoyment, wellbeing and usefulness (Sturm & Bogner, 2008). Authentic first-hand experiences apparently allow analyzing and constructing scientific assertions by offering realistic problems and experiments in realistic environments (Hofstein & Lunetta, 2004). Additionally, out-of-school classrooms apparently offer interesting and useful environments with a positive effect on well-being (Meissner & Bogner, 2011). All these positive aspects of out-of-school laboratories may offer suitable chances for students to really feel as a scientist for a short time. By including eTools and eResources in teaching and learning science in an out-of-school laboratory (Hofstein & Lunetta, 2004), further enrichment may occur by better understanding of complex issues and by increasing interest or positive attitudes towards the subject matter (e.g., Conradty & Bogner, 2011; Kiboss, Ndirangu, & Wekesa, 2004; Stern, Barnea & Shauli, 2008). In consequence, the combination of eLearning and out-of-school laboratories may match perfectly to offer a holistic learning environment.

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1.2. Visualizing the invisible: eLearning-supported learning and self-concept

In teaching molecular issues such as genetics, it often gets relevant to refer to a non-visible level to explain visible phenomena. With the help of dynamic visualization technology students can get a chance to watch the molecular level which is otherwise indistinguishably (Levy, 2013). In particular, virtual models ensure deeper understanding of topics and prevent 'inert' knowledge (Ferk, Vrtacnik, Blejec, & Gril, 2003; Ryoo & Linn, 2012). This may reason in directing a student's attention to task-relevant virtual manipulations (Barrett, Stull, Hsu, & Hegarty, 2015). Newly acquired knowledge by working with dynamic visualizations may not only act as a procedural-motor but also produce declarative and problem-solving knowledge (Höffler & Leutner, 2007). Furthermore, digital representations of abstract objects are suitable for students to construct abstract and complex concepts (Olympiou, Zacharias, & deJong, 2013). On a student's side, working with 3D representation formats causes positive attitudes, increases interest and let learning material appear more attractive by still maintaining cognitive loads compared to 2D formats (Huk, Steinke, & Floto, 2010; Korakakis, Pavlatou, Palyvos, & Spyrellis, 2009). Based on literature research, however, the mentioned positive predications of computer-based learning also require critical reflection as self-concepts repeatedly have been shown to affect cognitive achievement (e.g., Guay, Marsh, & Boivin, 2003; Marsh, 1990; Marsh & Craven, 2006). Marsh, Trautwein, Lüdtke, Köller, and Baumert (2005), moreover, showed self-concept as a valid predictor of subject grades in classrooms. By considering computer performance outcomes, the computer-related self-concept becomes a relevant variable (Christoph, Goldhammer, Zylka, & Hartig, 2015). Usually, it is defined as a dynamic phenomenon which affects a persons' ICT-related performance and itself is affected by past experiences with computers and a persons' individual environment (Janneck, Vincent-Höper, & Ehrhardt, 2013; Langheinrich, Schönfelder, & Bogner, 2015). Langheinrich et al. (2015) reported for boys a higher computer-related self-concept in school contexts which is in a strict relation to higher theoretical and practical basic computer skills according to Christoph et al. (2015). The latter described the computer-related self-concept as important by causing differences in computer-related learning issues. Janneck et al. (2013) presented the computer-related self-concept as a novelty to evaluate computer-related emotions, attitudes and behaviors. In school contexts, therefore, it becomes more and more important to take the effect of prior self-concepts into consideration when drawing conclusions about academic achievement (Marsh, 1990).

1.3. Research questions

To sum up, implementation of dynamic visualization technologies may offer teaching opportunities in non-visible levels and, thus, provide a good chance to support cognitive learning in outreach laboratories. Nevertheless, inter-individual differences in computer-supported learning need specific consideration as computer-related self-concept scores may differ substantially in an individual level. Based on the presented literature outcomes, our research questions are twofold: (i) Does a computer-supported gene technology module at an outreach laboratory increase individual knowledge sustainably? (ii) Does a high computer-related self-concept better retain permanent cognitive achievement levels than a lower one may do?

2. Methods

2.1. The gene technology module: DNA-Our genome

The learning content of our gene technology module *DNA-Our genome* strictly followed the Bavarian syllabus (Bavarian Ministry of Education, 2007). It was a day-long teaching unit by including six complete lessons (270 min) for completion including the implementation of the student survey at the end. All interventions were done by the same teacher and the same tutor. Students worked in groups of two. Our module was designed according to Scharfenberg and Bogner (2011) in a one-step approach (Table 1). It started with an initial pre-lab phase to prevent learning difficulties just because of lacking basic experimental skills (Bryce & Robertson, 1985; Scharfenberg & Bogner, 2011). The following experimental phases consisted of a theoretical minds-on phase followed by an experimental hands-on phase. All in all, two experiments were completed: the isolation of genomic DNA from mucosa cells and the agarose gel electrophoresis of the own isolated DNA. Both experimental sections were linked by a theoretical eLearning phase. During the eLearning unit, students received essential knowledge about the DNA structure while working with a 3D molecule viewer (interactive DNA model, see http://www.chemie-interaktiv.net; © R.-P. Schmitz). The 3D molecule viewer was a tool specifically designed for implementing in school contexts. The teaching-unit was pilot-tested to optimize experiments as well as learning materials.

2.2. Student sample and design of the study

Altogether, 162 Bavarian 11th graders at the highest stratification secondary school level labeled "Gymnasium" (age $M = 17.05$, $SD = 0.68$, 79 girls, 81 boys, 1 participant without reporting gender) participated in our study. For assessing knowledge increases, students completed a knowledge pre-test (T0) one week before the teaching unit, a post-test (T1) directly after the teaching unit and a retention-test (T2) nine weeks after the teaching unit (Fig. 1). The knowledge test consisted of 20 content items, 8 of them evaluating the project-oriented knowledge of the laboratory activity and 12 evaluating the content knowledge of the eLearning unit (item examples, see Appendix). At each test schedule, the order of questions was changed and also the answer ordering was switched. The reliabilities (Cronbach's alpha) are presented in Table 2. The teaching-unit as well as the knowledge test was following the Bavarian school curriculum. Therefore, content validity of the questionnaire is assumed. The analysis was conducted with sum scores: every correct answer was rated with

Table 1
Phases and descriptions of the gene technology module *DNA-Our genome*.

Phase of teaching	Description	Students' acitivities
Pre-lab phase	Introduction to working area	Hands-on
Experimental phase 1	Isolation of DNA from the mucous membrane	Mind-on Hands-on
eLearning phase	Learning the basic knowledge about the DNA using an interactive DNA model	Minds-on
Experimental phase 2	Agarose gel electrophoresis of the own isolated DNA	Minds-on Hands-on