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Does the issue of bionics within a student-centered module generate long-term knowledge?

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ABSTRACT

Our educational module focused on selected bionics examples linking the basis of technology to biology. 324 students participated in an outreach intervention in a zoo. We monitored individual knowledge acquisition at three testing points: two weeks before (T0), immediately after (T1) and six weeks (T2) after participation. We monitored a subsample of 191 for longer (twelve weeks (T3) and one year (T4) later). Our module consisted of two units, a seminar room module and an aquarium module with living animals. As expected, knowledge peaked directly after program participation and dropped back after six weeks, but never fell as low as prior knowledge. Even one year later, the knowledge level remained constant at the level reached six weeks after participation. Prior knowledge was shown to be dependent on technology interest and social implication scores before participation.

1. Introduction

Technology today is present everywhere (Ardies, De Maeyer, Gijbels, & van Keulen, 2015). The young generation grows up in a technical world including social media and communication technology (O'Keeffe & Clarke-Pearson, 2011). Although policy makers and commercial companies require a level of technological education, our society largely regards technology negatively (Ardies, De Maeyer, & David Gijbels, 2013). Therefore it is important that even young students be motivated for and interested in technology and science. For that it's necessary to show the prior knowledge of technology interest and social aspects of technology (Rennie & Jarvis, 1995). Thereupon students will become more favorable in science, when they make acquisitions with positive feelings and experiences in scientific fields (Akpınar, Yıldız, Tatar, & Ergin, 2009). Teachers often regard technology as an applied science with potential for social transformation, and for connecting science, society and technology (Bouras & Albe, 2008). It is this connection between technology and science that is for importance in the present study. George (2006) described young students as higher scoring in usability of technology and pointed to a transitional passage from primary to secondary school and to the need of motivation for science and technology. Secondary school students often have other expectations of science with motivational consequences effect upon long-term career choices. During a school career reduction of positive attitudes towards science have often been recorded (Speering & Rennie, 1996). To overcome this, teachers and teacher educators need to broaden their experience to promote positive attitudes to science in the transition from primary to secondary school (Mc Robbie, 2000). For this reason, it is necessary to develop appropriate educational programs. In general, innovative topics are assumed to promote students' interest in science (*Author*).

1.1. Bionics linking technology and science in classroom

Bionics is a research field which improves technical applications including the biology and technology point of views to find appropriate solutions and provides many examples of how nature can act as a source of technical solutions (Nachtigall & Wisser, 2013). As a new science field, it has produced numerous inventions and raised expectations for the next decade: the lotus-effect is one of the best knowns examples, where surfaces remain dirt-free although they grow in sludgy water. A self-cleaning mechanism based on a wax-coated, bumped surface has been identified as the reason for this, as such surfaces produce rolls of water that wipe away any dirt (Neinhuis & Barthlott, 1997). The lotus-effect has been adapted to produce some para-bionics products (Barthlott, Mail, & Neinhuis, 2016). Another example is shark skin, whose exiguous parallel ridges on a longitudinal body axis dramatically reduce drag (Oeffner & Lauder, 2012). Riblets adapted to shark skin ridges are used on aircraft to reduce air flow resistances (Bechert, Bruse, Hage, Van Der Hoeven, & Hoppe 1997). Archetypes in nature have inspired technicians to improve existing technology by copying and/or adjusting master plans of nature. New and interesting

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phenomena in nature have inspired technicians to improve existing technology and build up new inventions. Bringing this relevance of bionics into classrooms may motivate students towards science and technology (Neurohr & Dragomirescu, 2007).

1.2. Knowledge

Teaching is a very complex and exhausting duty as Mishra and Koehler (2006) have explained. A central dimension of teaching is knowledge: as traditionally content knowledge is required of almost all school curricula and is defined as the “amount and organization of knowledge per se” (Shulman, 1986, S.9). The learning outcomes are subject contents and also “a description of what is to be done with or to that content” (Krathwohl, 2002, S.213). Knowledge has also many other types such as pedagogical content knowledge. Teachers have to understand the difficulties and possibilities of content learning including different preconceptions such as students’ age, origin or cognitive abilities (Shulman, 1986). Pedagogical content knowledge is more than straight content knowledge, the teachers also need appropriate educational practices, which are represented in pedagogical knowledge. A third type of knowledge is technology knowledge, because “technologies have come to the forefront of educational discourse primarily because of the availability of a range of new, primarily digital, technologies and requirements” (Mishra & Koehler, 2006, S.1023). The Mishra and Koehler (2006) study suggests a connection between content, pedagogy and technological knowledge which is necessary for good teaching. The teachers have to consider these three dimensions when constructing learning environments. The pedagogical, technological knowledge of teachers helps to provide appropriate content knowledge, which could also assigned to the different domains as Bildungsrat (1970) suggested: reproduction, the repetition of straight content knowledge as taught; reorganization, students’ capacity to rearrange newly acquired knowledge; transfer, where common principles are transferred to similar concepts; and problem solving, where students use acquired knowledge to approach new problems. We focused on reproduction, reorganization and the transfer of content knowledge.

Surprisingly, students’ knowledge acquisition is not necessarily dependent upon the duration of modules. Even half-day programs produce sustainable knowledge increase, as *Author* have shown in the context of a drinking water module. *Author* had described similar results in a module of three consecutive lessons. Long-lasting knowledge is of interest to all studies independently of program duration: One-day or half-day programs are expected to show the best possibilities with the curriculum circumstances, where limited time forces teachers to employ short-time interventions. Differing teaching methods play an important role in the acquisition of long-term knowledge as Beers and Bowden (2005) has shown for problem-based learning. *Author*, for instance, demonstrated that long-term knowledge gains produced by week-long programs may persist for a half year. Farmer, Knapp, & Benton (2007) have also demonstrated long-term effects for environmental education school field trip one year after intevention.

1.3. Cooperative learning

Cooperative learning is more than putting a group of students together and letting them talk to each (Johnson & Johnson, 1994). There are five conditions under which cooperative learning shows positive effects: “1. Clearly perceived positive interdependence, 2. Considerable promotive (face-to-face) interaction, 3. Clearly perceived individual accountability and personal responsibility to achieve the group’s goals, 4. Frequent use of the relevant interpersonal and small-group skills, 5. Frequent and regular group processing of current functioning to improve the group’s future effectiveness” (Johnson & Johnson, 1994, S.32).

Cooperative learning in pairs or small groups seems to yield better achievement than individual learning scenarios: paired groups, for example, show better self-esteem (Bertucci, Conte, Johnson, & Johnson, 2010). The combination of hands-on and cooperative learning may generate better results compared to control classes (Bilgin, 2006). A meta-analysis of 65 studies in the context of cooperative learning showed both positive cooperation and better cognitive achievement and attitudes (Kyndt et al., 2013). We selected a cooperative learning approach where peers can motivate each other, potentially helping the low interest scorer to be motivated by a classmate. Studies of cooperative learning in a zoo are rare in the literature. For instance, *Author* monitored knowledge increase in a cooperative learning scenario at a zoo, where work stations discussing marine mammals showed a knowledge increase directly after participation, followed by a decrease six weeks later. A cooperative learning scenario at a zoo in combination with the topic of bionics issue offers the potential to increase knowledge and interest in science and technology in general.

1.4. Research goals

The present study focused on the cognitive achievement of a short-time cooperative learning program about bionics at a zoo. The objectives of our study were: (I) to analyse the change in knowledge in the total module and the sub-modules (II), to analyse the long-term effects over one year, (III) to examine the relationship between knowledge acquisition and individual technology pReferences

2. Methods

2.1. Intervention design and context

The bionics module required five school lessons (225 min) including completing a final survey (Table 1). All interventions were guided by the same teacher and the same tutor (university employees), and followed the same agenda. To ensure similar initial knowledge levels at the beginning the bionics module, a teacher-guided pre-group introductory phase focused on bionics and selected issues about bionics, biology and technology.

The following module parts (seminar room and aquarium modules) were cooperative learning forms, with students working in groups of 3 or 4. Teachers merely supervised in the background and answered student questions on request. The group work in the seminar room and the aquarium module was self-explanatory, with hands-on work stations guided by a work book, issued to every student at the beginning of the program. The seminar room module was conducted in a special classroom in the zoo and the aquarium module was held at the aquaria in the zoo. Both modules used several workstations, four in the seminar room module and four in the aquarium module (Fig. 1). Students were free to choose the sequence of stations, subject to availability.

2.1.1. Seminar room modul

In the seminar room module (in the zoo), students learned about streamline shapes of selected water animals by performing an

Table 1
Module phases and description.

Phase of teaching	Description	Students activity	Time (Minutes)
pre-group phase	introduction	teacher-guided learning	25
module 1 (seminar room module)	seminar room activity	hands-on	85
module 2 (aquarium module)	concentrating on the living animal	hands-on	85
post-group phase	exhibition “BIONICUM”	example of informal learning	30