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Digital Geogames to foster local biodiversity

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Abstract: The valuing of biodiversity is considered to be a first step towards its conservation. Therefore, the aim of the BioDiv2Go project is to combine sensuous experiences discovering biodiversity with mobile technology and a game-based learning approach.

Following the competence model for environmental education (Roczen et al, 2014), Geogames (location based games on smartphones) for experiential outdoor learning activities are developed. The Finde Vielfalt Simulation (FVS) Geogame focuses on adolescent visitors of German youth hostels. The FVS-players are involved in a narrative keeping the traditions of their ancestors' heritage as decisions are needed to balance biodiversity and economic success. They discover the natural environment and they solve location-based tasks at several places. If the players manipulate a simulation successfully they stand the test of the ancestors.

The initial theoretical framework consists of the components biodiversity-related attitudes, behaviour and knowledge, general environmental behaviour and attitude towards nature. According to the Uses and Gratification Theory, the game-related enjoyment is added. For the assessment different scales were developed or adapted and tested for secondary-school children. The framework evolved stepwise through systematic expert hearings, interviews with the target group, participant observation as well as through an online survey. In a first step the situational interest was considered to be important for the valuing of biodiversity. The final version of the framework was used and validated within a pilot study with 180 secondary school students.

The framework development was a highly transformative process engaging different actors, using complementary methodological approaches and integrating different disciplinary perspectives.

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1 Introduction

The aim of the current research project *BioDiv2Go (Biodiversity to go)* is to create sensuous experiences and an appreciation of biodiversity using mobile technology. Different types of digital games for experiential outdoor learning activities are developed and tested according to a framework derived from recent empirical findings.

Conceptual frameworks to increase the awareness, attitudes and knowledge are as diverse as the biodiversity itself: Menzel and Bögeholz (2009) construct a cognitive framework for biodiversity learning from a sustainability perspective, Lindemann-Matthies and colleagues (2009) focus on biodiversity education as (1) a holistic challenge comprising different perspectives, such as teacher-trainings, the implementation of different modules in schools including biological, economical, ethical, social and political concerns, outdoor activities and out-of-classroom settings. Furthermore they highlight (2) the understanding of the relationship between biodiversity and the individuals behaviour and (3) the understanding of the connection between biodiversity and human wellbeing.

Using mobile technologies in contextual and location-based learning could add value within well-designed learning environments in general and specifically in environmental education and education for sustainable development (Brown, 2010).

Using mobile technologies offer exclusive possibilities for learning and teaching. As explained in the SAMR framework (Anderson, 2013, Puentedura 2006, see table 1) technology could transform learning in a previously inconceivable way: For instance, one can easily access scientific learning platforms that allow to manipulate real experiments, to work on real data and to explore scientific concepts (*cf* learning with Atlas@CERN[1] or with the HOBOS[2] platform) easily via the internet. Considering the

1 http://www.atlas.ch
2 http://www.hobos.de

Table 1: The SAMR framework for the use of technology in learning processes (according to Anderson, 2013, p. 18, derived from Puentedura, 2006)

Level	Definition	Improvement	Stage
Substitution	Substituting an analogue task with a digital one	No functional change	Enhancement
Augmentation	Substituting an analogue task with a digital one with some improvement	Some functional improvement	
Modification	The original task is modified in such a way that learning is transformed	The technology facilitates a significant task redesign which transforms learning	Transformation
Redefinition	The original task is redefined in such a way that learning is significantly transformed in ways that would be inconceivable without technology	Learning is transformed by experiences that would not have previously been possible	

mobile technology, it is nowadays not very demanding to create educational tracks at the doorstep with a smartphone, enrich them with photos and videos, share them and thus create experiences for others during outdoor learning activities.

Location-based Geogames provide opportunities, according to the SAMR framework, to meet the requirements to redefine learning activities. Consequently, the evidence-based development of location-based Geogames (cf. 2.2) and the development of a theoretical research framework to evaluate their impact to biodiversity learning were connected. The results of several pilot studies during the first 18 months affected the modelling process of the theoretical framework and consequently several types of framework evolved. In this article the main steps of this transformative process are shown, obstacles as well as prospects are identified.

The *BioDiv2Go* project started in December 2013 in a transdisciplinary consortium combining expertise in biological education[3], in applied computer sciences[4] as well as expertise in dissemination with adolescents[5].

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2 Fostering the valuing of biodiversity with Geogames – a literature review

2.1 The valuing of biodiversity

The understanding of the valuing of biodiversity is manifold and, according to the specific discipline and professional fields, it elicits various associations. The economic perception focuses on the benefits that people obtain from ecosystems. Nature gets an anthropocentric, often monetary value to show its economic use and thus so-called ecosystem services approaches (Salles 2011) concentrate on persuading people to protect nature (Unmüßig, 2014; Sukhdev et al, 2014; Heinrich-Böll-Stiftung 2012; Naturkapital Deutschland – TEEB DE, 2012). But Unmüßig (2014) renders moot, that the 'real value' of ecosystems exists and calls for a separating line between the valuing as the urgently needed appreciation of nature and the monetary valuing with its social and ecological risks (Unmüßig, 2014, p. 14-15).

Another understanding could be derived from a pedagogical-educational discussion. Mayer (2006) for instance questions if biodiversity has a measurable value or if it is free of quantified values. This discussion emphasises the attitudes, the value system and the interest of people to influence the perception of biodiversity and the willingness to protect it (Menzel & Bögeholz, 2009; Mayer, 2006). The Competence Model for Environmental Education (CMEE, Roczen et al, 2014) shows that besides different facets of knowledge, the attitudes toward nature are the strongest predictors for general ecological behaviour. From the pedagogical point of view it is more important to focus on the values of adolescents rather than on the monetary measurement of biodiversity. Therefore in the BioDiv2Go research project the goals of *Biodiversity Education* concentrate broadly on the social, cultural, ecological and economical dimensions of biodiversity (Navarro-Perez & Tidball, 2012). Suitable strategies to popularize the topic, to motivate and to make people interested in biodiversity are examined and pursued, especially on the local scale (Lindemann-Matthies, 2002; Berndt, 2000; Krombaß et al, 2003; Menzel, 2007; Menzel & Bögeholz, 2009; Navarro-Perez & Tidball, 2012). There is a clear mandate to create more possibilities for nature experiences and adequate communication strategies for different target groups (Navarro-Perez & Tidball, 2012, p. 25).

One obstacle is the fact, that local biodiversity is hardly noticed by the general public (Benkowitz, 2013; Menzel & Bögeholz, 2009; Groß et al, 2009; BMU & BfN, 2010) and little importance is attached to the biodiversity-related knowledge and its protection (Lindemann-Matthies, 2002; Lindemann-Matthies & Bose, 2008; Menzel & Bögeholz, 2009). Nature experiences potentially can increase knowledge, influence attitudes and enhance the perception of biodiversity (Raith & Lude, 2014; Lindemann-Matthies et al, 2010; Benkowitz & Köhler, 2010; Menzel & Bögeholz, 2009; Benkowitz, 2013).

Therefore the valuing of biodiversity could be defined as a triad consisting of knowledge, perception and attitudes toward biodiversity and consequently research should focus on factors influencing it.

2.2 Geogames to foster situational interest and enjoyment

Geogames are mobile, location-based and location-dependent games (Schlieder, 2014) requiring locomotion and activities in the physical space. The geographical position of the player is part of the game flow (von Borries et al, 2007; de Souza e Silva, 2009) and Geogames for smartphones combine game-based and location-based learning (Schlieder, 2014). Ruchter, Klar & Geiger (2010) for instance developed digitaly supported location-based educational activities and they used smartphones as tools at a floodplain conservation site. One result of their study was that children´s motivation to partake in environmental education can be enhanced through mobile technology; an active and collaborative engagement is facilitated (eg. through tasks that need collaboration to be solved at a specific place in nature). Thus the central idea of Geogames as location-based learning with digital media is to link the real and virtual world.

Conceptually, Geogames can be allocated in the theoretical framework of Digital Game-based Learning (DGBL) that is understood as the transfer of knowledge and playing as an active form of entertainment (Prensky, 2001; Kerres & Borman, 2009).

Numerous studies have already shown that mobile technology as toolset supports knowledge construction (Perry & Klopfer, 2014; Ruchter et al, 2010; Lai et al, 2007; Chang et al, 2011; Huang et al, 2010), increases motivation (Lai et al, 2007; Ruchter et al, 2010) and enhances environmental perception. A nationwide review of mobile, location-based learning activities describes the potential of mobile electronic devices in environmental education and education for sustainable development (Bleck et al, 2012, 2013; Lude et al, 2013; Schaal & Lude, 2015). Schaal and colleagues (2012) used mobile devices to transform traditional learning environments for biodiversity education in pre-service teacher education and they illustrate the benefits of processing information and data directly in the field during location-based inquiry learning.

As Geogames combine DGBL and location-based learning one has to derive design criteria to combine a content-related, location-based engagement with activities focusing on game-experience and enjoyment as moderators of interest development (Rheinberg 2004).

Reviewing the literature leads to the assumption that the term *enjoyment* is often used but not always well defined: Enjoyment is defined as fun (Palmgren et al, 1985; Shafer, 2013; Gadjahar, de Kort & Ijsselsteijn, 2008), as emotion (Vorderer et al, 2004; Gajadhar, de Kort & Ijsselsteijn, 2008), as attitude (Nabi & Krcmar, 2004; Fang et al, 2010), as a combination of cognition and affect (Raney & Bryant, 2002), as cognition, emotion and physiological process (Vorderer er al, 2004), as an unspecific reaction to a media context (Miron, 2003; Tamborini, 2003) or also as a kind of flow (Sweetster & Wyetz, 2005; Fu et al, 2009; Jegers, 2007, 2009) and finally as the satisfaction of three psychological basic needs (autonomy, competence and social relatedness) related to individual wellbeing (Deci & Ryan, 1985; Ryan & Deci, 2000; Ryan et al, 2006; Kairimi & Lim, 2010). Tamborini et al (2010) seize the latter suggestion and they define *media enjoyment* as the satisfaction of intrinsic needs. The objects of their investigation were video games and they confirmed the understanding of enjoyment to be closely linked to the psychological basic needs.

Consequently, a framework to create Geogames for biodiversity education needs to consider the prerequisites for game enjoyment, for interest development as well as the empirical foundations for the individuals' valuing of biodiversity.

3 The Geogame “FindeVielfalt *Simulation*”

At a glance, Geogames fostering the valuing of biodiversity should provide an opportunity for adolescents to discover and to experience nature in an age-appropriate way relevant to their every-day life. Mobile technology helps to provide the storytelling (Lambert, 2006), the game mechanics as well as the spacial orientation.

Geogames for secondary school students were developed and provided at specific youth hostels at hotspot areas of biodiversity. The so-called “FindeVielfalt *Simulation*” Geogame (FVS) was designed according to Schlieder´s (2014) three game-design levels (see figure 1) to pique adolescent´s interest in local biodiversity, to increase the awareness of and knowledge about biodiversity and to reach enjoyment while playing. To make sure that the needs of the players and the requirements of the youth hostels are considered, a preliminary interview study with educational staff was conducted (Schaal et al, 2015).

At the narrative level the FVS focuses on an adolescents’ developmental task to cope with quandaries and dilemmas. The main character of the narrative, Adam, has to keep on the traditions of his ancestors’ heritage and he is thrown into a conflict between biodiversity- and profit-related decision-making. The player takes the role of Adam and within a simulation she/he manipulates two (max. three) variables (e.g. how to operate an orchard, see fig. 2) with the goal of balancing biodiversity and economic outcomes. Before Adam is allowed to make a decision in the simulation, the player has to discover the site (e.g. the traditional orchard representative for a biodiversity hotspot in Southwestern Germany), to conduct inquiry and to solve location-based tasks at several real places introduced by the smartphone game. Doing so, the player manipulates the simulation several times and gets insight into the dependencies and relationships relevant to cope with the dilemmas.

The FVS Geogame focuses on five different simulations representing habitats and biodiversity-related topics (traditional orchards, sheep and cattle keeping, lynx and wildcat reintroduction, urban biodiversity) for adolescents.

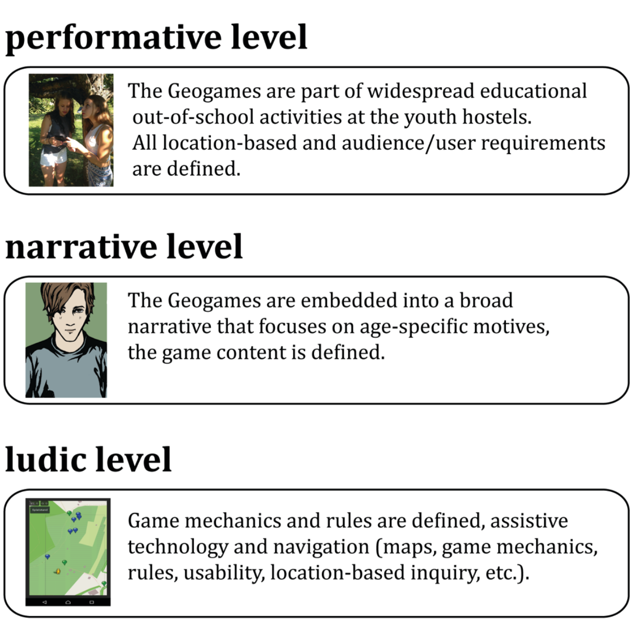

Figure 1: Levels of game-design (according to Schlieder, 2014)

4 Developing the Biodiv2Go-Framework as a transformative process

The BioDiv2Go Geogames are intended to provide nature experiences and game-related enjoyment at the same time. The main research questions are:

1. Does the use of the FVS Geogame foster the valuing of local biodiversity?
2. How will game-related enjoyment influence the valuing of local biodiversity?

These questions require a framework that is based on recent theory and verified empirically. This study describes the stepwise transformation of an initial theory-based framework towards a sophisticated framework respecting students’ appreciation as well as experts’ appraisals and empirical validation. A quasi-linear procedure is described which was in fact a process of parallel and interwoven sub-processes.

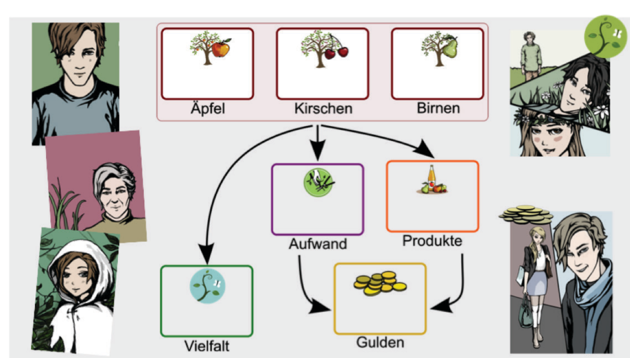

Figure 2: Simulation for traditional orchards with different game-characters

4.1 First step: adapting the CMEE model

The first BioDiv2Go framework is the result of a systematic literature review and an intensive discussion within a consortium consisting of the project members, experts in the field of nature conservation, environmental education practitioners and environmental psychologists. The Competence Model for Environmental Education (CMEE) by Roczen et al, 2014) provided the best fit for our purposes.

In the CMEE, three forms of environmental knowledge are distinguished and people´s attitude toward nature is shown as a strong predictor of their ecological behaviour (Roczen et al, 2014, p. 972). The CMEE is well established and the different scales were calibrated with Rasch-type models. The intention to adapt the CMEE model to the context of biodiversity was supported by the CMEE-developing research group. The first Biodiv2Go framework (see fig. 3) was very similar to the CMEE. The larger scope of nature and environment was reduced and biodiversity was brought into focus. According to the five scales of the CMEE, items for the context of biodiversity were developed with a transdisciplinary expert group. The dimension of game enjoyment was added to answer the second research question: How and to what extent does game-related enjoyment influence the valuing of biodiversity?

Enjoyment could either be measured using the Intrinsic Motivation Inventory (IMI) of Deci and Ryan (2003) or the Player Experience of Need Satisfaction

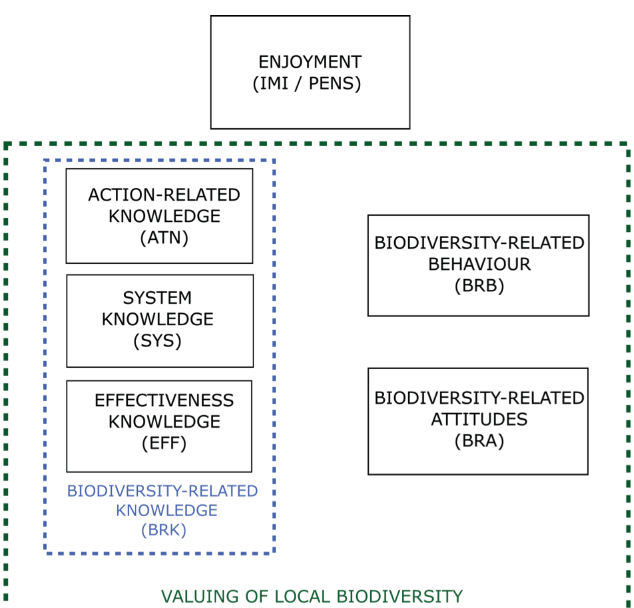

Figure 3: The initial BioDiv2Go Framework

(PENS) (Ryan et al, 2006) (see section 2.2) without further adaption. A list of Abbreviations can be found in Table 7.

The turning from Attitude Toward Nature (ATN) to Biodiversity-related Attitudes (BRA): In the CMEE a person´s attitude toward nature was assessed by a forty-item scale (Brügger et al, 2011) which is easy to understand and intellectually not demanding. Item examples are "I get up early to watch the sunset" or "I talk to animals". Attitudes are traditionally explained as an internal state that is associated with people´s evaluative response to an object (Eagly & Chaiken, 1993) which is in this specific case nature itself. Brügger et al (2011) propose to measure the ATN indirectly to avoid response biases and they use the Disposition to Connect with Nature scale (DCN). It asks for concrete personal preferences and behavioural self-reports (see Brügger et al, 2011, p. 326) and follows the Campell´s paradigm (Kaiser et al, 2014) which explains the attitude-behaviour relationship. To realize the adaption to Biodiversity-related Attitudes (BRA) several dimensions of nature experiences (Lude, 2006) which also include personal preferences and behavioural self-reports were considered and linked to the FVS Geogame topics (see section 3). BRA item examples are "The buzzing of bees in flowering orchard trees fascinates me" (aesthetic dimension) or "I enjoy observing a woodpecker picking an apple tree" (exploring dimension). Finally 74 items in nine dimensions of nature experiences were recommended by the experts, and ready for the first piloting.

The turning from General Ecological Behaviour (GEB) to Biodiversity-related Behaviour (BRB): A valid forty-item self-report instrument (Kaiser et al, 2007) is used in the CMEE to measure GEB. The GEB scale is well established, validated and specifically designed for adolescents and consist of 6 domains: recycling, waste avoidance, consumerism, mobility and transportation (Roczen et al, 2014, p. 980). Item examples are "I keep gift paper wrapping for reuse", "I buy canned drinks". The adaptation from GEB items to BRA items included the 6 named domains and refers to the FVS topics. 77 items were created, for example "If an apple has a wormy point, which can be cut out, I eat it anyway", "I help my parents with gardening".

The turning from the Environmental Knowledge scale to the Biodiversity-related Knowledge scale (BRK): The adapting-strategy described for BRA and BRB was also applied to the knowledge scale. According to Frick et al (2004) three different types of knowledge exert different influences on conservation behaviour. System Knowledge (SYS) in the BioDiv2Go Project is defined as knowledge about how the biodiversity system and biodiversity process function. SYS includes factual knowledge such as the knowledge of species but also the more complex procedural knowledge. Action-related Knowledge (ACT) is knowledge about how to protect and keep biodiversity and Effectiveness Knowledge (EFF) is knowledge about how effective one´s action is and which impact on biodiversity protection this action has. The topics and tasks of the FVS Geogame are represented in the 30 multiple-choice items of the BRK scale, eg. “If there were no bees, (a) there would be no honey, (b) there would be no grain, (C) there would be less species of fruit and vegetables. Each multiple choice-item can have more than one correct answer. BRK was assessed with 3-level-Likert multiple-choice items and the scoring was conducted severely – only entire right answers were scored.

The valuing of biodiversity is supposed as the combination of BRA, BRB and BRK.

4.2 Second step: piloting of the BRA and BRB scales with students and further literature review

Having established the first BioDiv2Go framework different problems emerged. We discussed the newly constructed BRA and BRB items with 7th and 9th grade students of a German middle school (n=8) to assure a target-related language. Female and male students were selected by their teacher. Both, German native speakers and students with a migration background were asked to participate. Many difficulties emerged with the comprehension of biodiversity specific terms. The students remarked, that some of the items had no relevance in their lives. These statements can be supported by the findings indicating that local biodiversity is hardly recognized by the general public (Benkowitz, 2013; Menzel & Bögeholz, 2009; Groß et al, 2009; BMU & BfN, 2010) and the knowledge about biodiversity and the willingness to protect it seems not to be important to them (Lindemann-Matthies, 2002; Lindemann-Matthies & Bose, 2008; Menzel & Bögeholz, 2009). Nature and plants are counted to the less interesting topics for adolescents (Sjøberg & Schreiner, 2010; Holstermann & Bögeholz, 2007). In contrast the GEB- and ATN-items are considered to be adequate for adolescents (Roczen et al, 2014, p. 980). Furthermore, there were difficulties to distinguish the BRA and BRB from the ATN and GEB. BRA is also a part of ATN and BRB is part of GEB. Finally the original scales of the CMEE cover a broader concept and they are established scales, especially for adolescents. Consequently the BRA and BRB scales were not considered for further analyses.

A second problem emerged during the process of the game design. The game turned out to become a short intervention of up to two hours. And such short interventions can hardly change stable personal traits like attitudes and behaviour (Bogner, 1998; Bittner, 2003). As a consequence, our assumption that the valuing of biodiversity can be defined as combination of the increase of knowledge and the change of attitudes and behaviour could not be kept up.

The investigations about the development of interest by Vogt (2007) showed further and helpful evidence for the operationalization of the term *valuing* of biodiversity. According to that, the first step is to create a positive person-object-relationship. If it is successful to interest a person (catch-component), the first obstacle, to initiate situational interest, is overcome. The satisfaction of the basic needs (autonomy, competence and social relatedness) is another factor in the development of interest (hold-component) (Rheinberg, 2004; Deci & Ryan, 1993). And according to Rheinberg (2004) the interest-related engagement with an object is considered a prerequisite for knowledge construction.

So the first BioDiv2Go framework was modified according to the new findings (see fig. 4). As a consequence, the valuing of biodiversity is defined as the Situational Content-related Interest (SCI) and Biodiversity related Knowledge (BRK). Situational content-related interest is – in brief terms - explained as a psychological state which is the result of an individual’s (inter-)action within a specific situation or context (Knogler et al, 2015). SCI is measured with the established KIM scale for interest and enjoyment (Wilde et al, 2009) and STATE scale for interest and boredom (Randler et al, 2011). Item examples are “I find the topic *biodiversity* important”, “I want to learn more about the topic biodiversity”. The GEB and ATN are now set as individual prerequisites and are tested only before the FVS intervention. Socio-demographics and co-variates (*eg* digital gaming experience, smartphone use, school grades) are also placed in the questionnaire, which was ready for piloting in spring 2015.

4.3 Third step: Validation of the biodiversity-related knowledge scale

As introduced in section 4.1 the initial knowledge scale (BRK) consisted of 30 items covering knowledge about biodiversity in the domains of traditional orchard, sheep and cattle keeping, lynx and wildcat reintroduction and urban biodiversity. All five knowledge domains were introduced into the scale to differentiate the knowledge construction in the topic the adolescents played and the transfer effects to the other biodiversity-related knowledge domains.

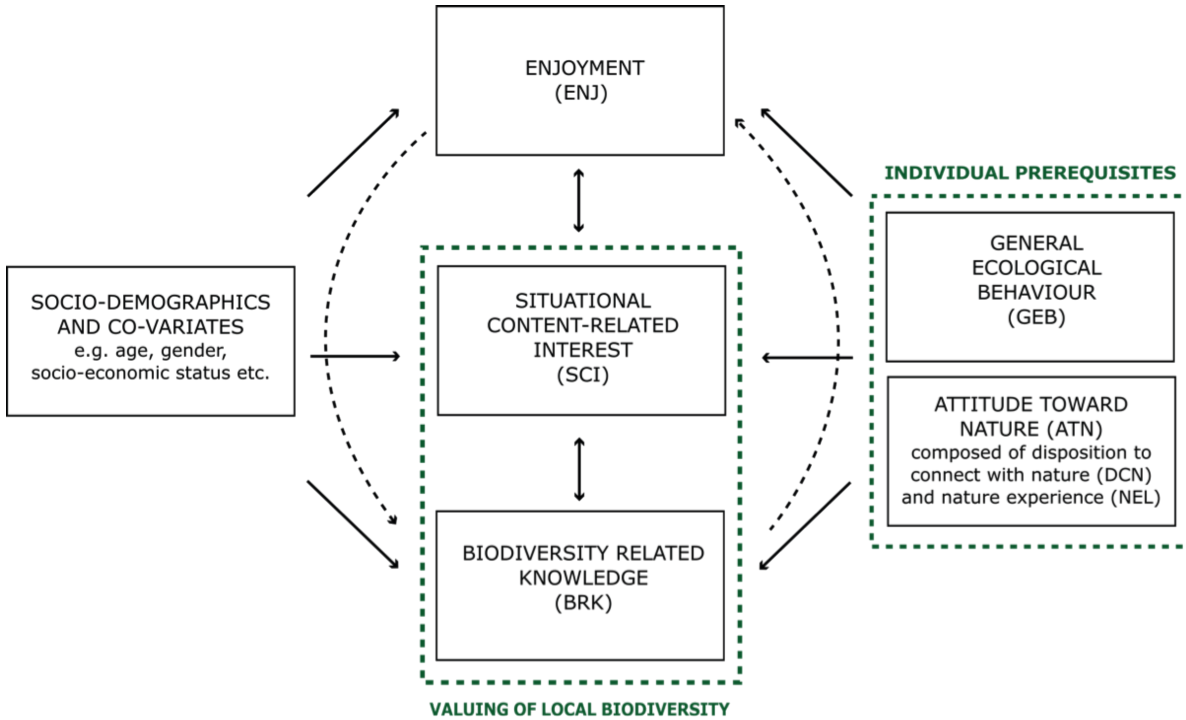

Figure 4: The BioDiv2Go Framework (var.2)

The knowledge scale (BRK) was piloted in an online survey March to May 2015 with N=208 adolescents (mean age 14.3 ± 1.2) and 104 datasets (mean age 13.2 ± 1.1) were added for statistical analysis from the FVS Geogame pilot study (see section 4.4). Despite the slightly higher age, the adolescents in both datasets were comparable in sex distribution and socio-demographic properties.

During the pilot study it transpired that the questionnaire was too long and the expected transfer of knowledge was constrained by the volume of the knowledge scale. Liefländer et al (2015) explain, that effectiveness knowledge (EFF) depends on the two other knowledge dimensions. Results shown so far indicate the strongest increase for system knowledge (SYS) and the least for EFF (Liefländer et al, 2015, p. 607). In this study, the FVS Geogame about traditional orchards was in the focus and thus only items (n = 14) for two FVS Geogame topics (traditional orchards and sheep keeping) as well as items dealing with general biodiversity-related knowledge (n = 7) were included into the Rasch analyses. Furthermore, due to the reduced item number and the fact, that differentiating SYS, ACT and EFF is not relevant for the research questions of the project, all items were pooled into a single factor.

The datasets of the online-survey and the pilot field study (up to May 2015) were pooled and N = 312 adolescents were included into a Rasch-analysis with the ConQuest software package. The BRK scale was calibrated using the simple Rasch model (SRM) (Rasch, 1960). The model fit was assessed using mean square values (MS). After eliminating two items of the general biodiversity-related knowledge, a very good fit is indicated by the fact that the MS value of the scale is “ideal” at 1.00 on average. None of the single items exceeded the range of an acceptable fit (0.

Table 2: The results of the Rasch-analysis of the BRK scale

Biodiversity related knowlege (BRK) **Pre, 19 items, N=312** **MC format (0=not correct, 1= totally correct)**		**Example**
M (MS)	1.00	If there were no bees, there would be no honey there would be no grain there would be less species of fruit and vegetables
Minimum (MS)	0.91	
Maximum (MS)	1.10	
Variance	0.796	
Reliability	0.690	

75 > MS > 1.30) (Bond & Fox, 2007).). The final biodiversity-related knowledge scale consists of 19 items (see Table 2) which were selected for the pilot field study described in the following chapter.

4.4 Fourth step: The pilot field study

The pilot field study was conducted from April to July 2015 using the FVS Geogame to discover traditional orchards with N=180 secondary school students in Southwestern Germany. Participants came from five classes of five different schools; 63% were female; the mean age was 12 (M=12,6 ± 1,04) years. Out of this sample 119 datasets could be introduced into the analysis with SPSS 22. A code name, which is signed on the questionnaire and used to sign up for the game session, allows a coupling between the questionnaire and the game session.

A pre-/post-test-design was applied, measuring 'General Environmental Behaviour' (GEB)^{pre}, 'Attitudes Toward Nature' (ATN)^{pre}, represented by the scales nature experiences (NEL)^{pre} and 'Disposition to Connect with Nature' (DCN)^{pre}, biodiversity-related knowledge (BRK)$^{pre/post}$, situational content-related interest (SCI)$^{pre/post}$, enjoyment (ENJ)^{post}, socio-demographics^{pre}, co-variates (e.g. age, sex, socio-economic status...)^{pre}.

Additionally, the players were asked further questions considering their personal opinion about the game (e.g. which parts of the game they liked, the general rating of the FVS Geogame, about the collaboration with the other group members, etc.).

The items of GEB (40 items) and DCN (40 items) were represented with two different response formats and were coded according to Brügger et al (2011). Thus low (0), intermediate (1) and high (2) DCN and GEB can be differentiated. For the NEL-scale (13 items) a five-level Likert scale ranging from 1 (never) to 5 (very often) was used. Negative items were also reversely coded.

The items of the SCI (9 items) and ENJ (29 items) were presented in a five-level Likert scale, ranging from 1 (not at all true) to 5 (totally true). Negative items were reversely coded.

The players furthermore were asked to comment on the questionnaire and the FVS Geogame in their own words. The qualitative data was used to improve the game and to get information about how they had coped with the questionnaire.

The FVS game sessions were accompanied by a participatory observation (DeWalt & DeWalt, 2011) for formative evaluation of the FVS Geogame and to detect obstacles in the field. Every game session generates many different logfile datasets, which give information about the duration of the game, how long the players work on each task, how they perform and which decisions they make in the simulation part etc.

5 Results of the pilot field study

Descriptive data: The results of the descriptive analysis indicate, that the players accepted the FVS Geogames to a high degree. They mostly appreciated playing autonomously in small groups, navigating with GPS and the alternation between the smartphone and tasks in nature (see Table 3).

Data introduced within the framework: The scale properties are very satisfying (see Table 4). All established scales show a high reliability. The situational interest (SCI) did not significantly change from pre- to post-test, the biodiversity-related knowledge (BRK) increased (t-test, see Table 5). The results for the enjoyment (ENJ) of the game indicate that the majority of the players enjoyed playing FVS (see Fig. 5). Medium and strong correlations were found between all scales except BRK and DCN / GEB (see table 6).

The feedback of the players and the qualitative data showed that the FVS Geogame can enhance the interest in local biodiversity of adolescents ("I didn´t expect there to be so many apple species", "I learned a lot") and they "enjoyed playing in nature". But the expectations in a Geogame are high ("There could be more action", "the idea of the game is good, but it wasn´t so exciting") and technical problems in this first field test or the influence of

Table 3: After the game the players answered the question "Which parts of the game did you like?" Answering options were fixed and could be signed or not.

Which parts of the game did you like?	frequency (N=119)	percentage
playing autonomously in small groups	73	61,3
to navigate with GPS	70	58,8
the alternation between the smartphone and tasks in nature	67	56,3
the tasks in nature	60	50,4
to collect game credits	55	46,2
the simulation	54	45,4
the game story (narration)	37	31,1
the cartoon characters of the narration	35	29,4
the explanatory video sequences	33	27,7

Table 4: The scale properties

N=119	M±SD	Cronbach´s α	Example	Reference
General ecological behaviour (GEB), 40 items 33 items: Three-level Likert scale (0=never, 2= very often) 7 items: dichotomous yes/no format (0=no, 2=yes)	1.18 ± .25	0.83	I keep gift wrapping paper for reuse. I refrain from using battery-powerd devices.	Roczen et al (2014)
Disposition to connect with nature (DCN), 40 items 23 items: Three-level Likert scale (0=never, 2= very often) 17 items: dichotomous yes/no format (0=no, 2=yes)	0.94 ± .40	0.91	I spend time in a park. My favorite place is in nature.	Brügger et al (2011)
Nature experience (NEL), 13 items five-level Likert scale (1=never, 5=very often)	2.66 ± .61	0.77	I climb on trees. I do night walks.	Lude (2006)
Situational content-related interest (SCI), pre, 9 items five-level Likert scale (1=not at all true, 5=totally true)	3.50 ± .90	0.89	I find the topic *biodiversity* important. I want to hear more about the topic *biodiversity*.	Item 1-3, KIM-Scale (interest/enjoyment): Wilde et al (2009) Item 4-9, STATE-Scale (interest; boredom): Randler et al (2011)
Situational content-related interest (SCI), post, 9 items	3.29 ± 1.01	0.90		
Enjoyment (ENJ), 29 items five-level Likert scale (1=not at all true, 5=totally true)	3.56 ± .75	0.92	I enjoyed playing the *Finde Vielfalt*-Game. I think I was pretty good at playing the *Finde Vielfalt*-Game. I felt close to my teammates.	Intrinsic Motivation Inventory (IMI), sub-scales: interest/enjoyment, perceived competence, effort/importance, value/usefulness, relatedness http://www.selfdeterminationtheory.org/intrinsic-motivation-inventory/ [accessed 21.08.15]
Biodiversity related knowlege (BRK), pre, 19 items Multiple choice format (0=not correct, 1= totally correct)	6.56 ± 2.57	0.50	If there were no bees, there would be no honey there would be no grain there would be less species of fruit and vegetables	Own scale
Biodiversity related knowlege (BRK), post, 19 items	7.58 ± 3.04	0.64		

Table 5: Results of the t-test for SCI and BRK pre and post

	SCI	BRK
Pretest (SD)	3,5 (+/- 0,90)	6,56 (+/- 2,57)
Posttest (SD)	3,29 (+/- 1,01)	7,58 (+/- 3,04)
Max.	5	19
p Wert	0,1063	0,0002***
t	1,6277	3,9011
SE	0,094	0,261

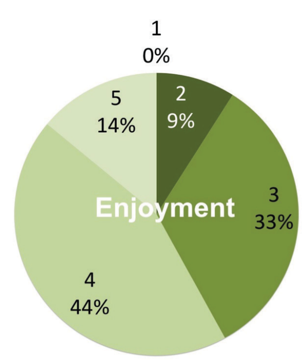

Figure 5: The results of the game related enjoyment from 1 (no enjoyment) to 5 (high enjoyment), N=119

Table 6: Correlation between the scales BRK, delta $^{post-pre}$, SCI^{post}, ENJ^{post}, DCN^{pre}, NEL^{pre} and GEB^{pre}

N=119	GEB	NEL	DCN	ENJ	SCI^{post}
Δ BRK$^{post-pre}$	.13$^{n.s}$	.08$^{n.s}$.	.12$^{n.s.}$	.17*	.21**
SCI^{post}	.55***	.43***	.53***	.77***	
ENJ	.37***	.34***	.39***		
DCN	.81***	.73***			
NEL	.58***				

Pearson's correlation (one-side, Bonferroni corrected),
$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$, n.s. $p > .05$

the weather are strong opponents ("GPS reacts too late", "Sometimes the game had breakdowns. That was corny", "It was too hot to play").

The comments concerning the questionnaire were nearly always the same: "Too many items, too long!". The upcoming challenge will finally be to shorten the questionnaire without passing up essential information that would be relevant for the scientific value of the study. Fortunately the correlation of the GEB, DCN and NEL scales will be one starting point to shorten the instrument.

6 Discussion

The FVS Geogame was designed to foster the valuing of local biodiversity. The majority of the players liked navigating with GPS, the alternation between the smartphone and tasks in nature and the tasks in nature itself (see table 3). This finding is in line with the requirements formulated in the literature to focus on nature experiences in biodiversity education (Navarro-Perez & Tidball, 2012), to enhance the perception of local biodiversity (Raith & Lude, 2014; Lindemann-Matthies et al, 2010; Benkowitz & Köhler, 2010; Menzel & Bögeholz, 2009; Benkowitz, 2013) and to draw interest moderated by the game-related enjoyment.

The data analysis revealed an increase in biodiversity-related knowledge (BRK). BRK has increased, whereas the situational content-related interest (SCI) did not change from pre- to post-test (see table 5). On first sight, this seems to be a disappointing finding keeping in mind that interest is considered as a strong predictor for knowledge acquisition and for the valuing of biodiversity. According to Hidi & Renninger's (2006) four-phase model, the interest development consists of personal and situational factors. In the pilot field study the data suggest that the FVS Geogame was not able to trigger situational interest successfully. Knogler, Harackiewicz, Gegenfurtner & Lewalter (2015) emphasize as result of a longitudinal study that situational interest as a psychological state is not confounded with pre-existing individual interest.

On a second glance the correlations render an explanation: The personal prerequisites (GEB, DCN and NEL) are strongly correlated with the situational, content-related interest (SCI) indicating that players with already high values in GEB, DCN and NEL had also higher SCI in the post-test. These players are more interested in the topics of local biodiversity than those with lower values in the GEB, DCN and NEL. The post-test SCI again – in contrast to the personal prerequisites – is correlated with the increase in BRK. Thus it can be assumed that SCI has a direct correlation with the BRK while the personal prerequisites seem to have an indirect, moderating influence in the knowledge acquisition. Tobias' (1994) model of the interest-knowledge relationship allows for the conclusion that personal prerequisites including GEB, DCN, NEL and prior knowledge are closely related to interest and vice versa. This relationship is respected within the final framework and the findings of the pilot field study can be matched with this assumption. Due to high correlations between the different scales for attitudes and behaviour, the framework was simplified using only GEB (general environmental behaviour) as one measure. Furthermore the fact that the increase in BRK is not directly correlated with personal prerequisites points towards the fact that within the FVS Geogames there is something to learn for every player!

The enjoyment – as theoretically expected – is strongly correlated with the SCI and the personal prerequisites as well are moderately correlated with the increase of BRK. Here again, those players with high values in GEB, DCN and NEL enjoyed the Geogame activity more than those with lower personal prerequisites in the context of nature and environment.

The challenge now for future developments within the FVS Geogames is to find a way to reach those players who do not bring along positive general ecological behaviours or positive attitudes toward nature.

As the total sample size is still small, an empirical validation of the FVS framework with more sophisticated methods like path analyses or multivariate procedures is not possible yet. But the preliminary results already allow the assumption, that the final framework can be used for the main study (see table 6).

The transformative developmental process from the initial framework towards the final version involved multiple perspectives working with educational staff, experts

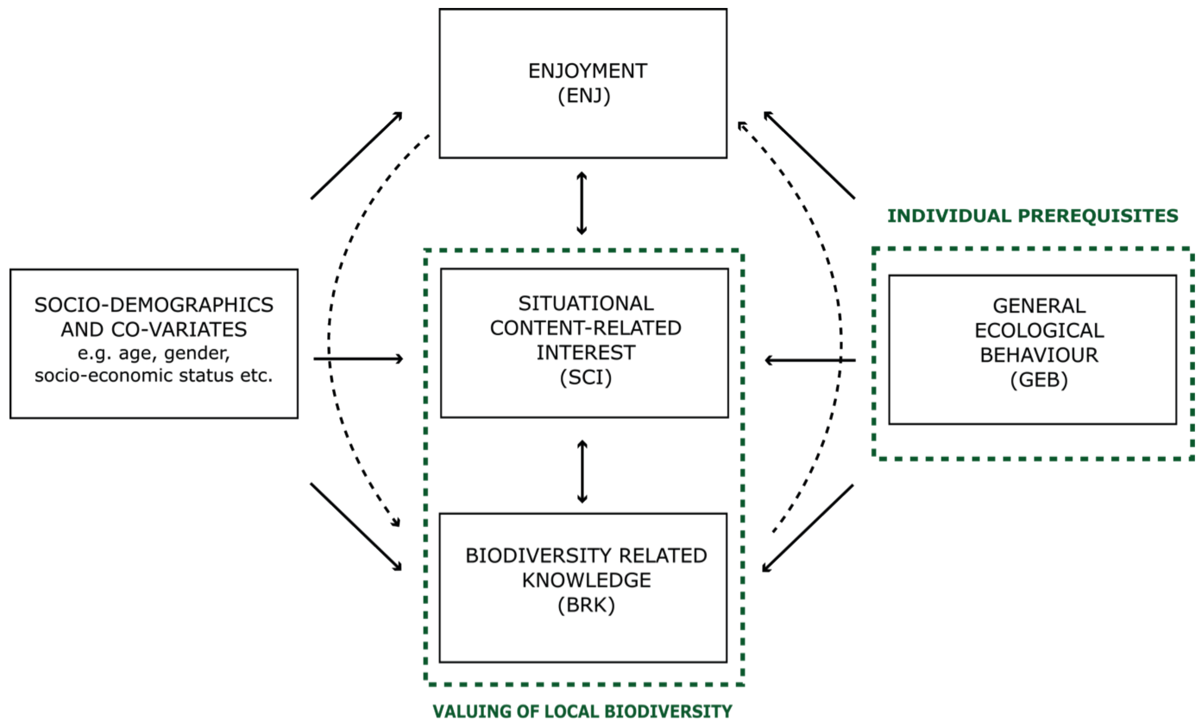

Figure 6: Final BioDiv2Go framework

in environmental science and psychology as well as with adolescent representatives.

7 Perspectives

The main study will start in March 2016 with the beginning of the vegetation period and the starting season for school trips to German youth hostels. It will last until September 2016. The main goal is to increase the number of players in different age groups, socio-cultural backgrounds and different school types. As a consequence, more complex statistical analysis will provide further insights into the effect of the FVS Geogame in general and the influence of the different dimensions like the personal prerequisites, the game-related enjoyment and other co-variates.

For an in-depth investigation and as an empirical triangulation, qualitative methods will be applied to assess the players, their interest development in local biodiversity and how the FVS Geogame can affect that. The selection can be realized with a latent class analysis to identify different groups of players for interviews.

Furthermore, a huge dataset of logfiles and qualitative data from the in-game task solutions will be available. The analysis of audio records of the explanatory statements for game decisions in dilemmas will show the depth of student's engagement with the FVS Geogame and offer valuable clues to the valuing of local biodiversity.

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Abbreviations

Table 7: List of abbreviations

ATN	Attitude Toward Nature
BioDiv2Go	Biodiversity to go
BRA	Biodiversity-related Attitudes
BRB	Biodiversity-related Knowledge
CMEE	Competence Model of Environmental Education
DCN	Disposition to Connect with Nature
DGBL	Digital game-based learning
EFF	Effectiveness Knowledge
ENJ	Enjoyment
FVS	Finde Vielfalt Simulation
GEB	General Ecological Behaviour
GPS	Global Positioning System
IMI	Intrinsic Motivation Inventory
KIM	Kurzskala Intrinsischer Motivation (short scale intrinsic motivation)
MS	Mean square values
NEL	Nature Experiences according to Lude
PENS	Player Experience of Need Satisfaction
SAMR	Substitution, Augmentation, Modification, Redefinition
SCI	Situational Content-related Interest
SRM	Simple Rasch Model
STATE	Situational Emotions Scale
SYS	System Knowledge
TEEB DE	The Economics of Ecosystems and Biodiversity Deutschland

References

[1] Anderson, M. (2013). Perfect ICT every lesson. Carmarthen: Independentthinkingpress.

[2] Benkowitz, D. & Köhler, K. (2010). Perception of Biodiversity - The Impact of School Gardening on Getting in Touch with Plants. In: N. Müller, P. Werner & J. Kelcey (Hrsg.). Urban Biodiversity and Design. Chichester: Wiley-Blackwell.

[3] Benkowitz, D. (2013). Einfluss von Unterricht auf die Wahrnehmung pflanzlicher Vielfalt. In J. Mayer, M. Hammann, N. Wellnitz, J. Arnold, & M. Werner (Hrsg.), Theorie, Empirie, Praxis (S. 270-271). Kassel: University Press Kassel.

[4] Berndt, K.-P. (2000). Interdisziplinäres multimediales Lehr- und Lernprojekt „Biodiversität in Großökosystemen". Brandenburgische Umweltberichte, 8, 12-20.

[5] BfN (2015). Artenschutzreport 2015: Tiere und Pflanzen in Deutschland. Bonn: Bundesamt für Naturschutz.

[6] Bittner, A. (2003). Außerschulische Umweltbildung in der Evaluation: Wirkungen kurzzeitpädagogischer Maßnahmen auf Umwelt- und Naturschutzinteressen von Schülerinnen und Schülern der Sekundarstufe I. Hamburg: Verlag Dr. Kovac.

[7] Bleck, S., Bullinger, M., Lude, A. & Schaal, S. (2012): Electronic mobile devices in environmental education (EE) and education for sustainable development (ESD) – Evaluation of concepts and potentials. Procedia – Social and Behavioral Sciences 46, 1232-1236.

[8] Bleck, S., Bullinger, M., Lude, A. & Schaal, S. (2013). Mobile elektronische Endgeräte in der Umweltbildung und BNE - erste Ergebnisse einer Studie. In: Michel, U. et al (Hrsg.): Digitale Medien in der Bildung für nachhaltige Entwicklung - Potentiale und Grenzen, oekom 77-85

[9] BMUB (2007). Nationale Strategie zur biologischen Vielfalt. Paderborn: Bundesamt für Umwelt, Naturschutz und Reaktorsicherheit.

[10] BMU & BfN (2010). Naturbewusstsein 2009: Bevölkerungsumfrage zu Natur und biologischer Vielfalt. https://www.bfn.de/fileadmin/MDB/documents/themen/gesellschaft/Naturbewusstsein%202009.pdf (accessed 14th June 2015).

[11] Bogner, F. X. (1998). The Influence of Short-Term Outdoor Ecology Education on Long-Term Variables of Environmental Perspective. The Journal of Environmental Education, 29 (4), 17-29.

[12] Bond, T. G., & Fox, C. M. (2007). Applying the Rasch Model: Fundamental Measurement in the Human Sciences, Second Edition. Journal of Educational Measurement (Vol. 2). Mahawa, NJ: Lawrence, Erlbaum.

[13] Brown, E. (2010). Education in the wild: contextual and location-based mobile learning in action. A report from the STELLAR Alpine Rendez-Vous workshop series. Nottingham: University of Nottingham: Learning Sciences Research Institute (LSRI).

[14] Brügger, A., Kaiser, F. G. & Roczen, N. (2011). One for all?: Connectedness to nature, inclusion of nature, environmental identity, and implicit association with nature. European Psychologist, 16 (4), 324-333.

[15] Chang, C.-S., Chen, T.-S.& Hsu, W.-H. (2011) The study on integrating WebQuest with mobile learning for environmental education. Computers & Education 57(1), 1228-1239.

[16] de Souza e Silva (2009): Digital cityscapes: Merging digital and urban playspaces. New York: Peter Lang.

[17] Deci, E.L. & Ryan, R.M. (1985). Intrinsic motivation and self-determination in human behaviour. New York: Plenum Press.

[18] Deci, E.L. & Ryan, R.M. (1993). Die Selbstbestimmungstheorie der Motivation und ihre Bedeutung für die Pädagogik. Zeitschrift für Pädagogik, 39,(2), 223-238.

[19] Deci, E.L. & Ryan, R.M. (2003). Intrinsic Motivation Inventory. http://www.selfdeterminationtheory.org/questionnaires/10-questionnaires/50 (accessed 14th June 2015).

[20] DeWalt, K. M., & DeWalt, B. R. (2011). Participant Observation: A Guide for Fieldworkers. MD: Rowman & Littlefield.

[21] Eagly, A. & Chaiken, S. (1993). The psychology of attitudes. New York: HBJ.

[22] Fang, X., Chan, S., Brzezinski, J. & Nair, C. (2010). Development of an Instrument to Measure Enjoyment of Computer Game Play. International Journal of Human-Computer Interaction, 26, 868-886.

[23] Frick, J., Kaiser, F. G., & Wilson, M. (2004). Environmental knowledge and conservation behavior: exploring prevalence and structure in a representative sample. Personality and Individual Differences, 37(8), 1597-1613.
[24] Fu, F., Su, R. & Yu, S. (2009). Computers & Education EGameFlow : A scale to measure learners' enjoyment of e-learning games. Computers & Education, 52(1), 101-112.
[25] Gajadhar, B. J., Kort, Y. A. W. & IJsselsteijn, W. A. (2008). Shared Fun Is Doubled Fun: Player Enjoyment as a Function of Social Setting Fun and Games. Fun and Games, 5294, 106-117.
[26] Groß, J., Lude. A. & Menzel, S. (2009): BNE und biologische Vielfalt im schulischen und außerschulischen Kontext - curriculare Vorgaben und Verständnis. Natur und Landschaft 84(3), 108-112.
[27] Heinrich-Böll-Stiftung. (2012). Grüne Ökonomie: Was uns die Natur wert ist [Electronic version]. Böll Thema, 1, 1-36.
[28] Hidi, S., & Renninger, K. (2006). The Four-Phase Model of Interest Development. Educational Psychologist, 41(2), 111-127.
[29] Holstermann, N. & Bögeholz, S. (2007). Interesse von Jungen und Mädchen an naturwissenschaftlichen Themen am Ende der Sekundarstufe I. Zeitschrift für Didaktik der Naturwissenschaften, 13, 71-86.
[30] Huang, W., Huang, W. & Tschopp, J. (2010). Sustaining interative game playing process in DGBL: The relationship between motivational processing and outcome processing. Computers & Education, 55(2), 789-797.
[31] Jegers, K. (2007). Pervasive game flow: understanding player enjoyment in pervasive gaming. Computers in Entertainment (CIE), 5, 9-17.
[32] Jegers, K. (2009). Pervasive GameFlow: Identifying and exploring the mechanisms of player enjoyment in pervasive games. (PhD thesis, Umea University Sweden) http://en.scientificcommons.org/47716935 (accessed 8th December 2014).
[33] Karimi, A. & Lim, Y. P. (2010). Children, engagement and enjoyment in digital narrative. ASCILITE 2010 - The Australasian Society for Computers in Learning in Tertiary Education, 475-483. http://www.scopus.com/inward/record.url?eid=2-s2.0-84870734315&partnerID=40&md5=5ffbf45449733fbf1dce396462fc3b75 (accessed 16th June 2015).
[34] Kaiser, F. G. (1998). A general measure of ecological behavior. Journal of Applied Social Psychology, 5, 395-422.
[35] Kaiser, F. G., Oerke, B., & Bogner, F. X. (2007). Behavior-based environmental attitude: Development of an instrument for adolescents. Journal of Environmental Psychology, 27(3), 242-251.
[36] Kaiser, F. G., Byrka, K. & Hartig, T. (2010). Reviving Campbell's paradigm for attitude research. Personality and Social Psychology Review. Official Journal of the Society for Personality and Social Psychology, Inc, 14(4), 351-367.
[37] Kaiser, F. G., & Byrka, K. (2014). The Campbell Paradigm as a Conceptual Alternative to the Expectation of Hypocrisy in Contemporary Attitude Research. The Journal of Social Psychology, 155 (February 2015), 12-29.
[38] Kerres, M. & Bormann, M. (2009). Explizites Lernen in Serious Games: Zur Einbettung von Lernaufgaben in digitalen Spielwelten. Zeitschrift Für E-Learning, 4(4), 23-34.
[39] Knogler, M., Harackiewicz J. M., Gegenfurtner, A., & Lewalter, D. (2015). How situational is situational insterest? Investigating the longitudinal structure of situational interest. Contemporary Educational Psychology, 43, 39-50.
[40] Krombaß, A., Urhahne, D. & Harms, U. (2003). Lernen mit neuen Medien: TREBIS. Entwicklung und Erbrobung eines Informationssystems zum Thema Biodiversität. In: H. Korn & U. Feit (Hrsg.). Treffpunkt Biologische Vielfalt, III, (S. 201-206). Bonn-Bad Godesberg: BfN.
[41] Lai, C.-H., Yang, J.-C., Chen, F.-C., Ho, C.-W. & Chan, T.-W. (2007): Affordances of mobile technologies for experiential learning: the interplay of technology and pedagogical practices. Computer Assisted Learning 23(4), 326-337.
[42] Lambert, J. (2006). Digital storytelling: Capturing lives, creating community. Berkeley, CA: Digital Diner Press.
[43] Liefländer, A. K., Bogner, F. X., Kibbe, A., & Kaiser, F. G. (2015). Evaluating Environmental Knowledge Dimension Convergence to Assess Educational Programme Effectiveness. International Journal of Science Education, (May), 1-19.
[44] Lindemann-Matthies, P. (2002). Wahrnehmung biologischer Vielfalt im Siedlungsraum durch schweizer Kinder. In R. Klee & H. Bayrhuber (Hrsg.). Lehr- und Lernforschung in der Biologiedidaktik, Band 1 (S. 117-144). Innsbruck: Studienverlag.
[45] Lindemann-Matthies, P. & Bose, E. (2008). How Many Species Are There? Public Understanding and Awareness of Biodiversity in Switzerland. Human Ecology, 36(5), 731-742.
[46] Lindemann- Matthies, P., Constantinou, C., Köhler, K., Mayer, J., Nagel, U., Raper, G., Schüle, D, and Beltran, C. K. (2009). The integration of biodiversity education in the initial education of primary school teachers : four comparative case studies from Europe. Environmental Education Research, 15(1), 17-37.
[47] Lindemann-Matthies, P., Junge, X. & Matthies, D. (2010). The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. Biological Conservation, 143(1), 195-202.
[48] Lude, A. (2006). Natur erfahren und für die Umwelt handeln. NNA-Berichte, 19(2), 18-33.
[49] Lude, A., Schaal, S., Bullinger, M. & Bleck, S. (2013). Mobiles, ortsbezogenes Lernen in der Umweltbildung und Bildung für nachhaltige Entwicklung. Hohengehren: Schneider Verlag.
[50] Mayer, P. (2006). Biodiversity - The appreciation of different thought styles and values helps to clarify the term. Restoration Ecology, 14(1), 105-111.
[51] Menzel, S. (2007). Learning Prerequisites for Biodiversity Education – Chilean and German Pupils' Cognitive Frameworks and Their Commitment to Protect Biodiversity. Georg-August-Universität zu Göttingen.
[52] Menzel, S., & Bögeholz, S. (2009). The Loss of Biodiversity as a Challenge for Sustainable Development: How Do Pupils in Chile and Germany Perceive Resource Dilemmas? Research in Science Education, 39(4), 429-447.
[53] Miron, D. (2003). Enjoyment of violence. In: D.R. Bryant & J. Cantor (Hrsg.). Communication and emotion: Essays in honor of Dolf Zillmann (S. 445 - 472). Mahwah, NJ: Erlbaum.
[54] Nabi, R. L., & Krcmar, M. (2004). Conceptualizing Media Enjoyment as Attitude: Implications for Mass Media Effects Research. Communication Theory, 14, 288-310.
[55] Navarro-Perez, M. & Tidball, K. G. (2012). Challenges of Biodiversity Education: A Review of Education Strategies for Biodiversity Education. International Electronic Journal of Environmental Education, 2(1), 12-30.

[56] Palmgren, P.C., Wenner, L.A. & Rosengren, K.E. (1985). Uses and gratifications research: The past ten years. In: P.C. Palmgren, L.A. Wenner, & K.E. Rosengren (Hrsg.) Uses and gratifications research: Current perspectives (S. 11-37). Beverly Hills, CA: Sage.
[57] Perry, J., & Klopfer, E. (2014). UbiqBio: Adoptions and Outcomes of Mobile Biology Games in the Ecology of School. Computers in the Schools, 31(1/2), 43-64.
[58] Prensky, M. (2001). Digital Game-Based Learning. Mc Graw-Hill.
[59] Ruben R. Puentedura, Transformation, Technology, and Education. (2006) http://hippasus.com/resources/tte/ (accessed 14th October 2015).
[60] Raith, A. & Lude, A. (2014). Startkapital Natur. München: oekom.
[61] Raney, R.M. & Bryant, J. (2002). Moral judgement in crime drama: An integrated theory of enjoyment. Journal of communication, 52, 402 - 415.
[62] Randler, C., Hummel, E., Glaser-Zikuda, M., Vollmer, C., Bogner, F. X., & Mayring, P. (2011). Reliability and Validation of a Short Scale to Measure Situational Emotions in Science Education. International Journal of Environmental and Science Education, 6, 359-370.
[63] Rasch, G. (1960). Studies in mathematical psychology: I. Probabilistic models for some intelligence and attainment tests. Studies in mathematical psychology: I. Probabilistic models for some intelligence and attainment tests. Copenhagen: Nielsen & Lydiche.
[64] Rheinberg, F. (2004). Intrinsische Motivation und Flow-Erleben. http://www.psych.uni-potsdam.de/people/rheinberg/files/Intrinsische-Motivation.pdf (accessed 14th June 2015).
[65] Roczen, N., Kaiser, F. G., Bogner, F. X. & Wilson, M. (2014). A Competence Model for Environmental Education. Environment and Behavior, 46(8), 972-992.
[66] Ruchter, M., Klar, B. & Geiger, W. (2010). Comparing the effects of mobile computers and traditional approaches in environmental education. Computers & Education, 54, 1054-1067.
[67] Ryan, R.M. & Deci, E.L. (2000). When rewards compete with nature: The undermining of intrinsic motivation and self-regulation. In: C. Sansone & M. Harackiewicz (Hrsg.). Intrinsic and extrinsic motivation (S. 14 - 54). San Diego: Academic Press.
[68] Ryan, R. M., Rigby, C. S., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. Motivation and Emotion, 30(4), 347-363.
[69] Salles, J. M. (2011). Valuing biodiversity and ecosystem services: Why put economic values on nature? Comptes Rendus - Biologies, 334(5-6), 469-482.
[70] Schaal, S., Grübmeyer, S. & Matt, M. (2012). Outdoors and Online – inquiry with mobile devices in preservice science teacher education. Word Journal on Technology, 4 (2), 113-125.
[71] Schaal, S & Lude, A (2015). Using mobile devices in environmental education and education for sustainable development - comparing theory and practice in a nation wide survey. Sustainability 2015, 7(8), 10153-10170.
[72] Schaal, So., Lude, A. & Schaal, S. (2015). Pädagogische Fachkräfte als Gelenkstelle zwischen Forschung und Praxis – eine qualitative Studie zur Inwertsetzung lokaler Biodiversität durch Geogames. FDdB: Hamburg.
[73] Schlieder, C. (2014). Geogames – Gestaltungsaufgaben und geoinformatische Lösungsansätze. Informatik-Spektrum, 37 (6), 567 - 574.
[74] Shafer, D. M. (2013). An Integrative Model of Predictors of Enjoyment in Console versus Mobile Video Games. PsychNology Journal, 11(2), 137-157.
[75] Sjøberg, S. & Schreiner, C. (2010). The ROSE project. An overview and key findings. University of Oslo.
[76] Sukhdev, P., Wittmer, H. & Miller, D. (2014). The Economics of Ecosystems and Biodiversity (TEEB): Challenges and Responses. In: D. Helm& C. Hepburn (Hrsg.). Nature in the Balance: The Economics of Biodiversity. Oxford: Oxford University Press.
[77] Sweetser, P., & Wyeth, P. (2005). GameFlow: a model for evaluating player enjoyment in games. Computers in Entertainment, 3, 1-24.
[78] Tamborini, R. (2003). Enjoyment and social functions of horror. In: J. Bryant, D.R. Roskos-Ewoldsen & J. Cantor (Hrsg.). Communication and emotion: Essays in honor of Dolf Zillmann (S. 417 - 443). Mahwah, NJ: Erlbaum.
[79] Tamborini, R., Bowman, N. D., Eden, A., Grizzard, M., & Organ, A. (2010). Defining media enjoyment as the satisfaction of intrsinsic needs. Jounal of Communication, 60, 758-777.
[80] Tobias, S. (1994). Interest, Prior Knowledge, and Learning. Review of Educational Research, 1(64), 37-54
[81] Naturkapital Deutschland – TEEB DE (2012): Der Wert der Natur für Wirtschaft und Gesellschaft – Eine Einführung. München, ifuplan; Bonn, Bundesamt für Naturschutz. https://www.bfn.de/fileadmin/MDB/documents/themen/oekonomie/teeb_de_einfuehurung_1seitig.pdf (accessed 14th June 2015).
[82] Unmüßig, B. (2014). Vom Wert der Natur. Sinn und Unsinn einer Neuen Ökonomie der Natur. Heinrich-Böll-Stiftung. Verfügbar unter https://www.boell.de/sites/default/files/140220_e-paper_vom_wert_der_natur.pdf [14.06.2015]
[83] Uzunboylu, H., Cavus, N. & Ercag, E. (2009). Using mobile learning to increase environmental awareness. Computer & Education, 42, 381- 389.
[84] Vogt, H. (2007). Theorie des Interesses und Nicht-Interesses. In: D. Krüger & H. Vogt (Hrsg.). Handbuch der Theorien in der biologiedidaktischen Forschung. (S. 9 - 20). Berlin: Springer.
[85] von Borries, F., Walz, S. & Böttger, M. (2007): Space, Time, Play. Zürich: Birkhäuser.
[86] Vorderer, P., Klimmt, C. & Ritterfeld, U. (2004). Enjoyment: At the Heart of Media Entertainment. Communication Theory, 14(4), 388-408.
[87] Wilde, M., Bätz, K., Kovaleva, A. & Urhahne, D. (2009). Überprüfung einer Kurzskala intrinsischer Motivation (KIM) Testing a short scale of intrinsic motivation. Zeitschrift Für Didaktik Der Naturwissenschaften, 15, 31-45.
[88] Yang, J. C., Chien, K. H. & Liu, T. C. (2012). A Digital Game-based Learning System for Energy Education: An Energy Conservation Pet. The Turkish Online Journal of Educational Technology, 11, 27-37.