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Closing the Gap: Potentials of ESE Distance Teaching

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Abstract: Environmental and sustainability education (ESE) traditionally relies on green teaching environments and active participation. Thus, during the lockdown phase, a gap between curricular goals and learning outcomes appeared. This study investigates the impact of ESE distance teaching on 288 Bavarian fifth-graders and learning factors that could bridge this gap. The influence of digital preferences on learning progress is examined and compared with the influence of fascination levels. A negative correlation between spending time outside in nature and spending time inside in front of a digital device is expected. A control group completed a learning unit about biological topics such as plant identification and environmental factors, as well as ESE topics such as characteristics of sustainable agriculture, at an out-of-school ESE center. The experimental group completed the same learning unit in distance teaching. Fascination with Biology (FBio) and Digital Nativity Assessment Scale (DNAS) were applied in addition to a customized knowledge test. Both values seem to have a positive impact on learning outcomes. There were no significant differences between the control and experimental group. Surprisingly, Fascination and Digital Nativity show a low, if not negligible, relationship. Implications for digital ESE, especially between outdoor learning centers and schools, are discussed.

Keywords: distance learning; sustainability teaching; digital nativity; fascination with biology

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1. Introduction

The United Nations (UN) *2030 Agenda* includes 17 Sustainable Development Goals (SDGs). These are intended to address global problems such as climate change, poverty, and inequality. SDGs can be implemented at the political and individual level. The former is encouraged, for example, by the SDG Index [1]. The index evaluates countries and cities based on the SDGs and assesses the extent to which they will achieve them by 2030 or in which areas they need to make improvements. According to the SDG Index, Germany should primarily work on Goals 12 (*Sustainable Consumption and Production*) and 13 (*Climate Protection and Adaptation*) [2]. Both areas can be improved through political guidelines. Additionally, citizens can exert influence on an individual basis. For example, the food market recently underwent changes regarding meat substitutes due to consumer demand [3,4]. Similar trends can be observed in housing and mobility [5,6]. Measures regarding climate protection have been pushed forward by both the government and citizen initiatives [7,8]. However, top-down measures, i.e., those initiated by the government, are perceived negatively by the population if citizens lack information on the environmental effects of these measures [9,10]. For example, the expansion of renewable energies in Germany is politically promoted, but citizens are skeptical about the successful implementation [11]. In bottom-up initiatives, i.e., projects initiated by citizens, a lack of environmental protection knowledge does not result in citizens questioning the effectiveness of the measures [12]. This suggests that poor scientific expertise, which is necessary to understand interconnections in the ecosystem, has a negative impact on citizens' perceptions only in the case of top-down measures. Consequently, sustainable education should, on the one hand, focus on knowledge transfer, and on the other hand, promote sustainable measures that have been proposed by citizens. A project that has made the leap from bottom-up to top-down, was the "Save the Bees" initiative of 2019, which was initiated locally and eventually implemented at the state policy level. Education for Sustainable Development (ESD) should support both the acceptance of political guidelines and the foundation of further citizens' initiatives [13].

ESD should build a bridge between citizens, policy makers, and scientists by communicating the latest research results in a comprehensible way and by taking into account and promoting affective aspects such as connectedness to nature. To draw attention this, the UN *Decade of Education for Sustainable Development* was initiated. However, the final report of 2017 points out significant shortcomings at the curricular level. To achieve the goals by 2030, curricula need to be further adapted and ESD institutions need to be expanded [14]. In this context, the German school system and regional curricula were analyzed for ESD elements [15]. The results are in line with the findings of the UN, which calls for stronger efforts to achieve the SDGs on the part of the German educational landscape. Furthermore, it was found that there were large differences in the implementation of ESD in the curricula between school types within one federal state and between the same school type in different federal states. The German school system does not offer different learning levels within one high school. After the fourth grade, students choose a type of school that is appropriately designed for stronger or weaker students or has a special focus on content. The new Bavarian *LehrplanPLUS* implemented the most ESD concepts compared to other federal states.

Although ESD covers a wide range of learning approaches, the term *environmental and sustainability education* (ESE) is considered more appropriate. It entails not only ESD, which is a relatively new term in environmental education, but refers to traditional approaches such as nature-based learning, outdoor education, or eco-justice education as well. ESE is implemented as projects supported or led by external cooperation partners supplemental to regular teaching. Due to the Covid pandemic, cooperation with such ESE centers proved to be difficult, as field trips could not take place and digital lessons were initially problematic. As a result, it is reasonable to assume that ESE has been able to make little progress in the past two years and achieving *Agenda 2030* goals will become even more important in the coming years to compensate for these setbacks. As the pandemic situation remains challenging, digital or distance-learning ESD initiatives are gaining importance.

Research approaches that refer to control groups and experimental groups are viewed critically in educational research [16,17]. In this article, these terms are also used, but the reader is asked to reflect on them at this point. Several aspects could have influenced the participants but were not measurable. First, the data collection took place during an exceptional situation. Pandemic-related distance teaching led to an interesting research approach. However, this resulted in a lack of values from regular classes, as these simply did not exist during that time period. Second, when researching learning scenarios, it is impossible to control all variables satisfactorily as compared to controlled experiments in a laboratory [18]. Students are individuals who hold individual experiences and learning capacities. Learning environments are thus perceived individually, too. The same is true for teachers, yet they play a minor role in this study design. Even if significant learning effects occur, they can never be attributed to a specific variable. The sample size should offer insights into a basic trend, though, which should be confirmed or rejected with appropriate follow-up studies [19].

1.1. Impact of Distance Education on ESE Learning Outcome

ESE often relies on out-of-school settings, as this is a suitable way to implement multi-perspectivity. Even though visiting these places requires additional organizational, temporal, and financial effort, teaching programs at out-of-school learning places are seen as worthwhile, as they can be conducive to linking knowledge, increasing motivation, and fulfilling curricular anchored cognitive as well as affective learning goals [20,21]. Actively engaging students in the out-of-school learning space fosters both affective and cognitive progress [22–24]. Curricular requirements such as the imitation of research procedures, action orientation, and applicability are met [25]. Finally, the high level of self-regulation and practicality should enable deeper learning and contribute to environmental awareness, which in turn can be intensified through cross-curricular arrangements and increase intrinsic motivation: A creative, authentic approach to the learning object should promote positive experience via multisensory experiences and explorations. Based on these findings, the intervention unit was designed to be problem-oriented and student-centered. However, the positive effects of an out-of-school learning site and certain aspects of discovery learning are difficult to replicate in distance education. This problem was encountered by many out-of-school learning curricula: even when they offered a digital fallback for processing at home, it was questionable what advantages would accrue from this facility. In addition to the complexity of ESE content, teachers also faced the methodological and technical challenges of emergency distance teaching [26]. Other studies indicate that low-achievers and marginalized groups had more problems with distance learning than high-achievers [27,28]. Thus, the present study assumes that students in distance learning will perform worse in terms of learning progress than the control group.

1.2. Impact of Digital Preferences on ESE Learning Outcome

Besides contextual challenges of ESE, students as well as teachers were confronted with additional methodological challenges due to spontaneous distance learning. It is implied that younger generations, by growing up in a digitized world, have inherent skills that are not developed, or at least, less developed in older generations [29]. One such theory is about digital nativity by Prensky. *Digital natives* are defined as people who were raised during the cyber age [30]. *Digital immigrants* are people who were not born into the cyber age but live in it. According to this theory, being surrounded by technology leads to intuitively knowing how to use (digital) technology, having a basic digital literacy, being comfortable with multitasking (performing different tasks at the same time), preferring experimental and collaborative learning methods, and perceiving information presented in images easier than in text [31]. According to these skills, students should be more comfortable in digital teaching environments than teachers. If this is not the case, digital ESE should take special care not to overburden learners, both methodologically and content-wise.

Whether digital nativity exists—and if so, what influence it has—is still debated. Some scientists doubt the existence of digital generations, or at least the scope of the differences between natives and immigrants [32,33]. Others have developed measurement instruments for digital nativity [34]. Because the presence of technology in everyday life has evolved even more dramatically since the 2000s, when the theory was first proposed, the differences in digital literacy should be much greater and therefore easier to measure today. In addition, the pandemic resulted in a period of thorough digitalization of the school system and therefore provided a unique opportunity to study students who had to work with digital tools daily.

Even before the pandemic, various studies had been able to establish a link between digital skills and increased cognitive performance and knowledge gains [35,36]. Educational environments are becoming increasingly digitalized, just like working environments. Basic digital skills are therefore a prerequisite for success in and out of school. Digital nativity deals with the extent to which skills such as the ones proposed by Prensky are inherent, or whether they have to be established before digital teaching methods can be implemented in a meaningful way. Compared to *Information and Communication Technology* (ICT) measurement tools, nativity scales go beyond skills and include personal preferences, such as sources of information and media use. In educational contexts, differences between *natives* and *immigrants* should be considered when conceptualizing digital as well as nondigital learning environments.

The *Digital Nativity Assessment Scale* (DNAS) was applied to track digital nativity levels for secondary-level students [37]. It was originally developed to assess self-reported competences such as multitasking and information processing in digital immigrants. The scale comprises four subcategories with a total of 21 items: *Grow up with technology* (5 items), *Comfortable with multitasking* (6 items), *Reliant on graphics for communication* (5 items) and *Thrive on instant gratifications and rewards* (5 items). DNAS was used successfully in other studies; however, the target groups have only been adults so far [38–40]. Students with high DNAS scores are considered to be generally comfortable with digital learning tools. Those with low scores are more likely to have difficulty navigating digital learning environments. The target group of fifth-graders at the beginning of the school year is particularly interesting because ICT has not yet been taught as a compulsory part of the German curriculum.

Previous studies are associated with tests focusing on ICT skills [41–43]. Most of them distinguish fundamentally between the use of digital methods inside and outside of school, i.e., in the context of digitalized lessons or for leisure activities. Before pandemic-related distance teaching, fifth-graders faced digital elements solely in the classroom. Therefore, such a distinction is not useful in this context. The DNAS focuses less on usage times of digital devices and ICT skills and captures more general tendencies and preferences of students. These underlying trends may also be valuable for nondigitized or only partially digitized schools. Another key factor in the selection of the measurement instrument was its user-friendliness. DNAS, with its 21 Likert-type questions, is easy for fifth-graders to use and for teachers to evaluate. Therefore, it is an instrument that could also be used in the classroom.

1.3. Impact of Interest on ESE Learning Outcome

Another aspect monitored in this study is *Interest* as a key factor for successful long-term learning e.g., [44,45]. *Interest* is a particular form of intrinsic motivation related to a specific object, learning content, or person [46]. Consequently, *being interested* is a focused, emotional state that has a positive effect on learning growth and competence acquisition. The concept can be differentiated according to situation and person. *Situational interest* is caused in a specific situation by external factors, such as the everyday relevance of the learning object or the interestingness of the learning environment. *Individual interest* is a stable personality-specific characteristic that expresses itself as a preference towards a certain learning object. For long-term learning effects, educators try to preserve situational interest through didactic-methodical procedures and to anchor it as individual interest [47]. In the context of this study, interest towards the learning object is assessed as *fascination* [48].

To track individual interest in biology, the *Fascination with Biology* scale (FBio) was applied. This standardized instrument has been used successfully in various on-site studies [49,50]. FBio is a subcategory of the *Fascination with Science* scale by Otto et al. [48], which tests affective, cognitive, and behavioral dimensions. Fascination is a latent construct that cannot be measured directly but indirectly through these three categories. The affective dimension measures positive feelings and emotions towards science. The cognitive dimension tests skills, knowledge, and willingness to solve complex scientific problems. The behavioral dimension tracks activities that students perform regularly in their spare time or as a hobby. The test consists of several statements which participants are asked to rate. The authors propose that when effortful actions are suggested in the test (e.g., going somewhere special or using technical devices), then if a participant agrees to make many of those efforts, that is evidence of deep fascination, whereas a person with low fascination will not agree to as many of the suggested actions. Thus, a person with deep fascination will agree to more statements from the test than a person with low fascination. For the target group of this study, it is particularly relevant that 10-year-olds have so far had very high scores in interest in science. In the intervention, this should primarily have the effect that the students stay engaged even in the case of difficulties with digital methodology due to their high individual interest in the topic.

A link has been established between declining individual interest and the decrease in STEM freshman enrollment in the United States [51]. This decline is most evident during high school. Therefore, fifth-graders have an excellent opportunity to build on and maintain high STEM interest. Other studies suggest that individual interest can be fostered primarily in informal learning environments within social learning scenarios, e.g., at an out-of-school learning site [52]. Distance learning can also be informal, but it takes more effort to maintain social learning opportunities. Thus, the developments of the last two years may pose an additional problem for STEM interest. It is therefore expected that fascination levels in this study will be rather low compared to other studies with high school students.

1.4. Importance of the Study and Research Goals

The main research focus of this study is to analyze the potential of digital ESE. Digital teaching methods have become the focus of educational research due to the recent exceptional pandemic situation. Distance learning forced ESE to be conducted remotely. To what extent this lack of nature-based learning experiences has created an educational gap that needs to be bridged remains open. The study will analyze the influence of students' preferences in regard to content and learning process on their cognitive learning progress. The *Digital Nativity Assessment Scale* (DNAS) measures whether students are comfortable with digital learning environments. However, it was initially designed for adults and thus needs validation with students first. The DNAS instrument may be suitable for school use due to its conciseness and comprehensibility. If it performs well in this age group, it may then be adopted for general use. The *Fascination with Biology* (FBio) Scale is used to measure individual interest levels. An initial validation regarding the target group will also be applied here. Both tools are analyzed regarding their robustness in an online ESE learning unit. Finally, results on the connection between digital teaching method, taught content, and ESE learning progress are explored. Accordingly, the following research questions are addressed:

1. How do fifth-graders perform in the German version of the DNAS?
2. To what extent can the internal structure of the FBio scale be identified in German students?
3. Which influences learning progress more: student fascination as measured on the FBio scale or Digital Nativity as measured on the DNAS scale? How do topic and method influence each other?

2. Materials and Methods

2.1. Participants and Intervention Design

The study was conducted in June 2019 and 2020 with 288 participants from eleven different classes form five urban high schools (10.8 ± 0.45 years, 41% ♀). Participation was voluntary. Students completed questionnaires before and after an intervention-style unit. The learning unit was designed with emphasis on an action-oriented approach to teaching central scientific working methods. Problem-based instruction and student activity are characteristics of good teaching in normal school settings. In distance learning, problem-based approaches have shown higher motivation and better learning effect [53]. The unit was not explicitly designed to change Nativity or Fascination Levels, but to relate them to knowledge gains. The results presented here are quantitative in nature as three validated instruments are further explored. However, there are also qualitative elements to the overall project that have been presented in other articles [54,55].

Two different approaches were used to teach curriculum-related content in botany and sustainable agriculture. The control group completed a conventional, one-day on-site intervention, whereas the experimental group completed an online asynchronous learning unit over the course of two weeks (See Table 1). Both groups received an electronic guidebook with tasks either based on information on-site or with links to learning platforms (e.g., *Prezi*). In both settings, teachers were instructed to not provide any additional learning material. Any ambiguities on the part of the students were passed on to the team of tutors consisting of university students, who in turn were instructed as to what extent they were allowed to help in terms of content. Said tutors worked with both the control and the experimental group.

Table 1. Timeline of the intervention (control group and experimental group).

Teaching Content	Control Group	Exp. Group
introduction "Save the Bees" plant characteristics plant identification biotic factors abiotic factors	9 a.m.–12 p.m.	Week 1
characteristics of pastures term "sustainability" sustainable dimensions of agriculture traditional vs. sustainable agriculture sustainable actions	1 p.m.–3 p.m.	Week 2

The first part of the learning unit covered botanical subjects such as characteristic features of plant families and how to determine plants by these features. Students learned, for instance, the botanical terms for flower shapes, leaf shapes, and growth forms. They also had to complete tasks such as determining known as well as unknown plants. The second part of the learning unit continued with prerequisites for ideal plant growth by contrasting different location factors. In order to achieve a comparable action orientation on-site and online, the experimental group was additionally given various DIY tasks such as building and implementing a rain gauge to track precipitation. Based on their findings, students had to choose the most suitable plants for their specific location from a given list with growth prerequisites. This task paved the way for the overall topic of species diversity in rural and urban areas. Students gained deeper insight into pros and cons of traditional and sustainable agriculture through three expert videos. To conclude, students were asked to select from a list of sustainable actions some that they thought would be meaningful for their community or hometown. If the students wanted to, they could present their selection of measures in the form of a poster digitally or on site.

In general, the learning unit was designed to let students work independently. They could, for example, make use of graded learning aids, or in case of the online version, contact tutors, which is recommended for hybrid or distance learning [56]. Another central point of the learning unit was the direct connection with the personal living environment of the students [57,58]. The relevance for the students themselves and their living environment was explicitly established in order to elicit as much personal initiative as possible. The student-centered focus was enhanced through DIY projects. In addition, the students' opinions on sustainable actions were included to show that they can make a difference themselves. According to Table 1, the working period in the online version may seem much more extensive. This design was chosen to meet the needs of the teachers. Instead of participating in a one-day field trip, teachers needed to be able to integrate the lessons into their regular schedules. All schools were in distance learning at the time of the study, meaning synchronous contact with teachers occurred only via video communication. Students in both groups worked with identical research notebooks, information materials, and work assignments, except for the DIY projects. The biggest difference may be the natural environment and the use of living specimens. For the study, suitable pasture sections were created and plants that could be easily identified were planted. The experimental group had to rely on pictures, videos, or plants in the home garden for plant identification. The intervention unit aligns with the *Next Generation Science Standards* (NGSS). It contains Science and Engineering Practices, for example, taxonomic procedures and measuring abiotic factors. Crosscutting Concepts are met in Systems and System Models (boundaries of the ecosystem "pasture"), Structure and Function (of reproductive organs of plants), Stability and Change (stability of abiotic and biotic factors of ecosystems determine their overall stability), as well as Cause and Effect (different methods of farming result in changes of the affected ecosystems). Biological Core Ideas are represented in ESS3.C (human impacts on earth systems), LS2.A (interdependent relationships in ecosystems), LS2.C (ecosystem dynamics, functioning, and resilience), and LS4.D (biodiversity and humans). Scientific Method Core Ideas are addressed, specifically MS-LS2-4 ("construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations") and MS-LS2-5 ("evaluate competing design solutions for maintaining biodiversity and ecosystem services").

2.2. Instruments and Data Collection

To measure the students' digital capabilities, the *Digital Nativity Assessment Scale* (DNAS) by Teo [37] was used. A team of experts was carefully selected for the German translation. Some language adjustments were made specifically for that age group, as well as incorporating new technologies that have emerged since the conceptualization of the DNAS. Before the questionnaire was used in this study, a pilot test with 24 students, who did not participate in the study later on, was conducted. Since there are generally mixed results for the reproduction of Teo's 4-factor structure [33,34] and in addition to translation into German further linguistic adjustments were made, the internal structure was first assessed by means of factor analysis. Since few data are available for this target group, especially regarding possible changes in DNAS scores over short periods of time, the questionnaire was completed before and after the intervention. The Likert-type scale ("strongly disagree" to "strongly agree") consists of four subcategories with five or six questions each. Unlike other international studies [38–40], a 5-point scale was used due to the age of the target group. Since the factor loadings of item M1 were not good in other samples [38], the subscale was reduced to five items.

Secondly, a subscale of the *Fascination with Science* Scale by Otto et al. [48] was applied. It covers behavior, cognition, and affection on a 5-point Likert-type scale ("strongly disagree"/"never" to "strongly agree"/"very often"). The original scale is comprised of 84 items in seven different topics: science in general, biology, chemistry, physics, astronomy, geology, and technology. Each subscale consists of 12 items. In this study, items measuring attitudinal preferences towards biology (FBio) were used. With such a young target group, particular care must be taken not to overwhelm the students with too many question items. As the Fascination scale is quite extensive, only one of the seven subscales was used—specifically, the one in line with the content of the intervention unit. Because no significant changes occurred in other fascination studies, the FBio questionnaire was applied once [59,60]. For both DNAS and FBio some items were reversed (=reworded for the opposite meaning) for data collection and then reversed again for data analysis. This was intended to eliminate students who only ticked maxima and to prevent the potential influence of positive phrasing on students.

A single-choice test specifically designed for this study was used to measure knowledge gains [55]. The items cover botanical knowledge such as typical shapes of plant families' flowers or the purpose of certain plant organs as well as knowledge about sustainability in agriculture and farming methods. The knowledge test was completed by the students before they started the learning unit (pretest) and after they completed the last tasks from the guidebook (posttest). Due to pandemic-related issues it was not possible to conduct a retention test to assess long-term learning. DIY projects and suggestions for sustainable actions were not considered.

2.3. Data Analysis

IBM SPSS 26.0 was used for factor analysis and its AMOS plugin for structural equation modeling (SEM). Level of significance is marked as $p \leq 0.05$ = *; $p \leq 0.01$ = **; $p \leq 0.001$ = ***. For factor analysis, values below 0.25 were left out. Sample size was adequate for behavioral research [61]. Samples larger than 30 ensure enough participants per subcategory, whereas a sample of more than 500 negatively influences sample error of standard deviation.

First, a Confirmatory Factor Analysis (PCA) of the Digital Nativity Assessment Scale (DNAS) was performed to validate the basic structure proposed by Teo [37] and Huang et al. [38]. The two points of measurement for DNAS were combined since *t*-test showed no significant differences from pretest to posttest ($p > 0.05$). Students who filled out DNAS twice were only regarded once, namely the first score.

Another CFA via AMOS was calculated to establish relationships among the latent variables. Finally, structural equation modeling (SEM) with maximum likelihood estimation was conducted to investigate the relationship between knowledge scores, FBio and DNAS. SEM is a commonly used method to analyze interrelationships between variables. Measured variables are drawn as squares; latent ones as ovals. Path values are standardized regression coefficients β. The larger the β value, the stronger the influence. R^2 values are the proportion of variance that can be explained by the independent variable. R^2 values—also called *effect sizes*—below 0.3 are considered weak and above 0.7 strong [62]. Model fit for both CFA and SEM was evaluated with the following conventionally used indices: relative Chi-square (χ^2/df), comparative fit index (CFI), root-mean-square error of approximation (RMSEA) and standardized root-mean-square residual (SRMR). For good model fit χ^2/df should be <3 and CFI > 0.95. CFI is dependent on sample size; thus, we expect it to be lower than 0.9 [63]. RMSEA > 0.08 or SRMR > 0.08 indicate poor fit [64].

3. Results

The findings are organized in two parts. First, DNAS and Fbio tools are analyzed separately. DNAS is designed for adults and thus needs analysis regarding the current target group. Fbio is one of several subscales and thus needs analysis regarding its internal structure. Secondly, structural equation modeling is applied with DNAS, Fbio, and knowledge gains.

3.1. Digital Nativity Assessment Scale

Following Teo's approach, CFA with Varimax rotation was applied on all DNAS items (Teo, 2013, see Table 2). KMO verified sampling adequacy at 0.802, χ^2 =1330.575 and Bartlett $p < 0.001$ (for KMO 0.70 to 0.79 = middling, 0.80 to 0.89 = meritorious, 0.90 to 1.00 = marvelous according to Kaiser [65]). Cronbach's α was at 0.826 (is considered > 0.7 as good, >0.8 as very good, >0.9 not acceptable; see [66,67]). Internal consistency (Cronbach's α) was assessed for each subcategory: *Technology* 0.844, *Graphics* 0.721, *Multitasking* 0.678, and *Rewards* 0.674. The overall mean score was at 2.76 (*SD* = 0.65). Mean scores for each subcategory were: *Technology* 3.24 (*SD* = 1.1), *Graphics* 2.93 (*SD* = 0.88), *Multitasking* 1.8 (*SD* = 0.81) and *Rewards* 3.06 (*SD* = 0.95).

To assess influences between latent variables *Technology*, *Multitasking*, *Rewards, and Graphics*, another CFA of DNAS via Amos was conducted (see Figure 1). It showed good fit indices with χ^2/df at 1.938, RMSEA at 0.068 (<0.08), CFI at 0.883 (>0.9) and SRMR at 0.069 (<0.08). Item R5 was eliminated due to ambivalent results in the CFA prior.

Table 2. Factor analysis with Varimax rotation of Digital Nativity Assessment scale.

Item	Factor			
	1 = Tech	**2 = Graphics**	**3 = Multi**	**4 = Rewards**
T2	0.815			
T1	0.787			
T4	0.705			
T5	0.660	0.253		
T3	0.509			
G4		0.724		
G2		0.684		
G5		0.679	0.271	
G3		0.616		
G1		0.253		
M4			0.767	
M6			0.596	
M2			0.467	
M3			0.422	
M5			0.410	
R5			−0.257	0.204
R2				0.695
R3				0.682
R4				0.586
R1				0.385

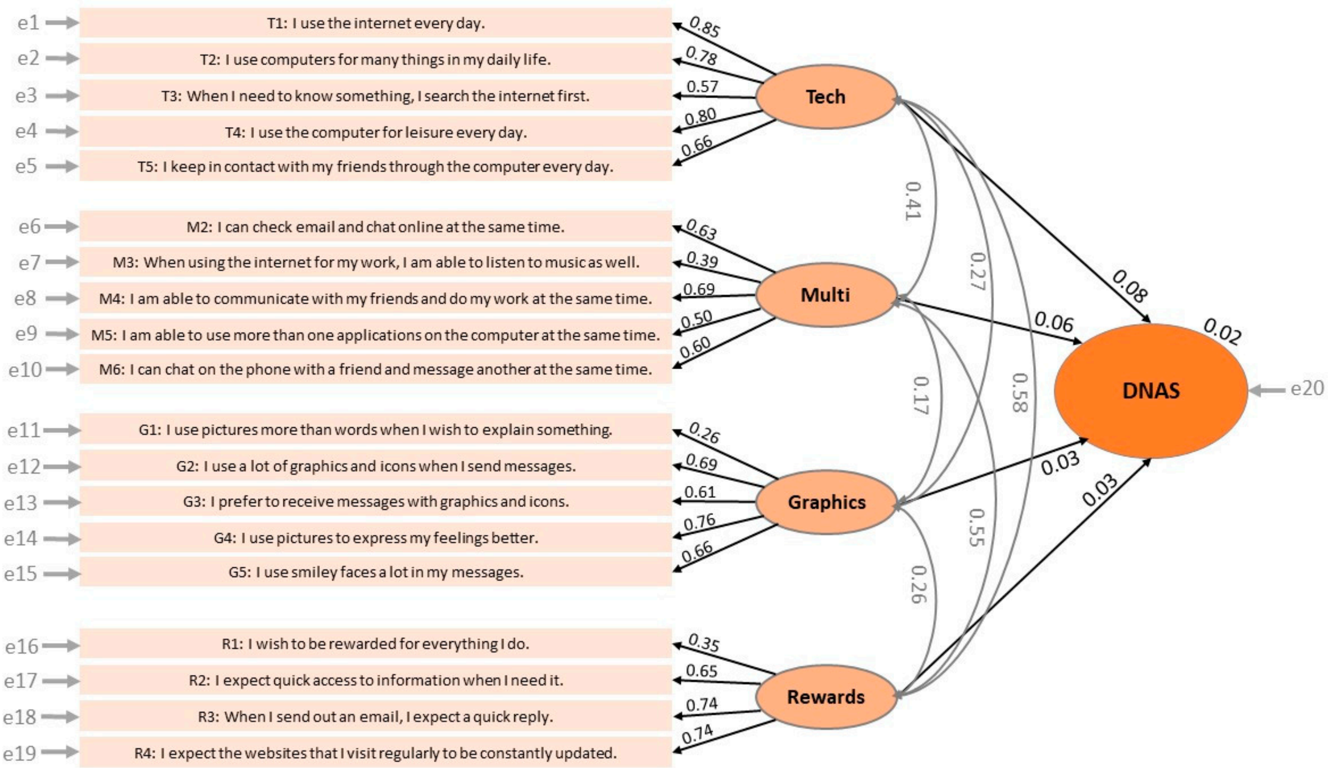

Figure 1. CFA of Digital Nativity Assessment Scale in AMOS.

3.2. Fascination with Biology

CFA of the FBio scale (see Figure 2) showed good values with χ^2/df at 1.569, RMSEA at 0.053 and CFI at 0.884 and Cronbach's α at 0.831. The overall mean score was at 3.54 (*SD* = 0.84). Mean scores for each subcategory were: *affective* 3.684 (*SD* = 0.75), *cognitive* 3.41 (*SD* = 1.08), and *behavioral* 3.42 (*SD* = 1.06). An independent *t*-test showed no significant differences between CG (M = 3.56, SD = 1.02) and EG (M = 3.54, SD = 0.64; t (147) = 0.121, p = 0.904).

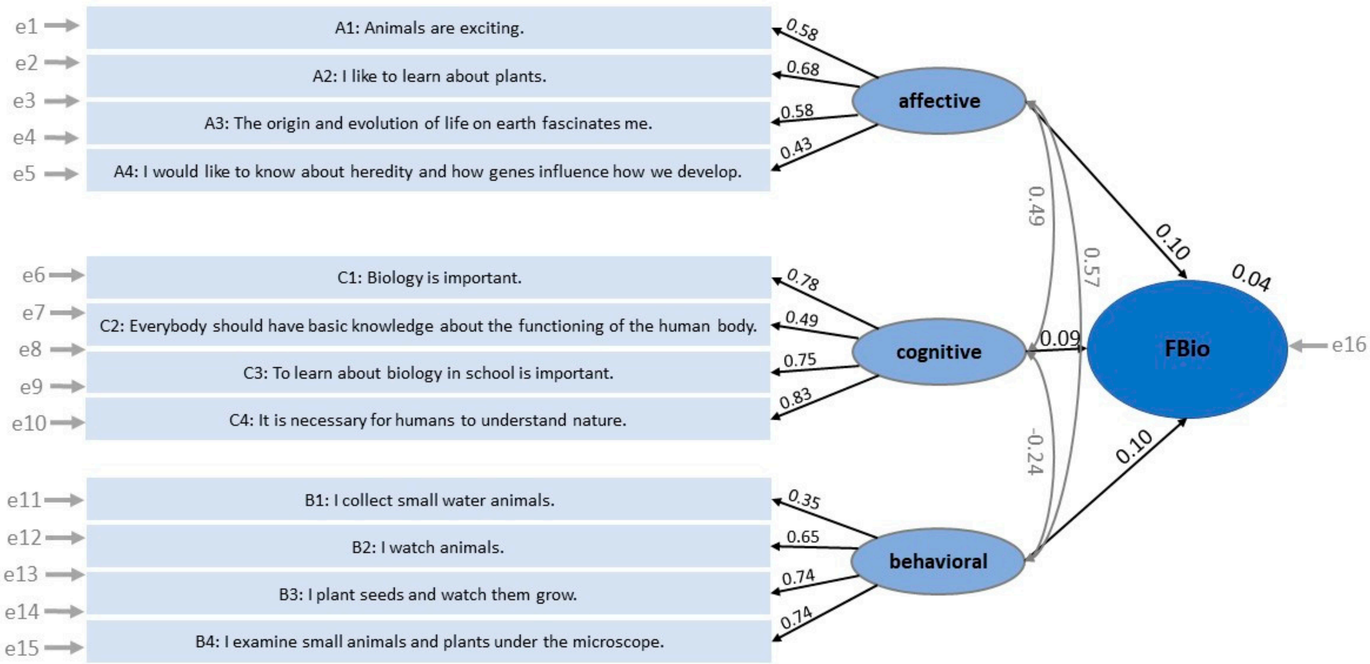

Figure 2. CFA of Fascination with Biology Scale in AMOS.

3.3. DNAS, FBio and Knowledge Levels

The knowledge test was previously confirmed a valuable tool via Rasch analysis amongst [55]. A comparison of pretest (M = 15, SD = 3.45) and posttest (M = 19.17, SD = 3.41) via t-test showed significant learning progress due to participation (t (183) = 58.96, p < 0.001; see Figure 3).

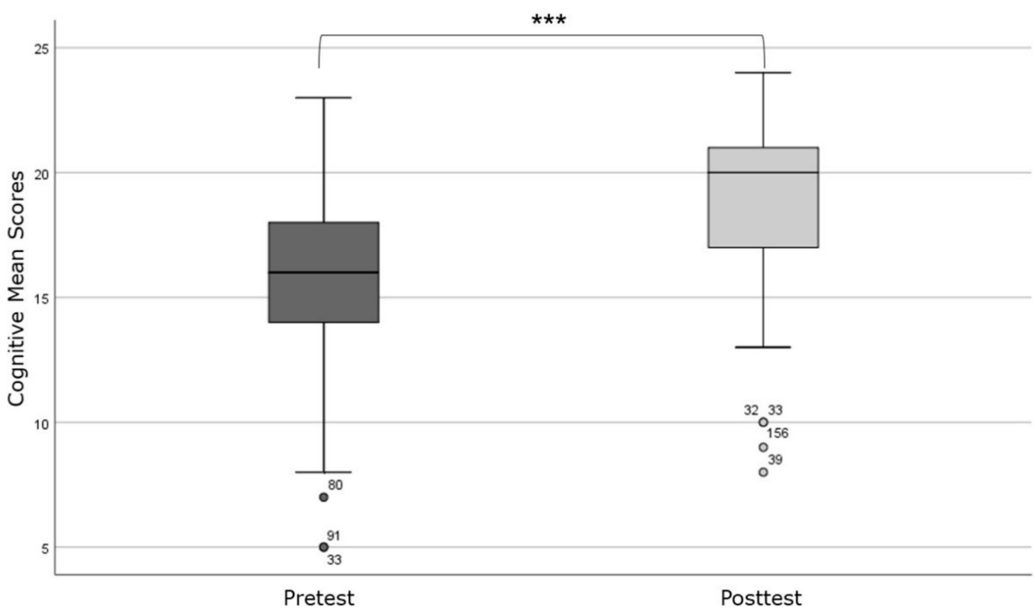

Figure 3. Learning progress in a digital learning environment.

The SEM of DNAS, FBio, and knowledge scores (see Figure 4) showed adequate model fit with RMSEA at 0.06, χ^2/df at 1.725, and CFI at 0.78. β coefficients between DNAS and knowledge gain (0.72) as well as FBio and Knowledge Gain (0.56) are high. Influence of FBio on DNAS is poor (0.18). R^2 values are indicated above each variable: knowledge gain = 0.98, DNAS = 0.16, and FBio = 0.11.

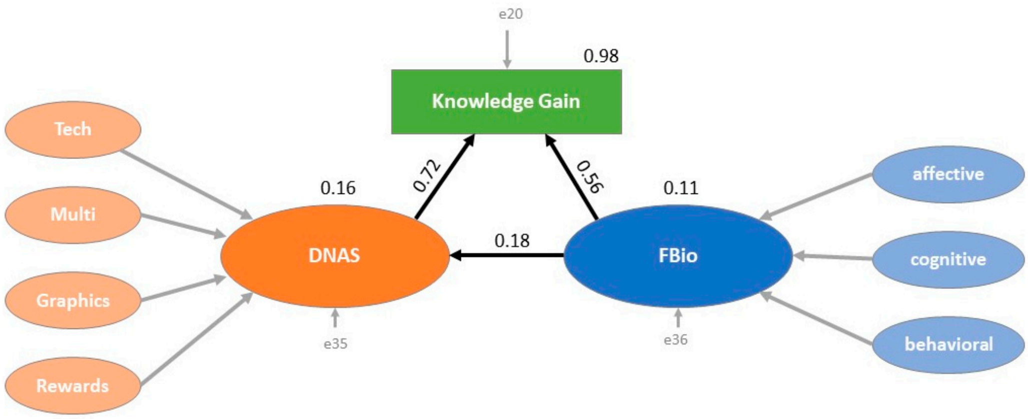

Figure 4. Structural equation modeling of DNAS, Fbio, and knowledge gains.

4. Discussion

Green issues can be taught effectively through online teaching in distance education, although many outreach and out-of-classroom studies depict natural learning environments as a central prerequisite for their success [49,68,69]. As the intervention took place during lookdown schooling, successfully teaching botanical contents without direct interaction with or in nature seemed doomed to failure. Several studies have shown that engaging with and in natural environments effectively increases individual interest and knowledge levels e.g., [68,70,71]. Yet, our findings have proven otherwise: knowledge levels increased significantly and no significant difference detected between online and on-site was found [55]. By examining the designed ESE unit through a triangulation of learning progress, content preferences (*FBio*), and methodological preferences (*DNAS*), it was shown that ESE learning can be similarly effective in on-site and distance learning. In the larger context of the bridge that ESE is meant to build between students, adults, and scientists, these findings provide hope. ESE initiatives can be expanded not by requiring citizens to visit specialized learning sites, but can be reached through online learning opportunities. This allows ESE to reach a broader audience. The integrative nature of the learning unit used in this study should be emphasized. Consequently, such learning programs should rely on action-oriented tasks and content from the target group's life in order to put learners in an active role. Besides effective knowledge integration, this could lay the foundation for bottom-up initiatives by emphasizing the learners' own scope for action.

Although the DNAS tool should be adapted to today's technology, it seems to give a general indication of students' digital condition. Thus, on the one hand, as an analysis tool, it offers possible starting points for methodological workshops with the students. On the other hand, the positive influence of *DNAS* scores on knowledge gain shows some potential for the school context. For example, subjects that do not generate much intrinsic motivation on the part of the students in terms of content could compensate for this loss of motivation by using digital methods. Surprisingly, no negative correlation between *DNAS* values and *FBio* were found. It seems that within the current digital generation "screen-time" is not preferred over "green-time". This provides interesting starting points for modern ESE teaching, which apparently does not necessarily have to take place in natural environments.

4.1. Assessment of DNAS Values

The DNAS instrument was used in this study to evaluate its potential in the school context. There are several established scales for ICT skills [42,72]. However, especially for young students, these are not applicable as the questions are too extensive and the skills tested are too specific. In addition, it seems unrealistic for such scales to be evaluated by inexperienced individuals, as this requires experience with statistical analysis. DNAS does not measure skills directly, but self-reported behavior and methodological preferences. Thus, if validated, it has potential to bridge the research gap in digital education at the primary level. An evaluation of DNAS results based on mean values seems to be well realizable for teachers. The extent to which these potential applications can be achieved with the current version of the DNAS will be discussed.

The students reached above average scores for *Technology*, *Graphics*, and *Rewards*. However, *Multitasking* was at 1.8. This low value could be grounded in the fact that some work processes described in the items are rather atypical for fifth-graders. For example, 10-year-olds do not send emails, but rather text messages. Therefore, items M2 and M4 seem unfitting for this age group. Although other studies point out that *age* is not a reliable indicator for digital nativity, low scores in the *Multitasking* category are supported by lower internal consistency scores for the subcategories compared to DNAS studies with older participants [38,40]. In the latter study, participants reached an overall average of 71%; in the former they reached at least 65%. Our sample reached an average score of 54%. This is quite surprising because Wagner's target group averaged between 19 and 29, (Huang: Ø 37,6 years) whereas our target group was between ten and eleven years old. Since the DNAS tool was used on a German sample for the first time, cultural and linguistic differences could explain lower mean scores.

Factor Analysis revealed some items to be problematic. For example, item M3 ("When using the internet for my work, I am able to listen to music as well.") showed low factor scores (see Figure 1). Possible explanations are cultural differences and social desirability, which is typical for this age group. In the German cultural area, it is unusual for students to listen to music while doing homework. Background noise is generally considered disturbing and distracting. Since the questionnaire measures self-reported behavior, although students were repeatedly assured that neither parents nor teachers would see the results, they may have expressed little agreement on this item—regardless of whether they preferred background music or not. However, to avoid overloading students with too many items, no social desirability or lie questionnaire such as the RCMAS was used in this study [73]. Should the results be refined with a follow-up study, the use of such a questionnaire is advised. The item could also be supplemented by "relaxation music" to exclude distracting noises. In order to tailor the scale to school use, activities that are typical for students should be considered. Additionally, changes in wording of M2, M3, and M4 should also be considered with reference to their β values for DNAS subscales (see Figure 1). *Multitasking* interacts with both *Technology* and *Rewards.* If items were adjusted, this influence would change, too. *Graphics* generally does not seem to interact greatly with any of the other subcategories. In summary, although modern terms such as *cell phone* or *tablet* were already implemented in the German DNAS, the adaptation of some items in relation to young target groups and modern technologies seems appropriate.

Since no significant differences between DNAS pretest and posttest were revealed, the learning unit apparently did not impact the students' digital nativity levels. This supports previous research, where such values are rather stable and thus change only over longer periods of time [29,74]. Research suggests that there are more similarities than differences between digital natives and immigrants [74]. Other studies have found that there actually are more than two generations [75]. Significant differences between first-generation digital natives and later generations are reported [76]. Accordingly, the first generation was the most innovative and excelled at adopting new technology, while the younger generations lagged in ICT skills. This could explain the rather low scores in the study presented here. Consequently, educators cannot assume that students have certain digital skills. Additionally, teachers seem not to be properly skilled to meet their students' needs for digital training [35]. Thus, DNAS could also be valuable for teacher assessment.

4.2. Analysis of FBio Values

In order to shape the behavior of students towards more sustainable lifestyles, not only cognitive but also affective components should be considered. Accordingly, in environmental education, motivational effects are considered to have a great influence on environmentally friendly behaviors [49,77]. Students showed high fascination scores with a mean score of 3.5 on a 5-point Likert scale. This is in line with other studies regarding individual interest levels in ESE [59,78]. It was, however, expected that students who had spent considerable time in distance teaching were detached from nature and thus not as interested in it. Apparently, spending lots of time inside in front of a digital device is not contrary to being interested in ESE topics. The basic structure of FBio was confirmed by factor analysis. As ESE topics are considered interdisciplinary, exploring other subscales of the *Fascination with Science* questionnaire seems promising.

The data suggest that the students were very interested in the content of the intervention. Fifth grade is regarded a critical turning point for science motivation [46,49]. Primary school students generally tend to score high STEM interest levels, which decline during secondary education. They either lose individual interest or develop very high long-term science motivation. It is also suggested that individual interest is conducive for pro-environmental values and behavior [50]. As addressed in this study, ESE should focus on young target groups to transform situational interest into individual interest to promote sustainable lifestyles. Since fascination scores seem to be independent of the learning site, it seems that ESE can be taught in a motivating way not only at of out-of-school centers, but also at home. However, the action-oriented approach of online learning units should be taken into account.

4.3. Influence of Digital Preferences and Fascination Levels on Knowledge Gains

When comparing Fascination with Biology and DNAS, surprisingly no significant relation appeared. Spending a lot of time in the great outdoors seems to be in contrast to spending time with tablets or computers. Therefore, a negative correlation was expected. One possible explanation is that mobile devices enable adolescents to combine being outside and online. Game-based research with a combination of outdoor/lab work and digital activities through mobile apps has been conducted in other STEM subjects [79,80]. Game-related interest seems to be a great predicator for cognitive and attitudinal increase. In biology, digital classification tools for plants have become best practice [54]. Other studies suggest a combination of outdoor and on-screen time [81,82]. Since the digital generation grew up with mobile internet, being interested in digital tools and biological subjects does not seem to be contradictory anymore. These findings bare implications for ESE centers to not only focus on nature-based education but also to adopt certain digital tools.

Students scored high on both interest and nativity. The positive influence on learning progress as shown by SEM analysis falls in line with previous research on the relationship between individual interest levels and knowledge acquisition [59,60,78]. The model also shows high correlations between both values and knowledge gains. This suggests that especially in groups that are not interested in biological topics, digital methods should be used to enable effective knowledge transfer. Thus, digital ESE modules could bridge the gap between less motivated adolescents and sustainability topics.

Studies confirmed that using modern learning settings is a valuable motivation booster [83]. This claim is supported by our SEM, as DNAS levels had an even greater impact on learning progress than fascination levels do. In consequence, future research scenarios should implement an ideal mix of method and subject in order to maximize learning efficiency. Other studies suggest a combination of collaborative settings and gamification elements to increase motivation levels as well as individual learning outcomes [84]. This provides interesting approaches for follow-up studies on fascination. Since FBio is only one subscale, similar teaching methods could be applied to content of other STEM subjects to trace the influence of fascination levels or their development. This has already been well-explored in on-site projects such as teaching–learning labs [85]. However, other STEM subjects are not as popular among students. Thus, educators could use the motivation boost that digital techniques provide. ESE could benefit from findings concerning the connection of being comfortable in digital learning environments and teaching content. We suggest replicating the SEM (Figure 4) with similar teaching techniques in physics, chemistry, and math.

Digital literacy is regarded a key prerequisite for individual learning progress in modern e-learning [86]. As previously discussed, being a digital native does not automatically imply mastery of ICT skills. Studies showed a discrepancy between everyday ICT use (social networking, surfing the internet, participating in online gaming or virtual communities) and skills needed for problem solving and collaborative learning, which are basic elements of STEM learning [87]. Thus, a direct correlation between growing up in a digitized world and better learning outcomes in digital learning environments has not yet been proven. Our findings suggests that in our sample, digital nativity levels have a high influence on knowledge gain. Considering a rather low CFI, other indices very well support the model fit. Low R^2 values indicate poor explanation for sample variance; β values still account for the central tendency of the model [88]. It can be concluded that this model gives a first indication but should be refined by a larger sample. As DNAS comprises several subcategories and does not specifically focus on ICT skills, it is rather an indicator of whether students are generally comfortable in digital learning scenarios.

5. Limitations

The abrupt lockdown phase was an exceptional situation and forced educational studies to use distance or hybrid instruction. Therefore, replication under normal circumstances is advisable, although special care was taken to minimize potential differences caused by the learning location. The lesson was designed to be student-centered and action-oriented. In addition to fascination and digital preferences, this could also be a motivational factor that has a positive effect on knowledge gains. In order to provide further insights into how online instruction should be structured for the digital generations, different e-learning concepts on the same topic need to be compared. To investigate the influence of digitization or the relationship between digital nativity and analogue and digital ways of working, an additional, completely analogue group could have been included. However, since most out-of-school learning locations are by now at least partially digitized, this seemed a rather unrealistic scenario. If the DNAS tool is adapted to this age group and to modern technology, the relationship between DNAS scores and learning growth or improvement of DNAS scores could be continued through certain training programs. In the unit examined in this study, digital skills were taught only passively through use. A unit that explicitly promoted ICT skills might have had a greater impact on DNAS scores. Nevertheless, the relatively low scores in some DNAS categories indicate that the validity of the instrument may be questionable. Here, a study in which different questionnaires on digitality are used and compared should generate further insights.

As FBio scores are expected to drop in high school students and digital skills are refined during that age, repeating the study for an older target group seems appropriate. CFI values of the SEM are rather low. This could be caused by interdependencies between individual factors or a small sample size for structural equation modeling. Thus, repeating the research setup on a larger scale should provide more information for the validity of the model.

6. Conclusions

Modern ESE should rely on both on-site and online teaching methods. Our results indicate that preferences for both teaching method and teaching content have a great influence on learning outcome and thus can be used to strengthen ESE. With digital learning programs, more participants can be reached. We suggest using digital elements to extend collaborations between authentic ESE learning sites and educational institutions. Our study provides additional evidence of the basic robustness of the Digital Nativity Assessment Scale. However, data suggest that some items should be adapted to younger users and state-of-the-art technologies. In addition, to make the scale more attractive for school use, activities from the learning contexts could be included (e.g., "I can take notes and pay attention to a learning video at the same time"). A meta-analysis of all available data from this measurement instrument could help identify problematic items. We generally suggest more comparative studies with digital immigrants and natives. The importance of fundamental differences between digitally proficient and nonproficient people is increasing in modern society. However, it remains to be clarified whether digital nativity is simply a question of age, or whether other factors such as social background or nationality may play a more important role. Structural equation modeling also confirmed a high influence of fascination levels on learning progress. To provide more accurate information about the relationship between method, subject, and learning progress, the other subscales of the fascination scale should also be tested both in online learning units and in the field.

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