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An app by students for students – the DPaCK-model for a digital collaborative teamwork project to identify butterflies

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Acquiring digital literacy has become one of the most important tasks in school. But also acquiring species knowledge is an important task and essential to understand the value of biodiversity. In order to achieve this, a toolbox was developed to enable students to create an identification key on any group of living species. This can be either a species group of animals or plants or living creatures of the school ground. It is based on the interactive identification tool "ID-Logics" which was changed into an easy-to-use learning platform for the students. The students (*n* = 26, age 11–13, Gymnasium) were interviewed using the method of Retrospective Inquiry into Learning Process to capture changes in imagination. The results were analyzed and discussed using the DPaCK-Model. Based on the data, we can demonstrate the utility of the DPaCK-Model and discuss the implications for (biology) teaching. The DPaCK-Model proves to be a useful tool for analyzing this student project from the subject didactic perspective. Compared to the TPaCK-Model, digitality brings up new aspects, which we discuss in terms of the implications for (biology) teaching. In summary, the focus of the ID-Nature project is on: Collaboration, cooperation, and participation combined with publication, sharpening the eye for characteristic items for identification. And this is the new challenge of digitality. The orientation framework for the acquisition of digital competences developed for teacher education should also be seen as an enrichment for students. In accordance with these results, guidelines were set up for teaching digital literacy. The project is furthermore seen as an example for Education for sustainable Development (ESD).

KEYWORDS

digitality-related pedagogical content knowledge – DPaCK, media in Science Education, app development, mobile learning, species identification, Education for Sustainable Development (ESD)

1. Introduction

As our world is becoming increasingly digital, schools are also becoming more and more digitalized. But although digital literacy was introduced into the German school system in 2017 (Kultusministerkonferenz, 2017), it has not really had an impact on teaching for a long time. However, the Corona pandemic with the worldwide lockdowns and the associated school closures has given the digitalization of teaching a major boost. It is also clear that it is not only necessary to continue investing in digital infrastructure of schools in Germany. It is particularly important to examine the new opportunities offered by digital learning environments. Valid statements on the effects of digitally supported learning offers can only be given on basis of empirical data in order to develop evidence-based learning environments.

Parallel to this process of digitalization, the world is experiencing another upheaval: Our world is also losing more and more species. Biodiversity loss is one of the greatest challenges of the 21st century. The global decline of species (Frobel and Schlumprecht, 2014; Hallmann et al., 2017) is accompanied by the decline of species knowledge and species identification. Therefore, species identification is an essential skill, which has also been recognized by the German government: it emphasizes the importance of taxonomy education and species knowledge for the conservation of diversity based on the National Biodiversity Strategy (NBS) of 2007 (Küchler-Krischun and Walter, 2007). Yet, the acquisition of species knowledge is a difficult task, especially for students at schools who experience less nature year after year. This leads to an ever-increasing alienation of young people from nature, even though they continue to show an interest in experiencing nature (Koll and Brämer, 2021).

Awareness of global problems such as the decline in biological diversity, climate change or land sealing has led to the proclamation of the UN Decade of Education for Sustainable Development (ESD) from 2005–2014 and the definition of the 17th Sustainable Development Goals (SDGs). Since then, "sustainability" has become an anchored basic principle in the education systems in almost all countries (Cebrián et al., 2021). Educational institutions can and should therefore consistently promote the development of sustainability skills. However, the complexity due to the networking of the diverse perspectives of sustainability (such as ecological, social and economic) remains a major challenge for classroom teaching, especially since sustainability skills are difficult to access (Riess et al., 2022). For this challenge, it is important for teachers to take into account that in addition to pedagogical knowledge and scientific knowledge (here on the topic of butterflies), digital skills are also necessary. It is precisely these competencies that are addressed with the DPACK-Model and are therefore the focus of this article (Huwer et al., 2019). The connection between species knowledge and ESD is close and important for understanding and protecting our environment: Species knowledge refers to knowledge of different species of plants, animals, and other living things that occur in a specific area. In order to understand the connection between species knowledge and ESD, it is necessary to clarify that all living things live in a certain environment and interact with other species. Each species fulfills a specific role in the ecosystem and depends on other species, like the caterpillar and its food plant. By learning about species and their ecological relationships, we can better understand how ecosystems function and how they are affected by human activities. By imparting this knowledge, we can help people to take an active role in protecting the environment and biodiversity. Thus, this project promotes the following ESD goals: Goal 4.7 (Quality Education): "all learners acquire the knowledge and skills needed to promote sustainable development (…)." (United Nations Department of Economic and Social Affairs, 2023) and Goal 15.5 (Life on Land): "Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species." (*ibid.*). In species identification, we follow the educational idea that you can only appreciate and then protect what you know. From this perspective, neighboring SDGs are also affected, such as Goal 12 (responsible consumption in production) or Goal 17 (partnerships to achieve the goals).

Many studies in recent years have shown that digital media can help contribute to this understanding (Ekin et al., 2023). However, it is often criticized that students are too often only users, but have little opportunity to participate. With our project ID-Nature described here, we set out to counter this criticism.

Our project "ID-Nature" offers a new digital learning environment and wants to train students to develop their own species identification app. It therefore combines teaching digital literacy and species knowledge and thus also makes a contribution to ESD. And it wants the students to be motivated. Therefore, "ID-Nature" wants to foster active involvement of young people in nature conservation – with digital media and technology. This shall be achieved by the following strategies:

- Consumers become producers:
  - Action-oriented development of a butterfly identification app.
- Teamwork leads to success:
  - Students experience consciously that sustainable action in a team is worth more than individual action.
  - Development of teaching material and long-term establishment in nature and environmental protection.
- Enthusiasm for active environmental protection:
  - Butterflies are a group of species that have positive connotations.

In order to achieve this, a toolbox was developed to enable students to create an identification key on any group of living species. This can be either a species group of animals or plants or living creatures of the school ground. It is based on the interactive identification tool "ID-Logics" (Groß et al., 2018). In this interactive identification tool, species groups are added step by step as subject scientists enter information about the species to be identified into the app's content management system (CMS). Originally, the system was developed so that experts could contribute their knowledge about species to the app. In the "ID-Nature" project, however, a completely new approach is to be taken that enables the students themselves to contribute their knowledge and actively participate in the project *via* the CMS. Therefore, this project has the challenge to create such a digital identification key for butterflies by students. In order to manage such a large project, over 500 students in 40 classes have to work together. This is made possible by developing an easy to use working and learning platform for the identification tool "ID-Logics." In the project students acquire digital skills and knowledge of species. But it offers much more, it creates new possibilities of participation and cooperation. This is possible in two ways: at first during the creation of the identification key. But after the identification key has been released during a students' convention, the app will be open for public access. So in a second step, students and anyone from the public will then be able to use it for identifying butterflies in nature as well as training their species knowledge. Teachers can practice these identification skills later on by using a gamification tool that allows students to "catch" a butterfly during a game. The implementation of this gamification tool is currently under development and will take place in a follow-up study.

The study is based on the following theoretical framework: according to the moderate constructivism approach (Duit and Treagust, 1998; Fosnot, 2013), we understand learning processes as the change of conceptions, i.e., an active process that takes place in the minds of the learners. This approach already shows how important research is in the field of the imaginary worlds of learners and how heterogeneity has to be dealt with accordingly. If the heterogeneity of conceptions in the subject of species identification is to be diagnosed, it is first necessary to agree on what conception means. It describes a possible combination of the sensory impressions we perceive in a meaningful way to explain a phenomenon (Johnson, 2005). It is not surprising that most people have a very similar conception of a concrete object (for example a butterfly) because it can be perceived directly. Only with abstract topics (for example an algorithm) does it become clear that several comprehensible and yet very different conceptions exist. Since this conception of building an app for species identification is different in the minds of many people, it is hardly possible to detect heterogeneity at this level. It therefore makes sense to examine language – and thus conceptions – at a more fundamental level. While the cycle principle or nutrition by substance intake belong to a category called notions, finer linguistic structures, so-called concepts, can also be identified (Figure 1). While words and other symbols are no conception themselves, they are the building blocks of our verbal communication. Terms can be identified by a meaningful connection of several words and thus indicate the first level of conception. The three dots represent the possibility of more (than two) elements forming a conception of the next level. Based on Odgen and Richards (1923), the model categorizes different types of conceptions and does not represent a chronological progression (Figure 1).

Concepts are formed by terms, which are connected by a relation. In their scope and complexity, they are one level below notions. The level of concepts enables an analysis of the conceptions which is on the one hand detailed enough for an individual diagnosis, but at the same time keeps the effort within limits. On the level of concepts, considerable individual differences can be found between learners (Johann et al., 2022). With help of these theoretical approaches, we can – on the one hand – shed light on statements made by learners in relation to the processes of meaning making. On the other hand, we can also use this approach specifically to develop learning tasks.

The essential idea of structuring knowledge is that the students no longer see biological topics – such as genetics, ecology and evolution – separately from each other (additive learning), but can link them together *via* basic concepts (cumulative or meaningful learning). Such basic concepts (such as "structure and function") were initially descripted for the development of lessons, i.e., for the teachers. Basic concepts were therefore primarily of importance for teaching – and less for learning. Later on, they were also made accessible to students (e.g., *via* textbooks) for structuring conceptions and have thus gained in importance. While basic concepts focus on areas of knowledge, competencies aim at skills that are needed to solve a challenge. For the implementation of digital competencies in teacher education, the "Digital Competencies for the Teaching Profession in the Natural Sciences" (DiKoLAN – Becker et al., 2020; Thoms et al., 2022) was developed. This orientation framework defines operationalized competencies with the aim of covering the skills and abilities required for teaching digitality. It introduces teachers to teaching in a digital world and to lay the foundation for technological pedagogical content knowledge (TPaCK, based on Mishra and Koehler, 2006). Even though DiKoLAN was developed for teacher education, it is used here to analyze students' acquired competencies, just as we use the DPaCK-Model for analyzing the project, which was likewise developed for teacher education. The DPaCK-Model (Figure 2), developed under the same premises as the DiKoLAN framework (Huwer et al., 2019), was proposed to reformulate the existing TPaCK-Model to include elements of knowledge about cultural change through digitalization

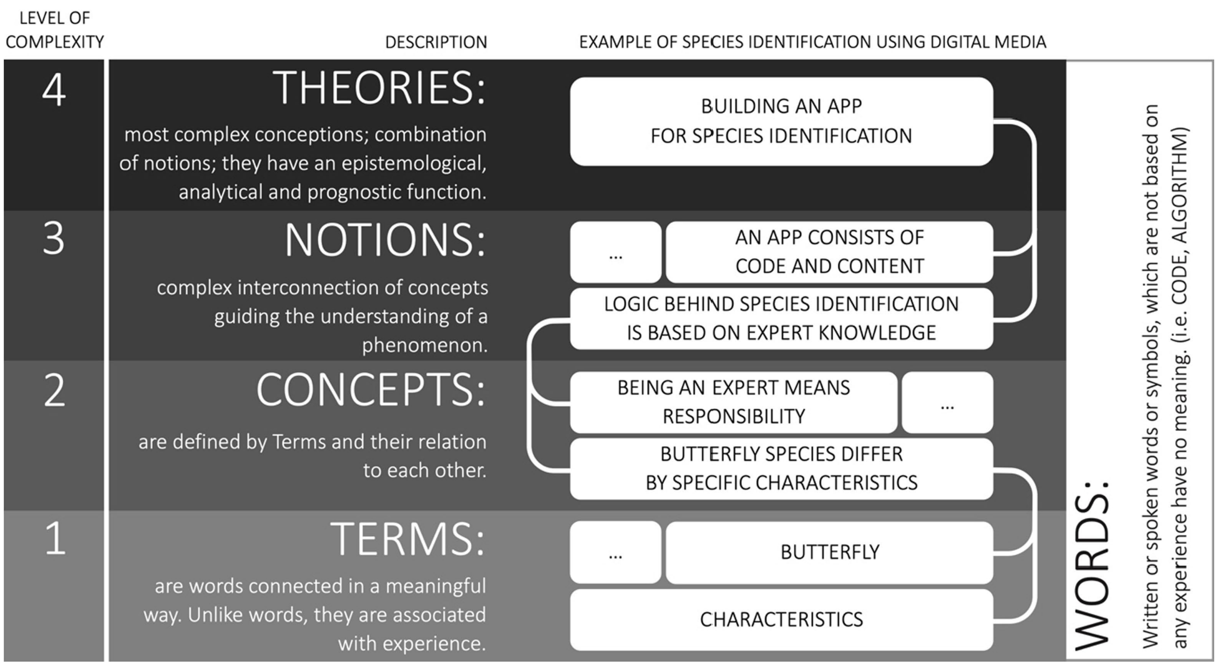

FIGURE 1
Hierarchical order of conceptions of different levels of complexity with examples on building an app for species identification based on Michelsen et al. (2022).

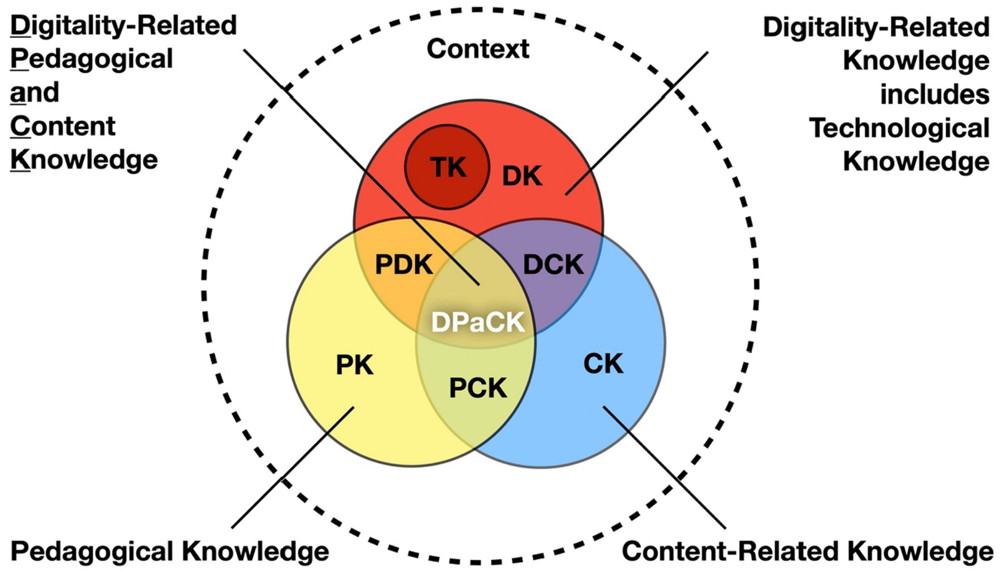

FIGURE 2
The DPaCK-Model based on Huwer et al. (2019).

into an expanded TPaCK-Model. This reformulation of the model is preceded by an expanded understanding of digitalization ("digitality"). Digitality (or "digitalism") is used to mean the condition of living in a digital culture, by analogy with modernity and post-modernity. The design of digitality requires appropriate skills as well as social, systemic, semiotic knowledge in the respective technical context to evaluate options in decision-making situations, to assess the consequences of digitalization in order to be able to act in a considered and competent manner. With regard to this knowledge, digitality in STEM classes therefore also requires specific analytical skills. This new model points out the intersections of the three relevant fields for designing digital education: pedagogical, content-related and technical knowledge: "Digitality-related pedagogical and content-related knowledge (DPaCK) encompasses the intersection of digitality-related knowledge, pedagogical knowledge and content knowledge. It therefore creates the foundation for the design of subject-specific teaching and learning processes with technologies. "(Huwer et al., 2019: 305). The possibility of using the DPaCK-Model as an analysis tool will be used here in relation to the ID-Nature project. And even though DiKoLAN was initially developed based on the TPaCK-Model, it can now be used interchangeably for the DPaCK-Model as well (Becker et al., 2020: 19).

For a learning environment to be effective, learner motivation is a crucial factor. It is not possible to influence it directly – but general conditions can be created that promote a higher quality of motivation. The Self-Determination-Theory (SDT, Ryan and Deci, 2000) provides a framework for both, designing and assessing the learning environment. According to the Cognitive-Evaluation-Theory (a sub-theory of the SDT), people strive to fulfill the three basic psychological needs (competence, relatedness, autonomy). If the goals intended by a learning environment enable the fulfillment of these basic needs, they are more likely to be pursued by the learners. Furthermore, the satisfaction of basic needs causes an internalization of the perceived locus of causality of motivation. As the degree of internalization (Figure 3) increases, the quality of motivation increases as well.

Since intrinsic motivation (no goal orientation) cannot be specifically encouraged for the design of product-oriented learning environments, the various levels of extrinsic motivation are significant instead.

Some research has been done already on the impact of teaching with digital identification keys: it promotes students' positive opinion about plants (Andic et al., 2022), brings enjoyment and learning about individual characteristics of plants compared to paper-based dichotomous identification keys (Finger et al., 2022). In this project although the students will create a digital identification app themselves.

In this article we focus on analyzing the impact of the ID-Nature learning opportunity considering the model of digitally-related pedagogical and contend-related knowledge (DPaCK). Therefore, the research questions of this study, which is dedicated to the app design process and the first iteration of a multi-step design approach, are:

1. What conceptions have students acquired in the area of DPaCK? The focus is on:
1.1: DiKoLAN as an example for the digitally related domain – digital competencies.
1.2: Motivation as an example for the pedagogical domain.
1.3: Subject-specific conceptions as an example for content domain.
2. What are the implications of these perspectives for designing digital learning environments to foster digital literacy and species knowledge?

Our article focuses clearly and exclusively on the education and target group of teachers and their actions in biology classes: based on the identification app "ID-Logics," students in our project develop a digitally supported learning program themselves (keyword: "by students for students"). They develop – and this is the challenge – an app for identifying butterflies, in which each class only creates a (digital) part of the app. The content is later brought together *via* a digital learning platform (CMS) to create the cohesive and complete

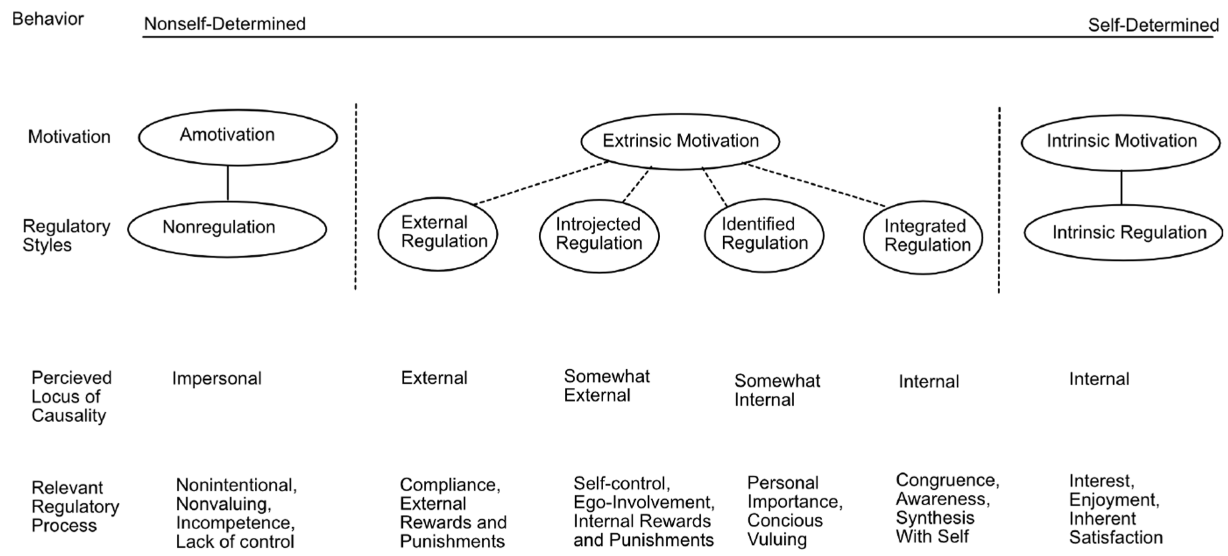

FIGURE 3
The continuum of motivation based on Ryan and Deci (2000).

app. That means: In contrast to existing school lessons, we qualify teachers in order to qualify students themselves. In order to measure the effects (possibly the learning success) of this ambitious qualification chain, it makes sense to primarily record the effect on the students. We are therefore specifically investigating possible changes in the perception of students (e.g., Chi, 2008). Based on these results, we can in turn and make recommendations for teachers.

2. Materials and methods

2.1. Participants and interviews

This study is based on design-based research (DBR; McKenney and Reeves, 2018; Scott et al., 2020). In DBR, CMS elements are collaboratively optimized with instructors and learners in recurring sub steps until they can achieve the best possible learning effects (Groß et al., 2020a). In order to answer the research questions, we need to be able to reflect on the students' experiences with participating in our project "ID-Nature." Therefore, we conducted a quantitative study in collaboration with two schools, a KGS (Cooperative Comprehensive school) and a high school (Gymnasium). We interviewed eight students from 7th grade in three groups and 18 students from 6th grade in four groups. This was done after they had participated in the ID-Nature project with their classes but before attending the students' convention. For the interviews with the students at school, we used the method of Retrospective Inquiry into Learning Process to Capture Changes in Imagination (Groß and Gropengießer, 2003). This was done by investigating learning processes that were initiated or promoted by specific app development situations in the classroom.

For that purpose, all students were contacted beforehand, concerning their willingness to be interviewed. From all positive responses, the 26 students from 11 to 14 years were randomly chosen for the interviews to produce an approximately equal distribution of interviewees with respect to location, age, gender, and the topic of their work with an emphasis on natural sciences. All personalized data were made anonymous.

Each interview lasted for about 30 min and started in general in a time frame of 30 min after their work on the app. We used a structured guideline to align the 26 interviews for reproducibility. Two different researchers conducted the interviews. The interview guideline integrates two methodological approaches: firstly, problem-oriented, open and half-open questions to collect the current conceptions about the different tasks of the DPaCK model conceptions about butterflies and secondly, the retrospective query on the individual learning process. Several basic questions were drawn from validated questionnaires (Paul et al., 2016), from which subsequent questions were built up. The interrelationship between questions and answers was validated by three different researchers based on qualitative content analysis (see Mayring, 2022). In addition, an internal triangulation process with similar questions on the same issue was integrated into the guideline. The first section of the interview established the context of the project carried out by the participant. In the second section, subjects were asked to think and reflect about their work and deduce general characteristics of scientific inquiry from their point of view. Appropriate questions were, for instance: 'How do you recognize butterflies?' or 'What experience do you have with butterflies and how do they reproduce?' The third section of the interview guideline linked to digital experience of the participants. Questions included, for example: 'What is your experience with entering your knowledge into the app?' or 'What are your expectations for the app later on? What did you particularly like, what was difficult for you?' Finally, within the fourth section, causes of possible conceptual changes were requested, if not already addressed during the interview before. For this purpose, we asked questions such as: 'Why did you change your conceptions about butterflies?' or 'Did your conceptions change regarding digital media or species identification?'

The interviews were captured using a voice recorder and processed according to qualitative content analysis (based on

Mayring, 2022; Michelsen et al., 2022). This method includes the following five steps: (1) transcription of voice recordings, (2) editing transcripts (transferring students' statements into a grammatically correct form), (3) organizing students' statements (summarizing the same or similar statements within one interview), (4) explication (interpreting statements by identifying conceptions and underlying experiences), and (5) structuring (formulating associated concepts). For reliability, coding and interpretation of students' statements (steps 4 and 5) were analyzed by two researchers working independently. The organized statements of the students were summarized into tables, where the conceptions mentioned retrospectively were differentiated from the current conceptions. By comparing these conceptions, we were able to construct the learning process on the basis of the detected conceptual changes or the additionally accrued concepts.

The aim of these interviews is to understand the cognitions, attitudes and motivations of the interviewees in relation to the implementation of the project. We used a structured guideline to align the interviews for reproducibility. The interrelationship between questions and answers was validated by three different researchers based on qualitative content analysis (Mayring, 2022: 691–706). For the interpretation of the interviews, we created a system of categories into which we classified the material.

2.2. The students' tasks

For a better understanding of the students' interview answers, here is an explanation about their tasks. The project itself takes about 3–4 h and it is up to the teacher's decision whether this is done during one long or two or more shorter sessions. Preferably, it should be integrated into a unit about insects or a certain ecosystem or to exercise determination. The class is then divided into groups with each group working on one butterfly species. The first task is to collect information about their butterfly species before entering those information into the app in a second step. The research is done with any of the following sources: identification books about butterflies, general research on the Internet as well as on special butterfly websites. By doing this, the students collect information about their butterfly's characteristic features, butterflies and caterpillar's food plants, the form of the pupa but also about the biotope they live in as well as their occurrence of their development stages in the course of the year and their distribution area in Germany. As an alternative method to pure research, the students can also dive into research by picking the matching distinctive-mark-graphics from the app which are printed on cardboard cards (Figure 4). These distinctive-mark-graphics are an essential element of the app "ID-Logics," making visible features for determination in simple drawings. By going through all the graphics of one feature, like the wing edges in Figure 4, the students have to have a close look at which distinctive-mark- graphic resembles their species in the best way. They might also choose two of them when it is unclear which graphic fits in the best way. Another example are the graphics of different habitats. For choosing the right one for their species, they have to gain the information of the habitat the butterfly lives in, for example forest, garden, meadow or wetland.

In the second step, the gathered information has to be inserted into the CMS. Therefore, they log into the CMS, find their butterfly and complete these three tasks: at first, they have to create a profile by inserting photos and writing texts in a mask about the above-mentioned aspects of their butterfly's characteristics, life and occurrence. The second task consists of finding confusable species on provided posters and identification cards by clicking on all similar species on a species list. Thirdly they have to assign the matching distinctive-mark-graphics by clicking on those. This last step thus represents the reversal of the later determination path within the scope of the determination by the app. Thus, the determination only leads to the correct species when this chosen graphic had been previously assigned to this species (see Figure 5).

Figure 5 shows the user level of the app. To start the determination, press the magnifying glass symbol. Then one identification question after the other has to be answered by selecting the most suitable distinct-mark-graphic and clicking on it. In Figure 5, the following identification question is shown: "What is the main color of the upper wing surface?" The question is also illustrated by an explanatory graphic, which in this case shows the outline of a butterfly with color circles next to it. Then the answer is given by clicking on one of the color fields, the distinct-feature-graphics. By making these selections, the number of species in question is thus reduced step by step. This reduction continues until only one species is left. To prevent misidentification, the app enables picture– and text-based comparisons with similar species. One example: If the peacock butterfly is to be determined and a decision has to be made between the orange or red color field, the correct result can only be reached both ways if the students have previously assigned both colors to this species while working in the CMS.

3. Results

In the interviews the students expressed a huge variety of aspects regarding their experience of the project. Many of them pointed out the anxiety about working on an app which will actually

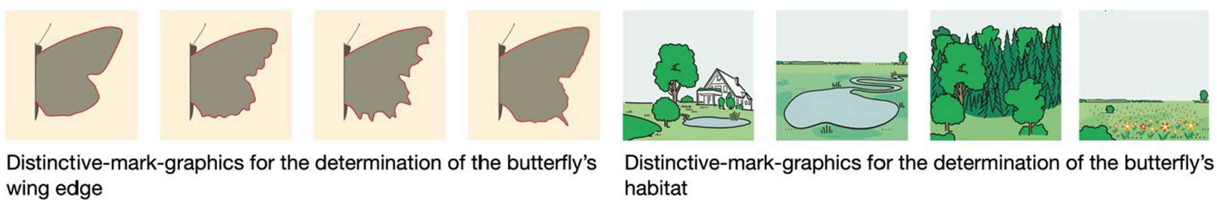

FIGURE 4
Distinctive-mark-graphics that encourage close inspection and knowledge acquisition.

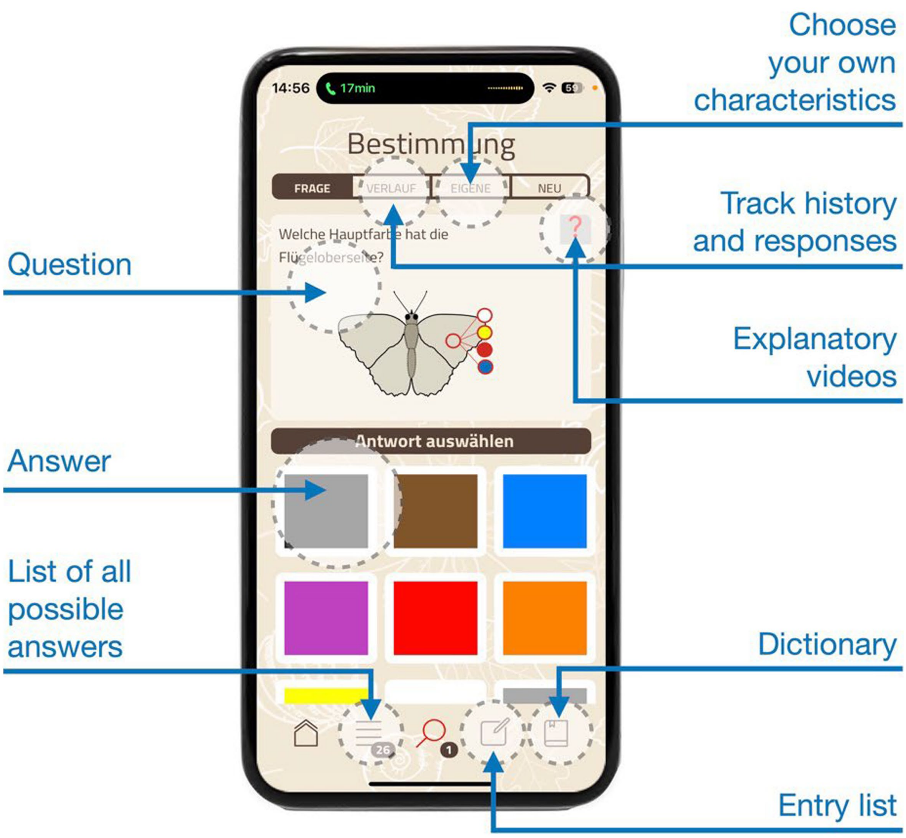

FIGURE 5
Screen of the butterfly determination app "ID-Logics" (Groß et al., 2020a).

be published for general use. They therefore expressed their feelings of responsibility in terms of writing a correct text as well as using photos with a correct copyright. Major technical problems and therefore frustration occurred with embedding these photos and losing their text on which they had worked on for quite a while because of problems with the memory function. All of them positively remarked the new aspects of biology they had learned, like the huge variety of native butterflies. By pointing out their problems they gave helpful advice on improving the CMS. And many of them emphasized their motivation on working with digital devices in this way.

3.1. Concepts from analyzing the interviews

As explained above, we analyzed the students' statements, identified conceptions and formulated associated concepts. In Table 1 the identified concepts are listed with their definitions and one anchor example, given further explanation below.

Concept: facilitation and frustration by design

This concept contains statements of the students regarding the technical and operational aspects. It happened quite often at the beginning that students deleted their written text, because they worked on more than one device on the same matter. Some of them pointed out the problems with doing research on their butterfly species, one student on the other hand referred to former search experience for presentations. Another problem pointed out by most of them was inserting photos from the internet into the CMS, especially when working on tablets. Some students remarked the easy use of the CMS.

Concept: opportunities for co-creation and collaboration

This concept contains student expression regarding their awareness of being part of a project together with other classes and their expression revealed their pride of being part in in. They also appreciated that their comments were relevant to ease of use, such as asking for larger buttons, discussing the need for another text box, or suggesting more sample graphics.

Concept: cognition by linking to previous knowledge

This concept contains remarks regarding the butterfly itself, its grade of endangerment, similar species and especially its special features that are necessary for a correct identification.

Concept: self-efficacy and responsibility by assuming the role of an expert

This concept contains remarks that express the motivation coming with being part in the project as well as the tension that goes with the prospect of having the own product being released and therefore read and seen publicly.

TABLE 1 Concepts, their definitions and anchor examples.

Sub-Concept	Anchor example
Concept: facilitation and frustration by design	
Sub-Concept	**Anchor example**
Difficulty of finding information	Mary: "Sometimes when we researched something, it did not come up directly like. You had to search on several websites and then came also always different things." (Int. Mary: 63)
Consideration on future use	Ina: "I have another question: how should you do it with the deter-mination app? Usually butterflies are gone pretty quickly. You cannot take a photo or describe them in any way that quickly." (Int. Ina: 31)
Difficulty due to technology	Alice: "It was somehow all deleted by mistake because we had not saved it." (Int. Alice: 88)
Concept: opportunities for co-creation and collaboration	
Sub-Concept	**Anchor example**
Participation in a large project	Nael: "We got the Apollo butterfly. And you said that students should work on this app. We do 15–20 species in contrast to the other school, they do a few." (Int. Nael:109)
Motivation through co-design	Lina (student's answer to concidering adding a text field to the caterpillar): "I would also have said that you write a text for each one, because if, for example, the reader uses the app and specifically wants to know something about the caterpillar or the egg, the information is right there and you do not have to read through the whole text to get to the information that you just want to know." (Int. Lina: 31)
Motivation through participation	Mary: "I think it was a lot of fun that we were allowed to do everything ourselves and that we were allowed to try out so many things ourselves." (Int. Mary: 61–62)
Concept: cognition by linking to previous knowledge	
Sub-Concept	**Anchor example**
Motivation about knowledge of forms and species	Alice: "I also did not know that a moth flies during the day. I also did not know there were different kinds of antennae either, and sometimes also so of wings." (Int. Alice: 22)
Associations with butterflies	Liam: "I thought butterflies are butterflies, there is not so much interesting." (Int. Liam: 16)
Concept: self-efficacy and responsibility by assuming the role of an expert	
Sub-Concept	**Anchor example**
Motivation through publication	Eymen: "At the beginning, I thought we were going to develop a whole app on our own, and I was a bit shocked because I did not know how we were going to do it with the whole class. But then it was a relief that the app was prepared." (Int. Eymen: 175)
Self-confidence by taking on the role of expert	Nael: "At first I thought that we would give them (the professionals) the information and that the professionals would then revise it and add it to the app instead of us doing it ourselves. That was something new for me to learn." (Int. Nael: 169–170)
Recognition of the significance of copyright	Jan: "I never paid attention to it at home, I just took a photo on Google that looked the best and then inserted it." (Int. Jan: 128)
Being an expert means responsibility	Sarah: "I used to think it was cool to develop apps like that. I've never done it before, except now. And then I wondered where they got all the information from and how to insert it." (Int. Sarah: 38)

3.2. Concepts assigned to the different categories of the DPaCK-model

These four above explained concepts of the students' comments were then assigned to the three domains of the DPaCK-Model and their intersections, see Figure 6 and Huwer et al., 2019: 303–305.

- → **DK** (Digitally-related knowledge) contains "the digitality knowledge about the handling of technologies." The Concept "Facilitation and frustration by design" refers to working in the CMS with the possibilities and challenges concerning its operation.
- → **PDK** (Pedagogical and digitally-related knowledge) contains "the intersection of digitally-related knowledge and the understanding of recent concepts to design approaches for training and learning processes" (as above). The Concept "Opportunities for co-creation and collaboration" refers to new ways of contributing to digital designs and connecting with other students by working in the same CMS.
- → **DCK** (Digitally-related and contend-related knowledge) "includes the intersection of digitally-related knowledge and scientific knowledge or scientific methods of the subject with regard to the handling of technologies" (as above). The Concept "Cognition by linking to previous knowledge" refers to possibilities of doing research about scientific knowledge of butterflies with the help of the internet.
- → **DPaCK** (digitally-related pedagogical and content-related knowledge) includes "the intersection of digitally-related knowledge, pedagogical knowledge and content knowledge. It therefore creates the foundation for the design of subject-specific teaching and learning processes with technologies (as above). The Concept "Self-efficacy and responsibility by assuming the

role of an expert" refers here for example to the role change made possible through the digitality: by using the internet for research to collect knowledge but more important by interconnecting with other students *via* the CMS.

These points will be taken up again in the discussion.

3.3. The ID-nature project assigned to the DiKoLAN framework

The ID-Nature project will now be placed in the DiKoLAN framework (see introduction). Table 2 below shows the competencies acquired by this learning experiment. The table gives the following information: the left column lists the competencies to be acquired. Column two shows the strength of acquisition and in column three this acquisition is specified.

The competencies to be acquired in the project are based on the four general competencies of documentation, presentation, communication/collaboration and information search and evaluation, as well as the three subject-specific competencies of data acquisition, data processing and simulation, and modeling. In addition, the subject-specific core competencies are also considered. Here, the competency expectations for each competency are divided into three competency levels (Naming = N, Describing = D, Applying/Doing = U). In addition, they are also divided into the four domains of teacher action: Teaching = T (DPACK), Methods, digitality = M (DPK), Content-specific contexts = C (DCK) and Special technology/ tools = S (DK). The competence "Communication/Collaboration" received the highest score, so it is the most promoted by the project. Considering the explanations given above and the DiKoLAN framework (see Workgroup digital Core Competencies website, 2023), the following competencies regarding "**Communication and Collaboration"** can be acquired:

"Teaching" (DPaCK)

They can use or apply the following: "plan and implement complete instructional scenarios with appropriate use of each technique, considering appropriate organizational and social forms" and "instructing learners in the techniques" (COM.T.A1 + A2).

"Methods/ digitality" (DPK)

They can "describe advantages in teaching with regard to the aspects mentioned." They can name the following: "list possible limitations and effects and aspects of the respective hardware or software use in the classroom with regard to forms of organization, group work processes in securing and elaborating, communication beyond the class time, technical problems and preparation time, group dynamic effects, self-organization and self-control, Data security, time effectiveness, motivation, effects based on BYOD usage and data or file exchange (COM.M.D1).

"Special tools" (DK)

They can apply the following: use collaborative software for text and data processing" (COM.S.A1).

Major competencies get also acquired in these competencies: "Information Search and Evaluation," "Data Processing, documentation, Presentation" and in "Technical core competencies."

Further results

Furthermore, we want to mention some results that we feel worth mentioning, but refer to categories of the DPaCK-Model which do not focus on digitality.

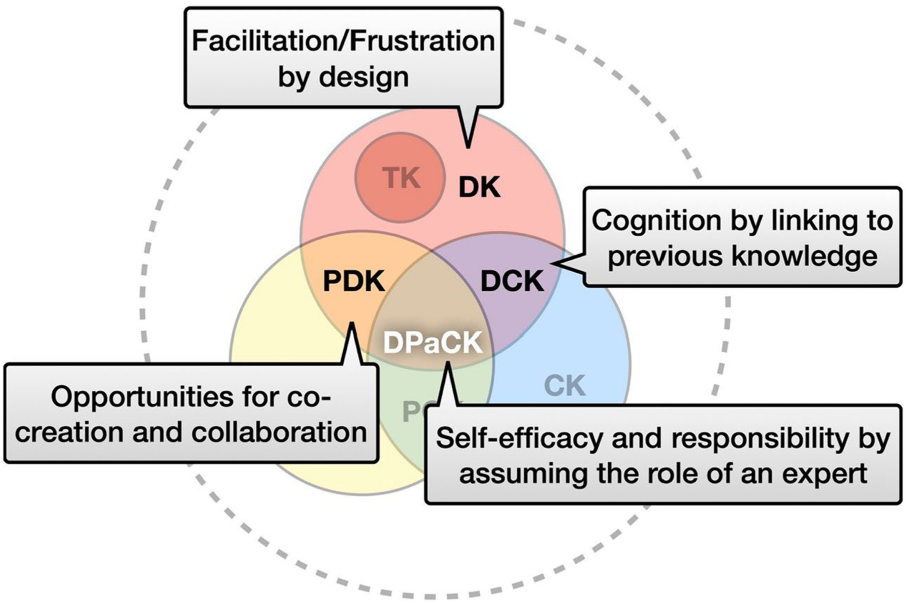

FIGURE 6
The ID-Nature project based on student statements through the DPaCK-Model lens based on Huwer et al. (2019).

TABLE 2 Classification of the teaching project ID-Nature in the competence areas of the DiKoLAN framework based on Groß et al. (2020b).

Technical core competencies	●●●○○	
General competencies		
Documentation	●●○○○	DOC.M.N1; DOC.C.N1
Presentation	●●○○○	PRE.T.N2; PRE.M.N2; PRE.C.N1
Communication/ Collaboration	●●●●●	COM.T.A1 + A2; COM.M.D1; COM.S.A1
Information Search and Evaluation	●●●●●	ISE.T.D2; ISE.M.D1; ISE.C.D5; ISE.S.D2
Subject-specific competencies		
Data Acquisition	○○○○○	
Data Processing	●●●●○	DAP.S.D2; DAP.T.D1; DAP.T.A1; DAP.S.A1
Simulation and Modeling	●●○○○	SIM.T.D1; SIM.M.D1; SIM.C.D1; SIM.S.A1

- Group work is motivating but needs a reasonable division of labor.
- Working in an all-girls group is difficult: Mary: "*I just noticed that it is quite difficult to work in an all-girls group, […] then of course there was bitch warfare […]. I would draw lots for the groups and mix girls and boys.*" (Int. Mary: 81).
- We learned more about butterflies in general, recognizing the huge variety of native butterflies, and finding out the specifics of butterfly species, such as their habitat, endangerment, and specific pattern.

Summarizing the interviews, it has to be pointed out, that the students expressed a huge variety of aspects regarding their experience of the project. Besides expressing their positive emotions about working on something for publication as well as their frustration on loosing their text on which they had worked on for quite a while, they also positively remarked the new aspects of biology they had learned, their new discoveries and gave helpful advice on improving the CMS.

4. Discussion

Looking at the project "ID-Nature" and the experiences the students have made so far, we will now have a closer look on the acquired conceptions by them in the area of DPaCK.

4.1. What conceptions have students acquired in the area of DPaCK regarding digital literacy?

To answer this question, the results of the student statements were related to DiKoLAN. The following discussion of the student statements on the essential competencies refers to Table 2 in the results section. This summarizes the digital competencies acquired in the project.

The ID-Nature project applies to the following competencies:

Communication and collaboration (especially related to teaching (DPaCK) and special tools (DK)):

The teacher plans synchronous work of groups using the digital tool "ID-Logics," a collaborative software, with the aim of a common goal, an app creation to identify butterflies. For this purpose, an easy-to-use CMS has been developed, which is shared with all participating students *via* individual login credentials. This makes it possible to work on the same document at the same time and even from different locations. Nael (see Table 1) expressed this by comparing the number of butterflies his class was working on with the work of other classes. So, he is aware of a common project. Mary also refers to being part of a big project:

Excerpt 1

> Mary: "One group only did it for one butterfly species, and then to do it for (…) 10 [species], I imagine that's really exhausting." (Int. Mary: 78).

And Eymen (see Table 1) describes here the result of a big process: the app-developers managed to create a CMS which is easy to use, even for students who worked hard on offering an easy-to-use CMS. When new hurdles appear, the app-designer try to do changes in accordance to the students' proposals. This is one example of having the students participate in the app-development.

4.1.1. Information search and evaluation

In order to create a proper profile of their butterfly in the CMS, the students get information and photos from books for determination as well as the internet, with references given for appropriate websites. It is still a challenge to find the necessary information, because they not only have to find the correct pages, but also have to deal with the technical language used on some of them. Mary mentioned the complications when she found contradicting information on different pages (see Table 1). It turned out that some students really had problems with the high amount of foreign terms, for example *lean grassland* as one habitat. Therefore, it is possible to hand in easier to read information beforehand for internal differentiation. The app also has a glossar which can be filled in by the students as well. Finding appropriate photos for the profile is a second difficult task, because the photos have to be chosen in accordance with the copyright guidelines which are not familiar to the students. Jan confessed that he had never thought of copyright before, so they got advice on where to find photos with public domain. As support and for time saving some photos of each species are being provided and can easily be inserted into the CMS.

4.1.2. Data processing (especially referring to teaching and special tools)

In comparison to conventional dichotomies determination keys, the ID-Logics app works polytomously, that means it uses an internal logic to ask the user specific questions about very different characteristics that can be answered easily.

By referring one or more distinctive-mark-graphics to their butterfly species for example, the students play their part in letting the app process the data in order to find the correct path for determination.

We could list many more competencies that the students acquired by joining the project ID-Nature. But we want to highlight some accompanying aspects that are a result of this digital project, which might only be possible through digitality. The first one is the effect that the future publication of the app has on the students. So, the non-digital competency of writing a text (about the butterfly) becomes an action where the students suddenly feel really responsible on writing a very good text – because it will be published and then seen by all the users of the app. This not only motivates the students, it changes their perspective of being a normal user to taking the role of an expert, as Nael explained (see Table 1). The second one is the possibility of participating in a huge project with many others – even though they have not met the other students yet. That will be the case at the students' convention. Furthermore, they can also participate in designing some parts of the CMS.

4.2. What conceptions have students acquired in the area of DPaCK regarding motivation?

In contrast to conventional learning environments, ID-Nature offers the opportunity to create a learning product with social significance through digital collaboration. The interviews show a connection between the basic psychological needs and the digitalization aspect of the learning environment. Satisfying the need for autonomy is often linked to the importance of the learning product as shown in Excerpt 2.

Excerpt 2 (asked about the way of designing the profile):

> Lina: *"If you ask me, I propose you write a text for each of them [the butterfly species], because if the reader uses the app and wants to know something about the caterpillar or the egg, the information is right there and you don't have to read through the whole text to get to the information you want to know."* (Int. Lina: 31).

In this case, the student adopts the perspective of a user of the app. He himself suggests to expand the profile a bit to save the user effort. This suggests that the relevant regulatory process is the deliberate valuation of the usability of the app. In this case neither reward, punishment (both external and internal), nor personal identification with the learning product can be considered as a regulation of motivation. For this reason, we assume an identified regulation (see Figure 3). In addition, the students were given appropriate leeway in the design of the profile. This holds both the potential of the motivating effect of autonomy satisfaction and the danger of being overwhelmed by the great importance of the project (compared to conventional tasks in school environments). Knowing that the student of Excerpt 2 has implemented her design idea and other students (Excerpt 3) have enjoyed their freedom to design, we assume autonomy as a relevant satisfied basic need.

Excerpt 3

> Mary: *"I think it was a lot of fun that we were allowed to do everything ourselves and that we were allowed to try out so many things ourselves."* (Int. Mary: 61-62).

However, because autonomy alone is neither important for a third party (Excerpt 2) nor fundamentally funny (Excerpt 3), we conclude that its effectiveness is related to the importance of the learning product. The way in which the product is important for the students becomes clear in two different aspects: the reflection of one's own role in the process of creating the app and the importance of one's own contribution for the user.

The nature of the reflection on one's own role is shown in Excerpt 4 and 5.

Excerpt 4

> Nael: *"I first thought that we would give you the information and then the professionals would revise it and put it into the app. Instead, we did it ourselves. Learning that was something very new for me."* (Int. Nael: 169-170).

Excerpt 5

> Sarah: *"I always thought it was cool to develop apps like this one. I've never done that before, except now. And then I wondered where they got all the information from and how to insert it."* (Int. Sarah: 38).

Both quotes show the same view regarding the making of apps: they are programmed by competent people. They also indicate that they did not belong to this group before – but afterwards they did. We infer that this competence experience was a relevant factor in motivating these students. Their utterances also suggest an identified or integrated regulation of motivation. The second aspect in which the learning product has meaning for the students is the quality of their own contribution. Excerpt 6 shows the difference between working on ordinary homework and creating the profiles for the app.

Excerpt 6 (asked about copyright and optical quality of the pictures):

> Jan: *"I never paid attention to that at home. I just took a photo on Google of what looked best and pasted it."* (Int. Jan: 128).

Unlike the other examples, it is not apparent whether the regulation of motivation is by avoiding internal punishment or by valuing a resource that is useful to third parties. Nevertheless, we consider this aspect of the importance of the learning product to be relevant because it was often mentioned in the interviews.

4.3. What conceptions have students acquired in the area of DPaCK regarding subject-specific conceptions?

The project has made students aware of the huge variety of butterflies and of the distinguishing features. They realized that a close look on the butterflies is necessary to become aware of them. Furthermore, when very similar looking butterflies are hard to distinguish, other features like habitat or range of distribution have to be considered as well. Here are some examples from students:

Excerpt 7 (asked about changed associations):

> Anna: *"With the lemon butterfly (Gonepteryx rhamni), for example, I somehow didn't know that it had such spots. Yes, it had such small dots on it. And you just don't see them normally."* (Int. Anna: 22).
>
> Ina: *"I think the next time I see someone who is, for example, only blue or something, I don't think I'll say he's only blue, but then you have to really look to see what else he has."* (Int. Ina: 22).

Close observation is also encouraged by the feature graphics (Figure 6). The project started with pre-made feature graphics, focusing on simple distinguishing patterns and not on lifelike replication. Pupils then had to choose the best fitting one for their species. When they could not find a fitting one for the pattern on the underside of the wing, they were encouraged to draw an additional pattern on a template. Figure 7 explains this process using the example of the Karst white butterfly (*Pieris mannii*). A professional graphic designer refined the students' drawing before it was inserted into the app. In the further process of the project other pupils can choose this pattern as well. This is not only an example of looking closely at and learning about wing patterns. It is also an example of how students can participate in designing the app.

This student quote is another example of close observation using the distinctive-mark-graphic cards to show three different ways butterflies sit:

Excerpt 8 (asked about changed associations):

> Lena: *"I thought every butterfly has the same posture as it sits."* (Int. Lena: 21).

At this point, it becomes clear that the use of distinctive-mark-graphic cards offers two special learning opportunities: First, they promote systematic comparison while remaining constrained to the expression of a single feature. Second, they give the identifier an overview of all possible feature expressions within the species group at a single glance. Especially the latter is not the case with conventional identification literature.

Overall, the students became more aware of the species group of butterflies. And they also got interested in them:

Excerpt 9 (asked about changed associations):

> Mary: *"I have known the common butterfly species, (…), I had the butterfly species forest board game (Pararge aegeria) and now I have really learned a lot about it. And just on this one sheet what you had handed out to us [Bestimmungstafeln] were already relatively many different butterfly species and there are still many many many more and I find that very amazing."*(Int. Mary: 61).
>
> Liam: *"I thought butterflies are butterflies, there is not so much interesting about them."* (Int. Liam: 16).
>
> Alice: *"I also didn't know that a moth flies during the day. I also didn't know that there are different kinds of antennae. And sometimes of wings."* (Int. Alice: 22).

Kokott (2023) investigated the interest of adolescents in insects and found out that nature experiences especially have an interest-promoting effect. Butterflies had a particular positive connotation. Even though the students in our project do not encounter real

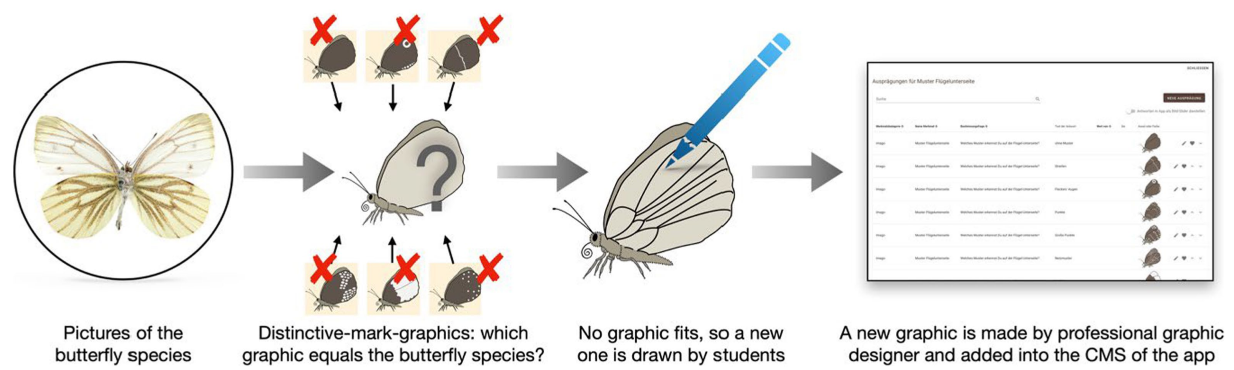

FIGURE 7
Students discover basic patterns and use them for designing the app.

butterflies, the intensive study of one species seems to promote interest very much. Jan, for example, also encountered the phenomenon of species extinction:

Excerpt 10 (asked about changed thoughts about butterflies):

> Jan: *"I also heard that the Black Apollo (Parnassius mnemosyne) is threatened with extinction, because the environment and other stuff doesn't do it any good and that's why there aren't many left."* (Int. Jan: 135).

Summing up, the focus on the project ID-Nature is on: Collaboration, cooperation and participation combined with publication, sharpening the eye for characteristic items for identification. And that is the new challenge of digitality.

4.4. Further conclusions on the DPaCK-model

At first glance, DPaCK and TPaCK only differ in the renaming of one of the quantity domains. In our view, however, there is a paradigm shift behind it.

The authors of the TPaCK-Model describe it as a tool for teacher training (Mishra and Koehler, 2006). Although technical knowledge also refers to digital technologies, it primarily relates to application in the design of teaching. The rise of social media in particular makes it clear that digitality has long since become not just a means to an end, but a representation of the user's personality. The statements from the interviews (e.g., Excerpt 4 and 5) show that both the app as a product and the role of the developer of such an app have great significance for the learners. Thus, with DK and CK, not only two aspects of lesson preparation, but two aspects of reality interact with each other. Their overlap makes it clear that many areas of everyday life now also have digital representations. Digitality is thus not to be seen as one of various teaching contents, but as a cross-sectional area of reality parallel to the analogue world (see Stalder, 2016).

This characteristic is important for the preparation of teaching, so that lessons can be designed to be close to life and contemporary. Since one goal of education is to enable people to shape our world, shaping the digital world should be a part of teaching. When learners gain experience in this way, according to the theory of experience-based learning (Niebert et al., 2014), the conceptualization of the learning process is necessary. The DPaCK-Model could help learners reflect on the interplay between analogue and digital structures in terms of referentiality (Excerpt 4 and 5), community (Excerpt 1, 2 and 6) and algorithmicity (Excerpt 11). Like the model of basic concepts ("Basiskonzepte"), which was firstly used for the preparation of teaching only and then expanded for the reflection by learners (Demuth et al., 2005), the DPaCK-Model could be used in a similar way.

It has become clear that digitalization is not a short-term trend. As it infuses different areas of life, it not only enables tasks that were previously unthinkable (Puentedura, 2009), but also new phenomena, such as artificial intelligence. Understanding them requires an active and purposeful engagement with digitality in terms of rerefentiality, communality and algorithmicity (Huwer et al., 2019).

In our opinion, the development of a general educational goal on digital literacy – similar to the Beutelsbach Consensus for the subject politics (LPD, 1976) – should therefore be discussed.

4.5. What are the implications of these perspectives for designing digital learning environments to foster digital literacy and species knowledge?

Regarding the above mentioned aspects, we offer guidelines for a successful teaching digital competencies:

4.5.1. Guidelines for teaching digital competencies

- Offer your students the opportunity to help shape their digital world. Just as we know ways to shape the real world through participation, this should also be possible for the digital world. This is one of the core concepts of digital literacy (see Excerpts 1, 2 + 3).
- Offer a comprehensible benefit and meaning for the students to promote identification as an expert for the learning product. Let them become producers instead of consumers (see Excerpts 4, 5 + 6).
- Do not hide learning concepts such as the DPaCK-Model from the students, but explicitly name them in the classroom in order to make learning processes visible and thus discussable.
- Problems in digital tools give students a higher burden so that problem solving seems to be easier in the real world due to experience. Therefore, digital tools must be designed for easy use and self-explanatory (see Mary in Table 1).
- By reflecting on the newly experienced expert role and the responsibility that comes with it, teachers are given the opportunity to address a critical approach to content in the digital world (see Nael in Table 1).
- The reduction to essential distinguishing features helps in the acquisition of shape knowledge which is essential for determining species. Distinctive-mark-graphics easily made in digital devices therefore support digital graphics therefore support the acquisition of species knowledge (see Excerpts 7, 8 + 9).

4.6. Outlook

In talking to teachers, we learned about their reservations concerning developing an identification app: on the one hand they felt unsecure about identifying species, on the other hand on working in a CMS. So, one of the main outcomes of this project ID-Nature is to have developed a teacher's manual with instructions on how to develop an individual identification app in class or school. In addition, we are working on an explanatory video to facilitate access to creating an individual app. In using this method, the teachers themselves do not have to be experts in the species they are dealing with, but get the students to become experts in their chosen species.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: The datasets are videos of interviews with students. We have the signatures from the parents who agreed to the interviews being filmed. Requests to access these datasets should be directed to baumann@idn.uni-hannover.de.

Ethics statement

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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