INCREASING INTEREST AND MOTIVATION OF SCHOOL KIDS IN NATURAL AND DATA SCIENCE

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Abstract

This paper presents an approach to increase children's interest and motivation in natural science and basic data science activities through a plant growing school experiment. This experiment is based on a theoretical foundation that integrates inquiry-based learning and a basic data science process, which ties together the activities in natural and data science. Specifically, children had to grow their own plants, water and measure them regularly, collect and analyse this data in a digital application, and answer research questions related to initial expectations with the help of a visual data analysis functionality. Overall, the results of this pilot study show that the children responded with high interest and motivation in participating in this experiment, which validates the effectiveness of the overall approach.

Keywords: Motivation, science learning, digital literacy, inquiry-based learning.

1 INTRODUCTION

In today's and future labour market there is an urgent need for people educated and skilled in the fields of natural sciences, engineering, and information technologies. However, at the same time a lack of interest in these fields can be identified in young people [1]. Therefore, there is a need for innovative didactic approaches that are suitable to engage and motivate pupils in the fields of science, technology, engineering, and mathematics (STEM).

This paper presents an approach and a pilot study that demonstrates and evaluates how interest and motivation in natural science and data science can be stimulated and increased. The core idea of this study is to combine a natural science experiment with a basic data science activity. These two parts are tied together in an overarching pedagogical concept that is based on inquiry-based teaching and learning methodology, where learners act like researchers.

The natural science part of the study consists in a plant experiment where children are asked to grow beans in a flower pot in the classroom. Every day they had to water the plant and measure the main characteristics, namely the plant size, the soil humidity, and the amount of water. For this task they were equipped with instructional material, as well as measurement instruments. Furthermore, they had to collect and enter these data in a digital application that has been created for this specific purpose. This application provides access to the entered data in different ways, for example diagrams displaying the increase of size, diagrams showing the daily use of water, and various visualisations comparing the plant data of the peers. At the end of the experiment the pupils had to answer several natural science research questions whose answers required the diagrams of the digital environment, for example the influence of the watering on the growth.

The main goal of the study was to validate that the application of this experiment in a class increases interest and motivation in STEM fields. For this reason, the experiment has been conducted as formal study. Positive and promising results allow us to recommend the conduction of the experiment in schools.

2 NATURAL AND DATA SCIENCE EXPERIMENT

The goal and purpose of the science experiment is to increase interest and motivation of young people in STEM fields. For this purpose, an experiment has been designed on the basis of a pedagogical model that integrates natural science and data science. The next section describes this theoretical basis, and the further sections describe the science experiment (Section 2.2.) and the digital application that supports the data science part (Section 3.3.).

2.1 Natural and Data Science Learning Model

The Natural and Data Science Learning Model (NDSLM) builds the theoretical foundation for the experiment [2]. Since the experiment includes and combines both natural science and data science activities, a common ground from a pedagogical perspective is needed. This model serves as the pedagogical foundation by incorporating both perspectives. It consists of five activities that form the basic structure for science experiments. These activities are defined by combining an Inquiry-based Learning Model and a Data Science Process Model (see Figure 1).

Inquiry-based Learning is an approach widely used in the field of science teaching and guides students and pupils to conduct research in a manner similar to that of scientists, resulting in an active and motivated learning style [3]. A method to implement Inquiry-based Learning in science teaching is described in the 5E Model [4]. This model names five subsequent activities: engagement, exploration, explanation, extension, and evaluation. These activities define a process of being actively engaged with a topic and developing knowledge from this understanding.

The Data Science Process Model [5] describes the process of performing data science tasks. This process consists of the six activities, which are research goal definition, retrieving data, data preparation, data exploration, data modelling, and presentation. Typically, data science is applied by skilled computer scientists on large amounts of data. Our approach makes use of this model by simplifying each activity, so that they can be applied by pupils at all ages.

The combination of these two models leads to the Natural and Data Science Learning Model. This model takes up all the activities and relates them to five activities that describe a process of how to conduct a science experiment with the help of data science concepts (Fig. 1). This leads to a process that starts with natural science research questions and tasks, continues with data collection, data organisation, and data exploration, and ends with answering the research questions with the help of the collected, organised, and explored data.

The application of this model aims at providing several benefits. First, it engages learners with a science topic by presenting them with research questions and a task to complete. Such involvement stimulates motivation and interest in the topic and task completion, as it requires active participation. Second, it engages learners with basic data science activities needed for completing their tasks. In this way they should become acquainted with working with data and develop respective skills. Third, through the integration of both perspectives the learners should get a deeper understanding of the natural science and the data science part. The natural science part is enriched with the data perspective, and the data science part becomes less abstract and more concrete though the natural science part.

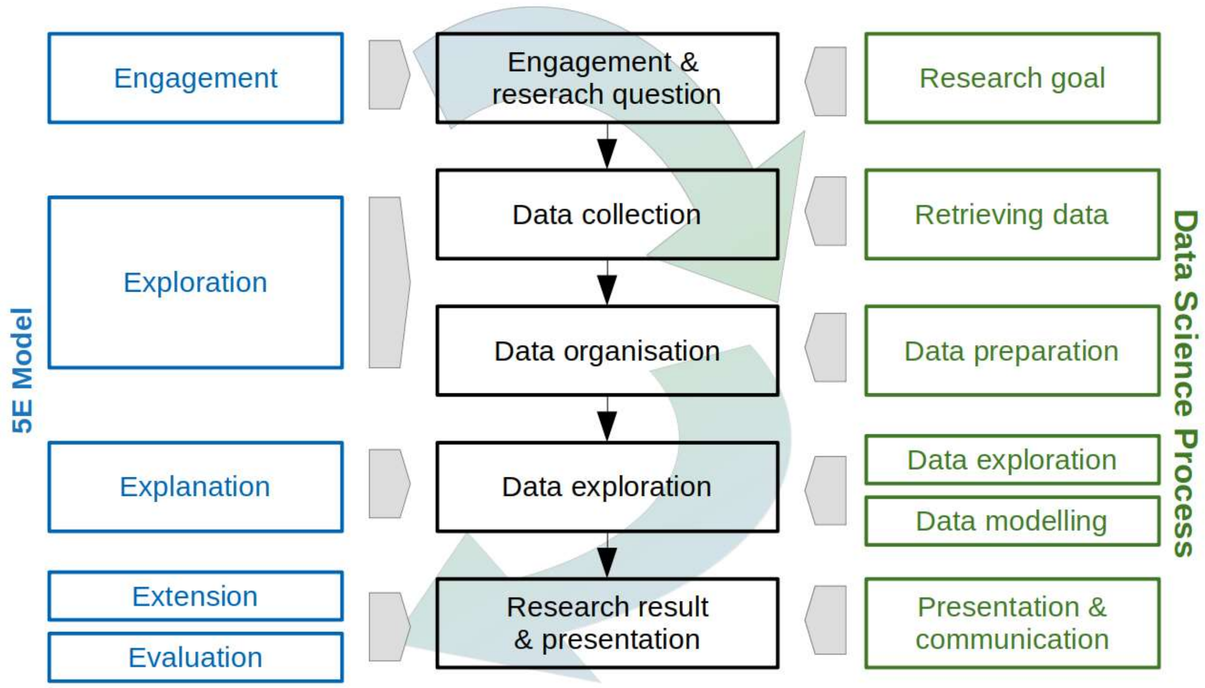

Figure 1. Natural and Data Science Learning Model

2.2 Plant Experiment

The plant experiment is an instantiation of the NDSLM and exemplifies its application. It has been created to both demonstrate and evaluate the concept including the increasing interest and motivation. It is based on the popular plant experiments in schools where pupils have to seed and grow plants, monitor the growth and development of the plants, and discuss related biological aspects. Using this type of experiment, we have integrated data science activities as described in the last subsection. In order to support the data science activities. A web application has been created that allows learners to complete them (Section 2.3).

In class, the experiment is usually carried out by creating small groups to conduct the experiment together. Working in groups has the advantage that the group members can discuss their activities and reflections, which increases both motivation and deeper understanding. Furthermore, as part of the gamification concept, the application also enables the comparison of the data between the groups, which is an additional stimulation for their motivation. The remainder of this subsection describes the activities to be performed.

2.2.1 Engagement and research questions

In this first step the pupils are presented with the task to plant beans in pots with soil and pots with sand. They are asked to water the plants every day for two weeks. Additionally, the pupils are equipped with a micro:bit that can measure the soil humidity, so that they provide so much water to cause a predefined humidity level. Then they have to measure the soil or sand humidity and the amount of water. Furthermore, the group discusses the research questions (1) how tall the plants will be in two weeks and (2) whether will grow faster in soil or sand.

2.2.2 Data collection

According to their task the children collect data on the main characteristics of the plants in a daily routine. This data includes the current plant size, the amount of water they used to pour the plant, the development phase of the plant, and the health condition of the plant. This data is collected and entered in the analogue handbook that provides a table for all plants and days. Additionally, the pupils have to enter the measured data in the digital application (Fig. 3).

2.2.3 Data organisation

The digital application enables investigating, editing, and deleting the collected data. The measurement data is represented as a table, where these operations can be performed (Fig. 3). In this way, the learners get an overview of their data, including missing data for certain dates or incorrectly entered data. So they can update, clean, and correct their data.

2.2.4 Data exploration

The digital application provides several graphical representations that present data from different perspectives and relate different features to each other. For example, the daily growth and water needs can be seen on a timeline (Fig. 4), the plant development phase and the plant health condition can be displayed in comparison with the plant size, and the daily growth differences of plants in soil and sand can be visualised. Such graphical representations help to get deeper insight in the plant and to answer the research questions.

2.2.5 Research result and presentation

Finally, after two weeks the school pupils are asked to discuss again the initially posed research questions. This time they can make use of the digital applications with its visual data representations to answer the questions. In this way they have to connect the natural science and data science parts.

Figure 2. The plant experiment setting with the required equipment.

2.3 Digital Application

The goal of the digital application is to enable learners to collect, organise, and explore their data on a digital device. For this reason, a web application has been created that provides these features in an easy-to-use manner (Fig. 3 and Fig. 4). The application has been designed in a way that it can be used on computers, laptops, tablets, and smartphones.

In addition to the core features, it also provides functionalities to user management and group building. Especially the latter contributes to the gamification concept, as the users and groups can choose a name and icon, which stimulates their motivation. Furthermore, the application provides a functionality to collect structured log data, which can be used for evaluation and studies. Finally, it provides a teacher tool that enables a teacher to get a quick graphical overview of the class and group activities.

Figure 3. Screenshots of the digital application. Left image shows the data input and the right image shows the data overview.

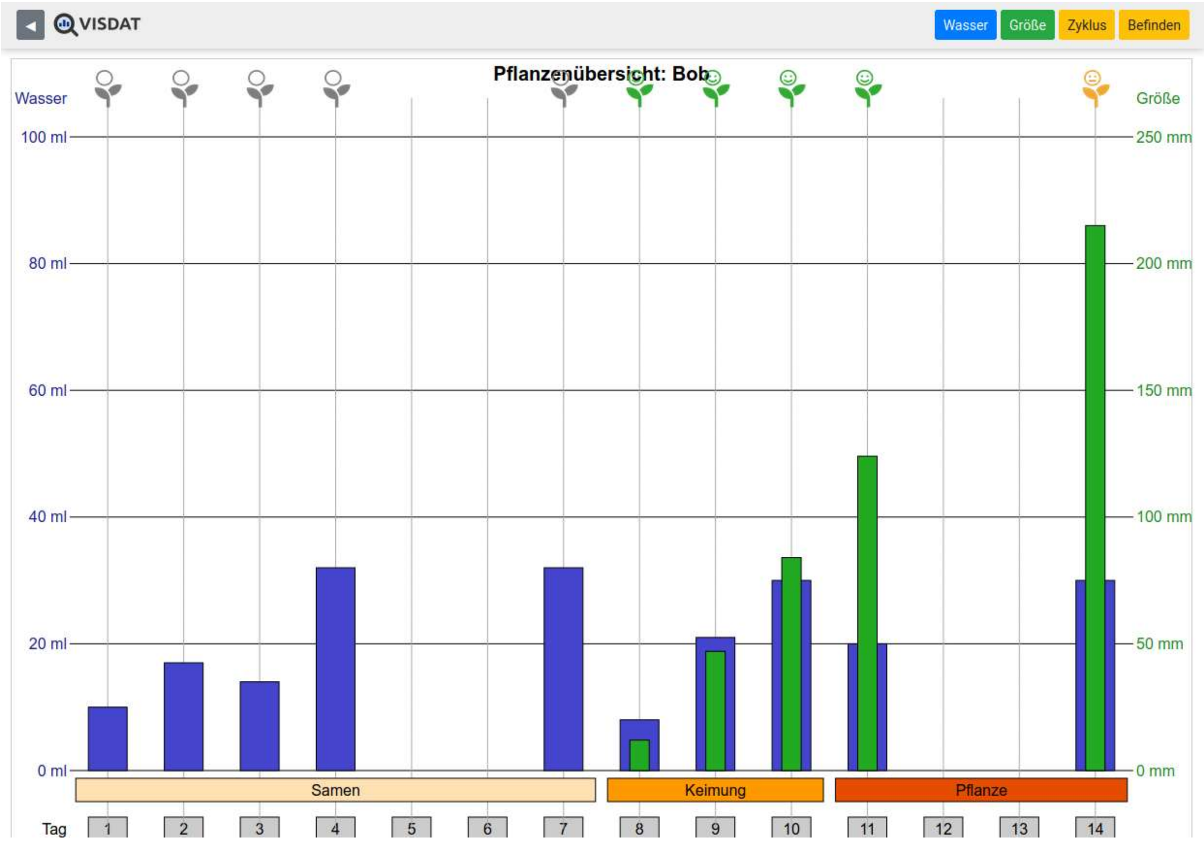

Figure 4. Data exploration tool that shows plant growth, water needs, plant development phase, and plant condition on a timeline of two weeks.

3 METHODOLOGY

The pilot study was conducted in three different classes (fourth grade) in two primary schools in Austria. In total 47 pupils participated, 26 males and 21 females, ageing from 9-12 years ($M = 9.31$, $SD = 0.60$). The plant experiment was implemented within two weeks in autumn 2020. At the beginning of the pilot study our project assistants gave an introductory lesson on the experiment and the digital application, and at the end of the pilot study the children got a lesson in which they discussed the findings and results. In the meanwhile, the class teachers supported the children to carry out the experiment. In total, the 47 pupils formed 12 groups (3.92 pupils per group on average) and raised 49 plants (4.08 plants per group on average).

3.1 Measures

Questionnaires before, during the lessons, and after the experiment collected data on interest and motivation in science in general and on the experiment in particular, as well as socio-demographic data like gender and age. We examined self-ratings of interest and motivation on a five-point Likert scale.

3.1.1 Assessment of interest

Before starting the experiment, the children rated their individual interest in natural sciences with five items [6]. During the experiment in the lessons they were asked for their situational interest at seven different points in time. These seven items depended from specific activities during the lessons and were defined using three phases (engage, explore and explain) of the 5E model referring to inquiry-based learning in science. At the end of the experiment in the final lesson we questioned the children for different interest variables. They were asked how often they thought of their plants during the two weeks, how much fun they had implementing the experiment, and how interesting, useful, understandable and difficult it was [7].

3.1.2 Assessment of motivation

The motivational items were part of the questionnaires at the end of the experiment. Three items were used to ascertain intrinsic motivation and another nine to assess the motivation during the lessons [7]. The latter relate to the self-determination theory, which defines autonomy, competence and relatedness as three basic psychological needs for autonomous motivation in various contexts [8].

3.2 Procedure

The implementation of the experiment took place during 14 days and was carried out by two project assistants. The first lesson started with a short introduction by the project assistants and then the children had to fill out a questionnaire assessing sociodemographic data and individual interest in science. Following the first phase of the 5E model, the children hypothesized about plant growth in the next 14 days. Additionally, the situational interest of the first phase was assessed (engage phase: 2 items). Then the children started with planting the beans related measurements, followed by further assessment of situational interest (explore phase: 3 items). After two weeks, the results were presented and discussed with the children, again followed by the final assessment of situational interest (explore and explain phase: 1 item each). In the end, the school pupils gave qualitative feedback and filled out the final questionnaires on interest and motivation.

4 RESULTS AND DISCUSSION

4.1 Interest results

Before starting the experiment, we asked the children to rate their individual interest in science on a general level. The overall mean showed a light interest (M = 3.92, SD = .78, Cronbach's α = .77). During the project the children were asked seven times to rate their situational interest. The items used were abstracted in three variables from the 5E model. The means of interest were in general high in all phases - two items from the phase engage: M = 4.21, SD = .98, Cronbach's α = .90; four items from the phase explore: M = 4.45, SD = .75, Cronbach's α = .82; one item from the phase explain: M = 4.15, SD = 1.19) (Fig. 5).

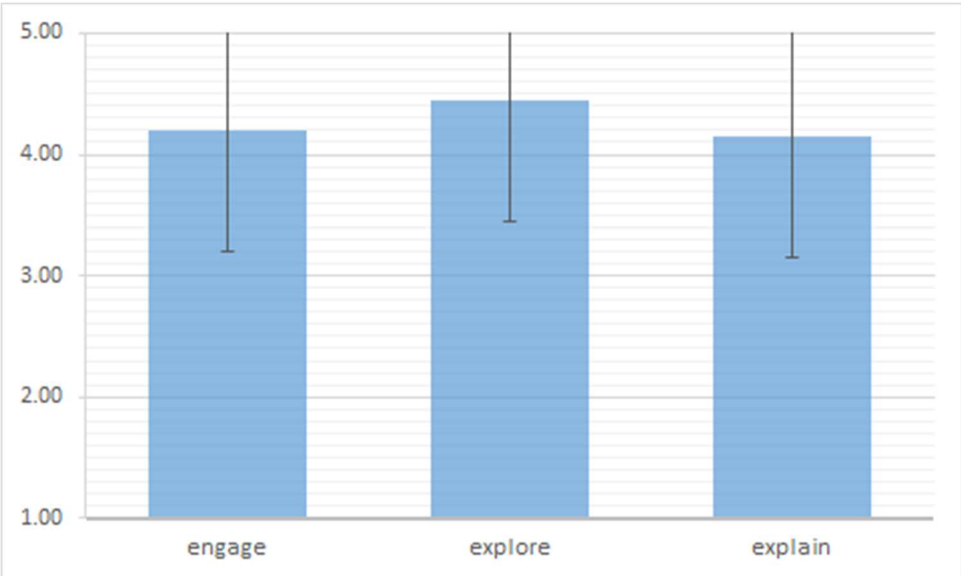

Figure 5. Mean and standard deviation of situational interest in the phases engage, explore and explain.

A comparison of mean values with a one-way ANOVA, sphericity correction necessary using Greenhouse-Geisser, determined that the three phases tend to differed from each other, $F(1.31, 56.47) = 3.42$, $p < .05$, partial $\eta^2 = .073$. A more detailed examination of this result was expressed in higher values in the phase explore compared to the phase explain. The phase engage did not differ significantly.

After the experiment five interest or interest related aspects were assessed in the final questionnaire (Fig. 6). The school pupils indicated a daily engagement with the experiment activity (thoughts). They think that they have learned a lot from this project (learning), that the content was interesting (interest) and easy to understand (comprehension) and not too difficult (difficulty).

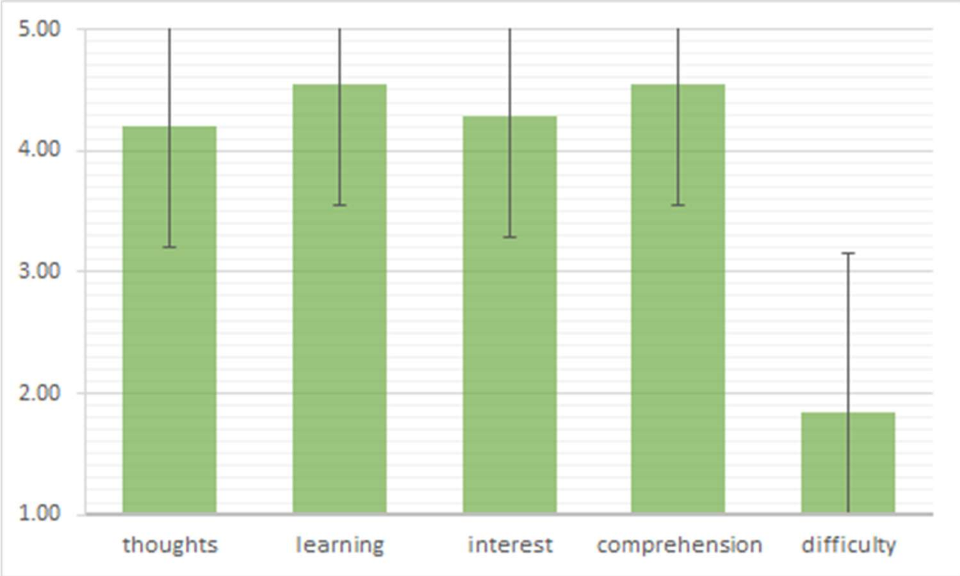

Figure 6. Mean and standard deviation of different interest variables in the final questionnaire.

4.2 Motivation results

Generally, the children showed a high level of motivation in carrying out the experiment. In detail all four motivational variables (intrinsic motivation, relatedness, competence, autonomy) showed high mean values above 4.0 (Table 1). However, the internal consistency of the variables competence and autonomy were rather low (Cronbach's α = .49).

Table 1. Mean, standard deviation and internal consistency for motivational variables of the final questionnaire.

	relatedness	competence	autonomy	intrinsic motivation
M	4.17	4.10	4.16	4.33
SD	0.80	0.88	0.78	0.82
Cronbach’s α	0.67	0.49	0.49	0.90

Due to the unsatisfactory internal consistency, different items of competence and autonomy seem to have been experienced differently in the study. Therefore, we compared the means of the three items within the scale competence and within autonomy separately conducting one-way ANOVAs (Table 2).

Table 2. Mean and standard deviation for the items of the scales competence and autonomy.

	comp1	comp2	comp3	aut1	aut2	aut3
M	3.57	4.15	4.60	3.38	4.50	4.61
SD	1.41	1.41	0.77	1.51	0.85	0.74

For competence, the ANOVA, sphericity assumed, determined that the items differed significantly, $F(2, 88) = 9.78$, $p < .001$, partial $\eta^2 = .182$. The mean values show a significant difference between all three items indicating medium to slightly high competence experience for item 1 (comp1: confidence in performing difficult tasks). Item 2 (comp2: confidence in working alone) was experienced significantly higher. However, item 3 (comp3: support when having difficulties) was the highest compared to item 1 and 2.

The items of the second variable autonomy were compared similarly. A one-way ANOVA, sphericity correction necessary using Greenhouse-Geisser, determined that the three variables within the scale autonomy differed significantly, $F(1.58, 69.25) = 25.27$, $p < .001$, partial $\eta^2 = .365$. It was found that item 1 (aut1: choosing between different tasks) with a medium agreement was significantly lower than item 2 (aut2: time for evaluating how to solve tasks) and 3 (aut3: working on tasks alone or in a group), which did not differ significantly from one another, but were perceived as high autonomy values among the children.

4.3 Discussion

Overall, interest assessed at different stages during the project was relatively high. The children were particularly more interested in activities in which they were actively involved (e.g. planning and carrying out the experiment, observing processes, and gaining new knowledge) than in other phases. The high interest values were also confirmed in the survey after the end of the project. The children thought and took care of their plants every day. They knew what their tasks were in the project and were able to carry them out successfully and learn the content independently.

The high intrinsic motivation indicates a high engagement for the experimental activities. The children found the plant topic really exciting, they had fun in the project and said, that they would like to learn more about this. A similar pattern can be seen in relation to the basic psychological needs. Generally, relatedness, competence and autonomy were experienced as slightly high or high among school pupils. These values are directly related to the educational setting implemented by our project assistants and should foster, according to the self-determination theory, intrinsic motivation in specific situations [8], which in turn can be confirmed by the high values of intrinsic motivation described above.

In general, this study showed that interest and motivation can be stimulated through classroom activities. However, due to the absence of a control group, high interest and motivation can be observed within the experimental group, but not in comparison to control groups. Additionally, though a high level of interest and motivation was measured during the experiment, long-term increases in interest and motivation in science activities was not measured in this pilot study.

5 CONCLUSION AND OUTLOOK

This paper presented an approach to increase children's interest and motivation in natural science and basic data science activities through a plant growing school experiment. This experiment is based on a theoretical foundation that integrates inquiry-based learning and a basic data science process, which ties together the activities in natural and data science. Overall, the results in a pilot study show that the children responded with high interest and motivation in participating in this experiment.

Next steps might include an update of the digital applications with more features and interaction possibilities regarding the visual representation of the plant data. For example, changing the X- and Y-scales (timeline, water quantity and plant size) would increase the understanding of diagram visualisations. Furthermore, an analysis of the log data captured by application can enrich the results of the study by comparing or correlating this data with the self-rating data provided by the children.

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