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Hochschule RheinMain

Storytelling and Gamification in Sustainable Development Education - a Pilot Study

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Prepared by the consortium of the grant project with AZ 37883/01:

- Hochschule RheinMain: Prof. Dr. Andreas Zinnen (Coordination)
- Universität Koblenz/Landau: Prof. Dr. Gerhard Reese
- SEEMIK: Triinu Jesmin, Prof. Dr. Jaanus Terasmaa
- AZN Vogelsberg: Dr. Martin Jatho

Project data sheet

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Summary

The project implements the cross-national use and pilot evaluation of gamification and storytelling to communicate sustainability to target groups. In addition to the application of a learning app, the project demonstrates that larger learning concepts are needed to instill the need for action on climate change in the minds of the public.

Tasks performed

In WP 1, the state of ESD in Germany and Estonia was examined. Subsequently (WP 2), conflicting goals and causes for a lack of knowledge and motivation of young people were compared. This report focuses on work packages 3 and 4. In WP3, actions were carried out for the country-specific adaptation of the SmartEducation app and integration of the results of WP1 and WP2 into the environmental learning content of the app. WP4 includes pilot studies, i.e. the use and evaluation of the SmartEducation App in workshops at three educational institutions in Germany and Estonia. The results of the pilot studies were evaluated by psychologists.

Results achieved

In the project, a learning concept was developed that implements education for sustainable development through a learning app (theory), practical experiments (practice) and discussions (activation). About 100 competencies on the topics of weather and climate, climate change, options for action on a small and large scale were written in both German and English. The target group is students over 16 years of age. The content is formulated in such a way that it can be easily adapted to other target groups. The concept was evaluated in different configurations at the Augustinerschule in Hesse (~ 100 students), the RheinMain University of Applied Sciences (~ 20 students) and the University of Tallinn (~ 20 students). The evaluation was coordinated by media and educational psychologists. In the following, we briefly summarize the results for Germany and Estonia separately.

In Germany, the concept of the app and the division into theory, practice and discussion was perceived positively. A large number of students would have liked even more time for the project day. The project has shown that mature concepts can achieve a change in awareness among students. Especially in the relation of STEM subjects to climate change and options for action, significant changes in awareness could be observed in only one morning. The use of the app was pushed into the background by the large amount of content. Opinions are divided on the gamification elements of the app. While some students answered a high number of questions and showed great interest in the high score, others were more interested in the group tasks.

In Estonia, the existing game was tested with focus group interviews and a larger number of participants (~20 people). The results show that while the current version has a lot of facts, it is not very engaging - the app is perceived more as a test rather than a game. According to the respondents the game did not create enough competitiveness and immersion hence the experience was rather informative than playful and the game was seen as more educational than entertaining. Some players reported to gain new knowledge, some of them didn’t. The

ones who didn't, said it was either because the game was not understood well because of English, there was too much information at once or they were distracted by the interface. Some respondents brought up that the game helped to remember facts and knowledge about the topic of climate and climate change they once knew but had forgotten. The game coincided with the values of most of the players (about nature and our environment), and they found that these are important topics which should be showcased more.Though most of the players concluded they would not prefer to learn using this type (exam/test type) of method, they would be willing to give the game another try after it has undergone some improvements.
There was a difference in opinions regarding the target group. Some respondents found it to be suitable for secondary school students, some for people who already are interested in the topic of climate change and some would have suggested it for university students due to longer texts, specific vocabulary and scientific concepts. The researchers collected a lot of feedback and the focus group had a lot of suggestions both for the technical and user experience side on how to improve the game. The interviews concluded that the app received a positive mindset overall but changes were requested in order to improve aspects of fun, enjoyment and ease of use/usability. From the results, new versions of the proposed topics were created that were better from the perspective of learning psychology.

The feedback shows that the teaching concepts in Estonia and Germany differ. It remains a challenge to provide learning content, e.g. on climate change and options for action, for different target groups. At the same time, however, countries need to address the issue together despite differences in education.

Recommendations for further action

To make it more relatable for the general public, the respondents suggested having examples from Estonia or having a global approach instead of only German examples. Some of them wished to learn from the game what can be done to fight climate change and suggested having more examples/questions on how to help lessen the impacts of climate change on a personal level. Respondents also mentioned a need for a tutorial or an interactive guide to explain how the app works. Estonian players expressed a need for an Estonian version of the game due to a language barrier complicating the app experience.

Both a change in public awareness of climate change and options for action and technological advances are needed to stop the climate change. We showed that mature concepts can achieve a change in awareness among students. Especially in the relation of STEM subjects to climate change and options for action, significant changes in awareness could be observed in only one morning. We could see that the perception of the app is different in Estonia and Germany. The education system in Estonia trains students more to work independently and critically, while in Germany teacher centered teaching methods still often sets the agenda. For this reason, Estonian students may have perceived the multiple-choice questions more negatively than German students. Adapting content to different target groups (culture, age, gender) is essential. However these promising results show the need and potentials of mature approaches to

address climate change. Focus on Activation (e.g. through own videos and own creation of the content of a learning app), focus on actual actions to combat climate change.

Introduction

The climate science facts are alarming, and past and present reports underscore the pressure to act. Climate change can be observed worldwide. Precipitation fails in spring, leading regionally to dust-dry soils by summer. In Central Europe, precipitation tends to decrease in summer and increase in winter (IPCC, 2022). The number of unusual weather events increases, as evidenced by floods, bushfires, or hurricanes. These impacts will strongly change agriculture, health and well-being of the population worldwide in the future.

Many attitudes, beliefs, and values are socialized in institutional settings, including higher education or schooling. A study commissioned by the German Federal Environmental Agency and published in 2020 underscores learners' desire for new narratives, creativity, and diversity. Education practitioners therefore believe that stronger links between academia and practice, and thus more intensive collaboration between the two professional fields, are useful, necessary, and worthy of support. Closer collaboration between out-of-school and in-school settings is particularly desirable to enrich the implementation and impact of environmental education programs and formats. This could also contribute to persuasion of effectiveness among both those being educated and those being educated.

This project has managed to unite different actors in the field of education for sustainable development. Nature education institutions together with universities including the departments of psychology, computer science and environmental engineering have investigated new concepts for teaching in schools.

The project used gamification and storytelling across countries to communicate sustainability in a way that is appropriate for the target group. The learning content was implemented in an app. Through the Estonian experience in the field of digitalization and the German experience in sustainable education, learning processes could be meaningfully adapted and evaluated. In four work packages, a participatory, target group-oriented environmental education program was developed and evaluated as a prototype, which, in cooperation with the target group, establishes a lifeworld reference and thus incorporates relevant topics.

- WP1: Analysis of sustainable development education at selected higher education institutions in Germany and Estonia, taking into account the results of the study by the German Federal Environmental Agency (documented in the interim report).
- WP2: Cross-national comparison of conflicting goals and causes of young people's lack of knowledge and motivation in working for sustainable development, both on the psychological and structural level (documented in the interim report).
- WP3: Country-specific adaptation of the SmartEducation app and integration of the results of WP1 and WP2 into the environmental learning content of the app. Here, the relevance for the target group is to be increased through the use of target group-oriented education.
- WP4: Pilot study - usage/evaluation of the SmartEducation App in workshops at three educational institutions in Germany and Estonia.

Main part

Representation of the individual work steps

Work package 1 (interim report)

Start	Month 1	Duration	2 Months
Partner	RheinMain UAS, Tallinn University, Koblenz-Landau University, AZN		
Analysis of education for sustainable development in selected universities and schools in Germany and Estonia, taking into account the results of the study of the German Federal Environmental Agency.			

Educational Analysis Sustainable Development (Estonia)

The Sustainable Development Act was adopted in Estonia in 1995, and the Estonian Commission for Sustainable Development was founded in 1996. The Commission oversees the implementation of Estonia's Sustainable Development Strategy, which is integrated into government sectoral and thematic strategies and action plans. The Strategy Estonia 2035 is the country's main long-term reform plan, aiming to integrate sustainable development into all policy fields. The government and NGOs implement various measures and activities in all 17 areas of sustainable development goals, which are interlinked and aim for a desired outcome in both social and environmental inclusiveness. In addition, the Estonian sustainable development strategy prioritizes the preservation of the viability of the Estonian cultural space, and Sustainable Development Goal 18 is defined within the strategy for this purpose. Estonia was ranked tenth in the global Sustainable Development Report in 2019. (Review of the implementation…. 2020) The Estonian sustainable development strategy prioritizes education as a key factor in achieving sustainable development goals. The strategy aims to promote sustainable development education and awareness-raising activities in all levels of education. The National Curriculum for Basic Schools and Upper Secondary Schools, as well as the curriculum for vocational education, includes the teaching of sustainable development and related topics.

The Estonian Commission for Sustainable Development comprises a network of non-governmental organizations from various sectors of sustainable development, including education, environmental protection, culture, health, local government, academia, companies, and agriculture, among others. The inter-ministerial working group on sustainable development coordinates and monitors the attainment of the Sustainable Development Goals (SDGs) and collaborates with the Commission in various activities. The Strategy Unit of the Government Office serves as the Secretariat for the Commission and provides technical services and support. A set of sustainable development indicators has been compiled, and Estonian positions for SDG negotiations and the Estonian review of Agenda 2030 implementation have been

drafted through the collaboration of the Commission and the inter-ministerial working group. (Review of the implementation…. 2020)
The Estonian sustainable development strategy recognizes the importance of education in achieving sustainable development goals and has established a comprehensive system of sustainable development and environmental education in schools. The connection between the sustainable development strategy and the education system in Estonia is crucial in promoting sustainable development education and awareness-raising activities, and ensuring the integration of sustainable development into all levels of education.

Educational Analysis Sustainable Development (Germany)

As early as 1980, the Standing Conference of the Ministers of Education and Cultural Affairs (KMK) of the Federal Republic of Germany formulated goals for environmental education in schools (KMK, 1980). In the wake of the United Nations Development Goals (United Nations, 2000) and the concept of education for sustainable development introduced there, the KMK also adopted an "Orientation Framework for Global Education" in 2007, which was renewed in 2015 and followed in 2017 by a national action plan on education for sustainable development to implement the UNESCO World Programme of Action on Education for Sustainable Development (KMK, 2022). Thus, although German education policy has long been concerned with the topic of sustainable development and environmental education, this thematic area is not firmly anchored in the respective education curricula (Weber, 2000). In many cases, areas of education for sustainable development are covered by individual school subjects such as geography or social studies. Moreover, whether environmental and sustainability topics are addressed in class often depends on the respective federal state ("German educational federalism"), the type of school (e.g., Gymnasium versus Hauptschule), and also on the commitment of the respective teacher (e.g., Börtlitz, 2019; Dawe et al., 2005). In addition, many concepts of education for sustainable development are not described in much concrete detail in the curricula and - unlike other school-based topics - hardly any pedagogical support is offered for achieving the associated learning goals (Hanisch et al., 2015; Weber, 2000). This general tendency for education for sustainable development and environmental education to depend on the commitment of individual schools and teachers is also reflected in the report on education for sustainable development published by the Federal Environment Agency (2020). Here, an evaluation study showed that most educational programs on sustainability and environmental education were offered outside of school, i.e., had to be actively used by schools or took place entirely outside of school (Umweltbundesamt, 2020).

Work package 2 (interim report)

Start	Month 1	Duration	3 Months

Partner	RheinMain UAS, Tallinn University, Koblenz-Landau University, AZN
Cross-national comparison of conflicting goals and causes of young people's lack of knowledge and motivation to engage in sustainable development, both at the psychological and structural levels.	

Conflicting goals Sustainable Development (Estonia)

Estonia faces many conflicting goals regarding sustainable development. The country has made significant progress in recent years, with economic growth and improvements in living standards, but it also faces challenges that need to be addressed to ensure long-term sustainability. This chapter discusses the main conflicting goals in Estonia's sustainable development, including forests, deforestation, energy sources, peat extraction, wetland conservation, and mining phosphorus.

Forested land covers approximately 50% of Estonia's territory (EFI 2022), making them a significant and dominant landscape type in the country. National law and policies recognize that forests are a natural and ecological resource that needs to be considered from an economic, social, ecological, and cultural perspective. Despite this recognition, Estonia has increased the amount of forest clear-cutting each year, which raises concerns about deforestation and its negative environmental impacts. Forests are crucial for carbon storage, biodiversity, and the provision of ecosystem services such as soil protection, water regulation, and climate regulation. Therefore, balancing economic interests with environmental interests is essential for achieving sustainable development in Estonia.

Estonia's main energy source is oil shale, which puts it at the top of CO2 polluters per capita (Report “Energy sector in Estonia”, 2022). At the same time, wind is the most reliable energy source in Estonia, but the country has not built any industrial windmills since 2016. Estonia faces a significant challenge in balancing the need for energy security and economic growth with the need to reduce carbon emissions and promote sustainable energy sources. (Estonian Renewable Energy Association, 2022) By promoting the development of renewable energy sources and reducing dependence on fossil fuels, Estonia can contribute to global efforts to combat climate change and achieve the SDGs. Additionally, investing in renewable energy can bring economic benefits, such as job creation and energy security.

Peat extraction is a significant industry in Estonia, with around 1 million tons extracted each year. However, it has negative environmental impacts, such as the destruction of wetlands, loss of carbon storage, and increased greenhouse gas emissions. Wetlands are crucial for preserving ecological and social benefits, such as biodiversity, water regulation, and cultural heritage. Estonia's universities are putting in a lot of effort into wetlands restoration, but it is challenging to balance economic interests with environmental interests.

Estonia faces pressure to start mining phosphorus, which could have negative environmental impacts, including pollution of the Läänermeri, one of the most polluted seas globally. In the Soviet times, people successfully stopped the building of new Phosphorus mining sites in Estonia. However, today, the excavators are pushing the government to start mining phosphorus at a rate of 4.4 million tonnes per year. Balancing economic interests with environmental interests is essential to achieve sustainable development in Estonia. (ERR, 2021; Estonian Ministry of the Environment, 2021)

Balancing economic, social, and environmental interests is crucial for achieving sustainable development in Estonia. The country faces many conflicting goals, such as deforestation, balancing energy security with carbon reduction, promoting sustainable peat extraction practices, and wetlands conservation. Achieving sustainable development in Estonia requires the government to prioritize environmental interests and consider alternative energy sources. The government must work with stakeholders to promote sustainable practices, such as sustainable forestry, wetlands conservation and restoration, and sustainable peat extraction practices. The success of sustainable development in Estonia will depend on the effective management of these conflicting goals.

Sustainable Development Goal Conflicts (Germany)

By definition, sustainable development is a concept that encompasses several conflicting goals. Sustainable development means the pursuit of humane and social development in which people live ecologically, economically, and socially in a way that does not limit the development potential of future generations (United Nations, 1987). Thus, sustainable development should not place the economic dimension above the ecological or social. Sustainable development is thus a typical Pareto paradox, i.e., improvements in one variable should not be accompanied by declines in another variable (e.g., Bithas & Nijkamp, 2006). This is often difficult to adhere to because, for example, improvements in economic development are very often accompanied by deteriorations in the ecological situation (Kahatu, 2006). In Germany, the successful implementation of sustainability policies often fails due to the problem that effective environmental policies are associated with restrictions on previous lifestyles, such as banning certain plastic items, reducing fossil fuels or avoiding unnecessary air travel, but the acceptance of restrictive policies in Germany is rather low. For example, a recent representative survey in Germany found that 43 percent of respondents oppose a ban on air travel within Germany, although a majority of 79 percent of another representative sample said they are willing or have already started to avoid domestic flights (Presseportal, 2021; Statista, 2022). Many people are thus against this effective measure, although they themselves would not experience any restriction in their own behavior. In the German media, environmental policy is also often portrayed as a "prohibition dictate" or "freedom-stealing" measure (e.g., Seha, 2019). Thus, in recent years, sustainability and environmental policies in Germany have come to smack of being at odds with the freedoms of individual consumers (e.g., Knie, 2020). This is in drastic contrast to the general awareness of environmental issues among the population, which has increased massively in recent years. In the last Eurobarometer, for example, the overwhelming majority stated that the environment and climate change are among the most important political problems of the present (European Commission, 2020). In Germany, however, concerns about

environmentally friendly taxes (Frondel et al., 2022), the "not-in-my-neighborhood mentality" (Bertsch et al., 2016; Liebe & Dobers, 2019), and environmental federalism (e.g., Ohlhorst, 2015; Saurer & Monast, 2021) are among the main factors hindering the implementation of effective environmental and sustainability policies.

Work package 3

Start	Month 2	Duration	7 Months
Partner	RheinMain UAS, Tallinn University, Koblenz-Landau University, AZN, SmartEducation UG		
Country-specific adaptation of an existing learning app and integration of the results from WP1 and WP2 into the environmental learning content of the app. In doing so, the relevance for the target group is to be increased through the use of target group-specific education.			

Deployment as WebApp

Midway through the project, the decision was made to make the app available as a WebApp. SmartEducation UG implemented the necessary changes promptly and put them online. This decision proved to be advantageous in the studies. The application could be distributed across many users with reasonable effort. The application was also usable on all end devices. Problems during installation were avoided. Changes to the application could be made available on the end devices without reinstallation.

Privacy, User accounts and access

All services (except App Indexing) have successfully completed the ISO 27001, SOC 1 , SOC 2, and SOC 3 assessment process, and some have also completed the ISO 27017 and ISO 27018 certification process. Compliance reports and certificates for Firebase services subject to GCP terms of use can be requested through the Compliance Reports Manager. The location of the data is in Belgium, ensuring European data protection guidelines. A login and password were created for each participating user. This login was also used in the psychological evaluation to establish a correlation between gaming behavior within the app and the items of the questionnaire.

Adaptation of the competences

Navigation elements and competencies were translated by DeepL[1] in the first version. The translations were subsequently revised and improved by students of the University of Tallinn. The studies in Tallinn used a large set of competencies with about 100 competencies. For the studies in Germany, the set was reduced to about 40 competencies. This was necessary because school students did not have the time during a project day of maximum 4-5 hours to deal extensively with the large amount of knowledge in addition to the practical experiments, the

[1] https://de.wikipedia.org/wiki/DeepL

conducted discussion on STEM subjects. Lastly, competencies on the need for STEM subjects were added and all graphics were translated into English.

Work package 4

Start	Month 7	Duration	6 Months
Partner	RheinMain UAS, Tallinn University, Koblenz-Landau University, AZN		
Use/evaluation of the learning app app in workshops at different educational institutions in Germany and Estonia.			

User study at Augustinerschule (Germany)

Fig. 1 - User study at Augustinerschule

RheinMain UAS, Uni Koblenz/Landau and AZN conducted an evaluation at Augustinerschule Friedberg (Gymnasium, 11th grade) with about 100 students on Wednesday, 10/19/2022. Fig. 1 shows impressions of the project day. At the beginning, students filled out a questionnaire with questions about attitudes towards gamification, climate change, options for action, and STEM subjects as a technological opportunity, and to slow down climate change. After the presentation of the app, theoretical content on weather and climate, climate change, causes, and options for action were discussed. In the process, the students were motivated to use the app on the side. Following the theoretical part, the group was divided into smaller groups. This was followed by practical exercises and discussions on the footprint of different activities as well as a discussion on the contribution of STEM subjects in addressing climate change. Finally, students were given the opportunity to experiment the effects of climate change through practical experiments, before completing another questionnaire at the end.

Part 1 (theory): The theoretical part includes about 40 competencies on weather and climate, climate change, and options for action. The 40 competencies were a selection from the original 100 competencies, because due to the short time and the large amount of content, it was not realistic to work through all of the content in a meaningful way. Fig. 2 shows an example selection of competencies as they were displayed on users' smartphones.

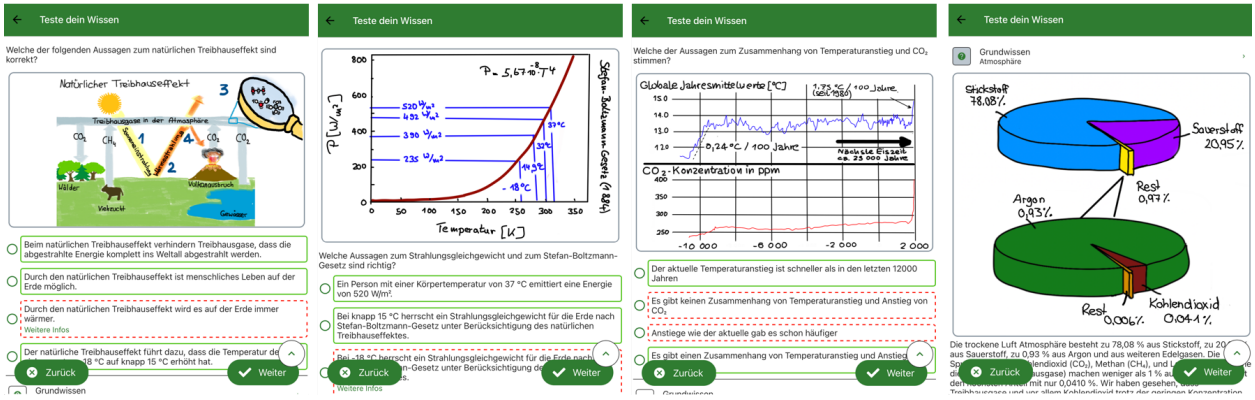

Fig. 2 - Screenshot of the Climate APP

The processing of these competencies was completed by tasks within the app. Students could earn a longer break if a certain number of competencies were answered as a group, and the best received a free drink. The best student answered 792 competencies correctly in one morning, followed by 750 for the second best.

Part 2 (discussion): In the first part of the discussion, students calculated tasks related to personal footprint in certain actions. Afterwards, the results were discussed and the total footprint of a German was put in relation to the necessary reduction to achieve the set climate targets in Germany. In the second part, it was motivated that the individual contribution is probably not sufficient. The contribution as a group is also likely to be insufficient or too late, for example, because important laws are not passed quickly enough. Technological progress is very important. One can study STEM subjects like computer science, mathematics or chemistry and develop ideas, methods and machines that can save the climate. Video streaming, smart farming, meteorology, fuel cell, hydrogen and heat pump are examples that were discussed with the students in the study. The students' task was to understand the concepts (see Fig. 3 for an example) and communicate them to other students in a short presentation. It was important for us that the students see that you come into contact with STEM subjects in very many subjects and applications. It was also important for us to convey that research is diverse and fun. Specifically in the discussion, conflicting goals became apparent among the students. All agreed that climate change is one of the biggest problems facing humanity and that action must be taken quickly. However, the students were often not aware of the consequences of their own actions, e.g. by flying and eating meat.

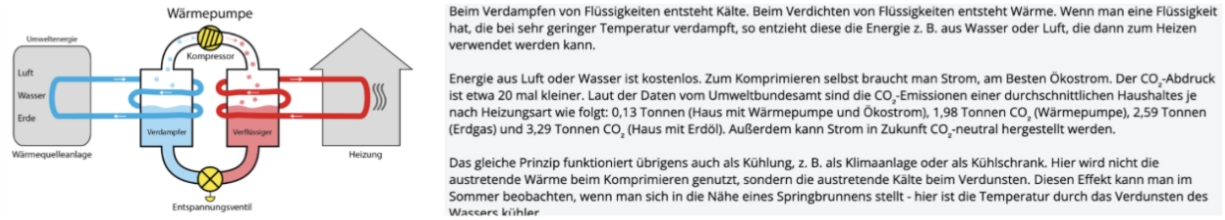

Fig. 3 - Sample Exercise / Explain Technological Progress

Part 3 (practical experiments):

As part of the project days for school classes, both demonstration experiments and experiment stations were used for the students. For the understanding of the greenhouse effect, the basic properties of thermal radiation interacting with matter (transmission and absorption) were demonstrated using a thermal imaging camera. Furthermore, it was shown that after the addition of CO_2, the temperature in a test vessel open at the top rises when this is illuminated with a halogen spotlight. Finally, the students were able to watch live how the CO_2 concentration changes in a closed experimental vessel with foliage leaves while a candle burns down. Experiment stations allowed students to explore various aspects of renewable energy and climate change adaptation:

- Wind energy: buffering volatility through battery storage (wind energy)
- Photovoltaics / fuel cell: buffering of diurnal and seasonal fluctuations through hydrogen technology (solar house), (fuel cell)
- Reduction of building energy demand through building envelope insulation and energy efficient appliances (thermal insulation), (electricity consumption), (crank generator)
- Consequences and adaptations in urban and landscape planning and agriculture (hidden object picture: city and countryside in climate change), (urban greening on a model), (irrigation), (absorption and reflection)
- Climate as statistics of weather (Climate pinball)

During the experimentation phase, the students could turn to supervisors at any time, or work through the stations independently. Following the approximately one-hour phase of self-organized learning, the students shared their findings in the forum and were able to discuss higher-level questions with the supervisors.

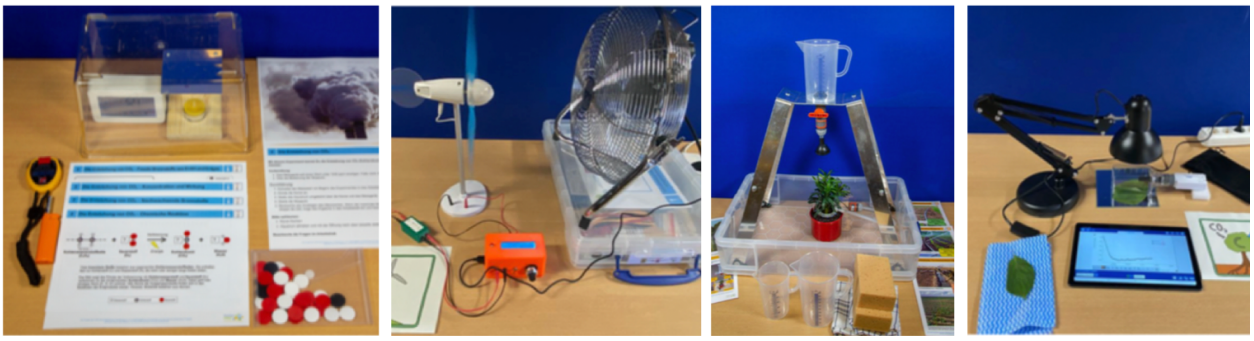

Fig. 4 - Practical experiments on the topic of climate change

Sustainability Project Day with "Junior Engineer Academy (Germany)

An exciting project day, which was part of the research project "Storytelling and Gamification in Sustainable Development Education - a Pilot Study" of the Deutsche Bundesstiftung Umwelt (DBU), was experienced by students of the Immanuel-Kant-Schule in Rüsselsheim on Monday, February 27, 2023, on the campus of the Department of Engineering in the Environmental Engineering course. The eighth and ninth graders from the Junior Engineering Academy came

together with their specialist teachers Mr. Duncker and Mr. Link for a whole day to deal with sustainability issues.

After an introductory theoretical part, the group went on a tour of various laboratories at the university that deal with environmental topics. This included a visit to the IT laboratory ITE, the process engineering laboratory and the current racing cars of the Scuderia Mensa. Afterwards, the students were able to conduct a large number of experiments on the topics of electricity consumption, renewable energy production and climate change. They were accompanied by Prof. Dr. Andreas Zinnen and Dr. Martin Jatho from the AZN Naturerlebnishaus Heideberg, who had come especially to give the students a very clear understanding of the topic of sustainability.

User study at UAS RheinMain - Cleaner Production (Germany)

Motivation: Results of the studies at Augustiner Schule as well as in Tallinn University have shown that activation and deep learning are central challenges in education for sustainable development. Activating teaching pursues the goal of expanding the students' existing knowledge structures by offering them stimulus for deeper reflection and active mental engagement with the subject matter of teaching and learning, e.g. through assignments.

Overview: In the second pilot study, we wanted to generate learning success in particular by involving the learners themselves rather than creating a ready-made app ourselves. We applied the concept idea in the Cleaner Production lecture at RheinMain University of Applied Sciences. 19 students actively participated in the event, and prepared content and questions on the following topics: Aluminum, copper, sand, cement, building deconstruction, paper, soy, palm oil, electromobility, phosphorus, space debris, circular economy. In the course, it is already the case that the students deal with exciting topics themselves and formulate questions for the exam. In addition, students had to put the questions into digital form so that they could be incorporated into the app. In addition to the questions to be learned, a narrative could also be created through which an emotional connection to the topics could be established. The students were thus able to click through the app to prepare for the exam and at the same time deal with what the problems mean for real people and what can be done about them.

Fig. 5 - Sample Competences of the Cleaner Production APP

User study in Estonia (SEEMIK)

The user study in Estonia at Tallinn University was done using more qualitative methodology. The aim of the study was to get more personal and qualitative feedback about the app, not quantitative measurement. Therefore the two, Estonian and German setups of the user experience studies complemented each other and provided a more extensive overview of the application while using mixed methodology.

First, TLÜ has a course called LIFE (ELU - in Estonian, interdisciplinary studies project) where the 12 students participating in this project acted as a focus group. They first got to know the application, played around with it and gave two types of feedback: technical and content related. First round of feedback was in written format and after that the focus group interview with sharing of experiences in an oral form followed.

The second stage of the study was playtesting with interviews conducted by the same 12 students. They had to find fellow students who played the app and gave feedback to them. Around 20 students were interviewed by the members of the ELU project. Their feedback was compiled into a unified file of testers feedback from where results are described below.

Results and discussion

User Studies

User study at Augustinerschule (Germany)

Summary: Most of the students reacted very positively to the project day. The atmosphere was very good, there were no disturbances. Even shortly before the end, everyone was still concentrating and giving constructive feedback on the various topics. Students often remarked that the time period should be extended. Due to the three blocks of theory, discussion and practice, the schedule was clocked. Many students would have liked to have more time in each area. Both teachers and students would like to see a repetition with more time spent on each of the three blocks.

Statistical analysis (app): To use the app, students had to choose an anonymous username (alias), a motto, and an avatar image. The choice of motto (see table 1) provides initial information about the target group's perception of climate change. The vast majority of students believe in climate change and humans as the cause. Only just under 9 percent do not believe in man-made climate change. In the context of this study, it was also difficult to filter fun answers, so this number could also be lower. What is clear, however, is the large majority in the last 3 mottos that emphasize man-made climate change. Here, female students often show uncertainty about the options for action, but see the urgency of action.

#	Motto
5	For me, climate change is a conspiracy theory and all measures against it therefore do not make sense.
3	I think climate change is real, but I don't think humans are the main cause, which is why human efforts hurt the economy and don't produce a mitigating effect.
7	I believe man-made climate change is real, but the current measures and especially the demands of the climate movement are excessive.
8	I don't know much about climate change and human impact, but would like to learn more about it and thereby draw my conclusions about actions.
12	I believe in man-made climate change and would like to do more about it, but I don't know how.
37	I believe in man-made climate change and that it is one of the most important tasks currently facing us humans. Therefore, in my opinion, many changes should be initiated, also by us in our own lives.
17	I consider man-made climate change to be real and currently the greatest threat to humanity. Therefore, in my opinion, a social change must happen quickly, and I want to be a part of it.

Tab. 1 - Distribution of mottos when chosen by students

In addition to the perception of climate change and options for action, we can also anonymously extract from the user data how gamification affects user behavior. In figure 6, we see on the left that many students are more engaged with the learning content through rankings. The top 3 collectively solved just under 2000 competencies correctly, and did so in only about 3 hours of time. On the right side of graph 6 we see the cumulative number of answers over time. Three peaks are clearly visible here. The first peak results from the presentation of the app and the distribution of access data. The other two peaks are due to breaks in which students were asked to solve challenges in order to earn longer breaks and an earlier closing time. Despite the later timing of the group challenge, the final peak is higher. This suggests that female students prefer group tasks to individual tasks.

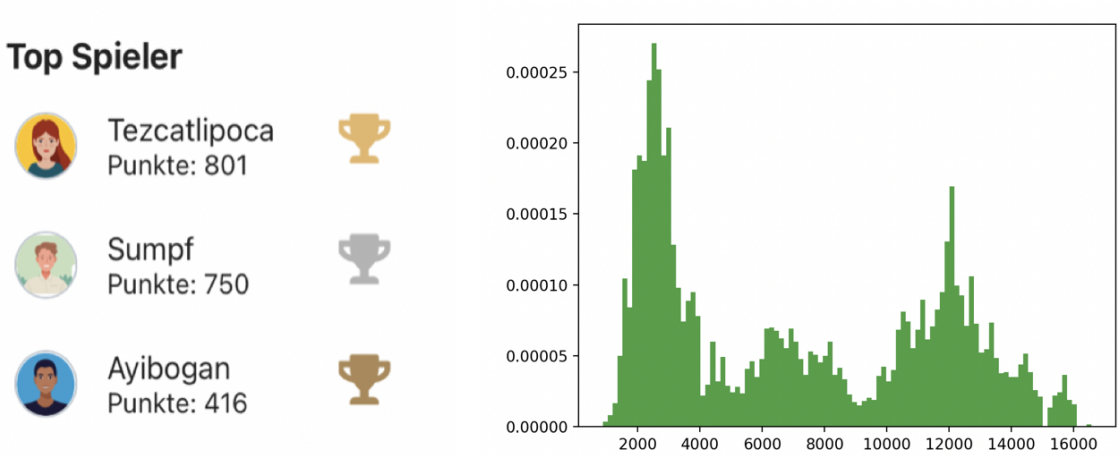

Fig. 6 - Time use of the app

Statistical Analysis (Questionnaires): The following section summarizes the results of the questionnaires. In the first user survey, 96 students participated, 52 of them female, 37 male and 7 diverse. At time two, there were a total of 61 students, 30 female, 27 male, and 4 diverse. We use the method of an intervention study with two measurement time points (pre-post design). At the first measurement point, the students answered questions about their evaluation of STEM subjects, their favorite subject, desire to study, and unworldly attitudes. At the second measurement time point (post-intervention), they answered the same questions again. In addition, some questions regarding the evaluation of the experiments and the app were added. Participation was voluntary at both time points.

At both measurement time points, students were asked to rate STEM subjects on various assessment dimensions. Responses were given per item on a differential of 1-7. At the second measurement point - after conducting the experiments and playing the app - there was a slight increase in students' assessments that STEM subjects are "alive."

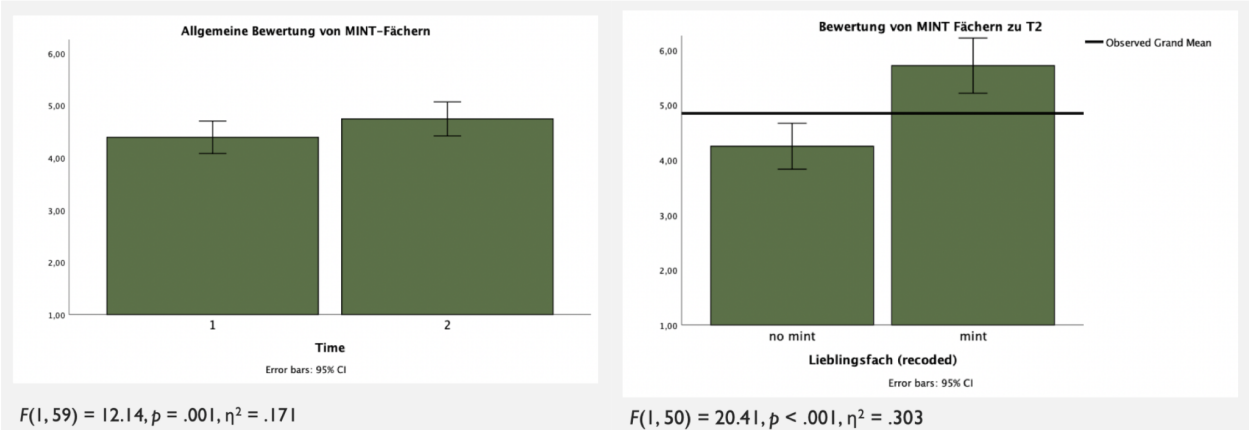

Fig. 7 - Assessment of STEM subjects

There was a significantly greater change in students' perceptions of STEM subjects in relation to climate change. At the second measurement time point - after conducting the experiments and playing the app - agreement with the statement that "STEM subjects help combat climate change" increased significantly. Similarly, agreement with the statement that "STEM subjects offer solutions to climate change" increased significantly (both significant at Bonferroni-corrected significance level). In the general trend, there was a slight but significant improvement in the evaluation of STEM subjects on average across all assessment dimensions at the second measurement point. The evaluation of STEM subjects at T2 was best among adolescents who indicated a STEM subject as their favorite subject at T1 (=high prior interest in the subject). This increase is all the more encouraging because the students already had a very high level of prior knowledge and understanding at the beginning of the study.

At the second measurement time point, students were asked to rate the app, gamification experience, and experiments on various evaluation dimensions. Responses were given per item on a differential of 1-7. A comparison within the students shows (paired samples t-tests) that overall they rate the features of the app significantly more positively than the concrete gamification attributes (e.g. score display etc.) and the experiments. Girls rated the experiments more negatively than boys (may be a role-model effect). There were no significant effects of favorite subject or gender (or even interactions of the two) on evaluation of the app and gamification experience.

Because of the late stage in the project, the study could not be evaluated by the psychologists. We therefore decided to allow and document informal feedback. The concept of the app as a support for learning competences for the upcoming exam was positively received by the students in the course. However, at the time of the short evaluation, about two weeks before the exam, only about one third of the group had played the app. When asked by the instructor, it was felt that the remaining students in the course were still planning to use the app before the exam. It was argued with previous lack of time in the examination or learning phase and the prioritization of examinations of other courses. In principle, however, the students are in favor of using the app as part of the lecture.

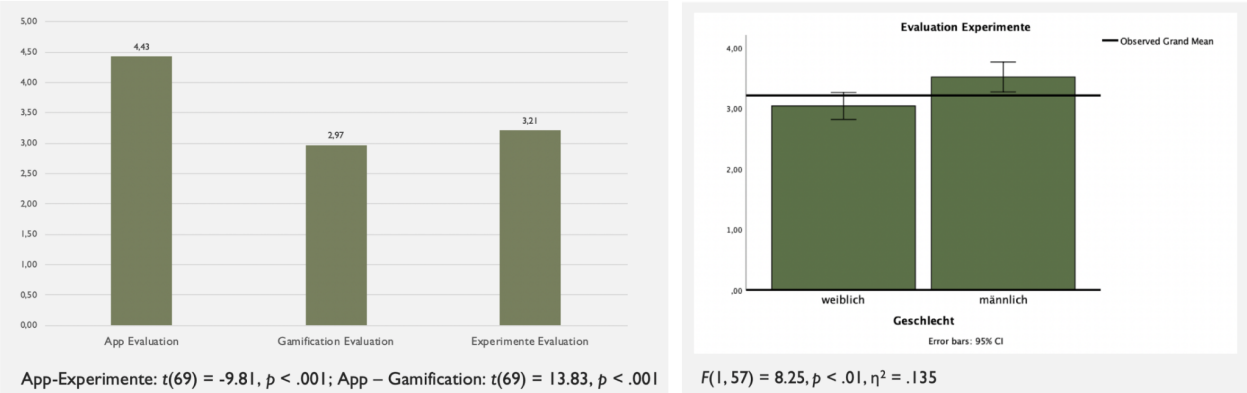

Fig. 8 - Assessment of App, Gamification and Experiments

User study at UAS RheinMain - Cleaner Production (Germany)

One has clearly seen that the success of the concept suffers from the students' motivation regarding the submissions. Despite multiple agreements on when and how the content for the app should be submitted, the submissions are only handed in days or even weeks later. In addition, many of the submissions are incomplete and no response is given to requests for missing parts, or only very late. The quality of the submissions also varies greatly. While a few groups really made an effort, the majority of the groups had faulty spelling and grammar and the questions were reduced to a minimum. The incomplete elaborations create gaps that impair the flow of the game and thus the full potential of the app cannot be exploited.

User study in Estonia (SEEMIK)

The Estonian team aimed at a more qualitative approach with several rounds of interviews. The following is the summary of the conducted interviews. The students used a browser version of the application as there were some translation issues. The report is based on feedback given by Estonian university students who were tasked to play and analyze the game. There were 18 people who played the game and provided feedback in the form of an interview. This feedback report is about the content and personal experience of the game.

The game was perceived rather like a test, quiz or an exam you would take in a class instead of a game. According to the respondents the game did not create enough competitiveness and immersion hence the experience was rather informative than playful and the game was seen as more educational than entertaining. The user experience was not reported to be too great: the respondents found the platform was uncomfortable and rather confusing to use. The players experienced a language barrier, it was difficult to understand the interface and how the game worked. Some players struggled with profile creation and understanding the mechanics of the game took them more time and effort than they would have preferred.

Few players mentioned that the “Achievements” did not make sense to them due to not having any effect (they brought out that an achievement promised a chocolate or a longer break). The competences page did not seem to be of much use and was found to need more content: explanative texts or more detailed analysis about the player’s progress.

The long explanatory texts were enjoyable and interesting but at the same time a bit overwhelming and dry. The players liked having additional information about the topic but at the same time the large amount of information and text became overwhelming. Due to that, respondents suggested that the game could be more suitable for people who are already interested in the subject of climate change. However on the other hand players enjoyed that there were short texts/sentences explaining which answers are correct and why and that some additional information was optional.

Some players reported to gain new knowledge, some of them didn’t. The ones who didn't said it was either because the game was not understood well because of English, there was too much information at once or they were distracted by the interface. Some respondents brought up that the game helped to remember facts and knowledge about the topic of climate and climate change they once knew but had forgotten. Though most of the players concluded they would not prefer to learn using this type (exam/test type) of method. However the players said they would be willing to give the game another try after it has undergone some improvements.

Comments about the game experience included:

- Many players reported feeling uncomfortable while playing the game (with user interface and English language)
- Players did not like that the game was not in Estonian and it made it either “uncomfortable”, “tiring” or “demotivating” depending on the person
- Confusing UI: There was a need for a short introduction of the game and how it works
- Players wanted more interactiveness and variety (questions and tasks)
- Players would have liked more game-like features
- The content was too dry and heavy to provide entertainment
- Game was found to be a helpful tool in remembering facts and being an additional/supportive tool in the learning process

There was a difference in opinions regarding the target group. Some respondents found it to be suitable for secondary school students, some for people who already are interested in the topic of climate change and some would have suggested it for university students due to longer texts, specific vocabulary and scientific concepts. However if the target group is university students a player suggested using references to make the game more credible. Especially if the game’s goal is to provide arguments that climate change is real. To make it more relatable for the general public instead, the respondents wished for a more personal and practical approach. They suggested having examples from Estonia or having a global approach instead of only German examples. Some of them wished to learn from the game what can be done to fight climate change and suggested having more examples/questions on how to help lessen the impacts of climate change on a personal level.

In conclusion the current statement was that most of the respondents would not play the game again or recommend it to a friend. The respondents did not find the game easy to use in the beginning and it created confusion amongst the players. They also wished to have a more playful and fun experience with the game. They concluded if the game interface, design and engagement were to be improved and if it were to be translated into Estonian language the respondents believe it could be a lot more fun and they'd give it another try. The game coincided with the values of most of the players (about nature and our environment), and they found that these are important topics which should be showcased more. Overall the game received a positive mindset but changes were requested in order to improve aspects of fun, enjoyment and ease of use/usability.

Limitations of using only an app as it is at the moment:

- No deep learning: Sparse learning due to gamification elements such as ranking, achievements, … (Learning not optimized on learning content and interest, but on achieving the points)
- App alone does not achieve the high effectiveness as the combination of teaching methods (case analysis, debate, group work)
- Multiple choice and text as a question form do not achieve the goals

Cross-country results

Overall, the results of the project were promising. Since only a cooperative solution across national borders will be successful, multi-cultural cooperation in research projects on ESD makes sense. However, we also found out that there is no single solution that will work in all countries. There are already major differences between countries in the way knowledge is transferred and perceived. Moreover, the focus in the project we worked on was on knowledge transfer. The past project does not provide an answer to the question of how to actually change the behavior of schoolgirls in the long term. It remains to be seen whether activation can be the key to success here. Involvement of different disciplines including teachers, pedagogues, sociologists, psychologists and technicians is inevitable in answering the open questions.

If we take a closer look at the perception of the app, differences in Estonia and Germany become clear. Students in Estonia rate the content of the app as rather boring, while German students rate the app positively. One reason could be different teaching concepts. Teaching and teaching concepts differ greatly between Germany and Estonia. While learners in Estonia are encouraged to take initiative, communicate and critically evaluate learning content at an early stage, these skills are still rarely taken into account in Germany. German students are more used to answering multiple choices, including re-using information. Another reason for the difference in perception could be the design of the application. While in Germany a project day consisted of 3 larger blocks (theory, practical experiments, discussion), the evaluation in Estonia was based on the app alone. Lastly, Estonians have very high expectations regarding user-experience.

Project Management

Timeline and Project progress

The project was completed in compliance with the original schedule. All milestones were achieved. Similar studies were originally planned in Germany and Estonia. Through discussion with the educational psychologist at SEEMIK, we decided to continue on two tracks, which must be different constellations of questions through different education. In Germany, we focus on evaluation, i.e. using the existing app with revised content to get early feedback from students on the overall concept. In addition, we see great potential in learner participation in the design of the app. SEEMIK instead focuses more on the psychological aspects and tries in parallel to gain experience in digital content design and story elaboration to enable Deep Learning.

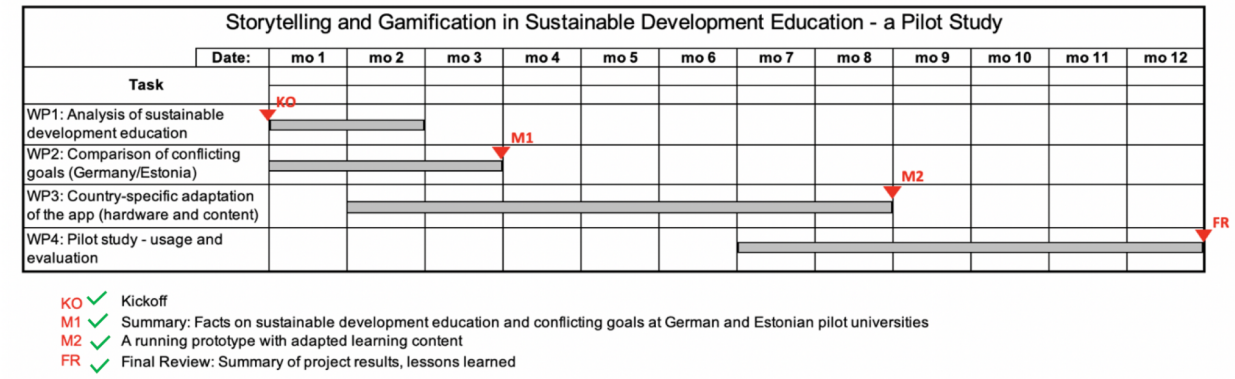

Fig. 9 - Original schedule in the application

Administrative cooperation

The administration of the RhineMain University of Applied Sciences took over the administrative processing of the project. On the professional level, Prof. Dr. Andreas Zinnen took over the project management and coordination of joint actions. Although the University of Tallinn on the one hand and the RhineMain University of Applied Sciences, the AZN and the University of Koblenz/Landau on the other hand decided early on to follow different paths in the evaluation, the cooperation was very valuable. Especially due to the different approaches, which were examined in pilot studies, a multitude of research questions arise, which can be addressed in further projects in cooperation between the partners.

Professional cooperation

The professional cooperation is perceived as very efficient by all partners. Due to the different locations and the number of partners, regular project meetings were held online. In September, we had a project meeting on site in Rüsselsheim. In addition to technical discussions about the

ongoing project, the guests were able to visit laboratories of the Environmental Engineering Department.

Fig. 10 - Project meeting on site in Rüsselsheim

These took place either with all partners or only with some of them in order to process the tasks as efficiently as possible. Especially the discussions with software developers and psychologists led to results in the project that were underestimated by many at the beginning. By using a cloud folder on which the documents were shared, it was possible to work partly separately and often together. The task now is to summarize and note the results.

The Estonian team was also very happy with the international cooperation. We were very glad that it was taken with great interest and open mindedness that we brought to the project about learning from a psychological point of view. We learned a lot from each other and are more than willing to work together in the future and pursue this fruitful collaboration further. We are willing to contribute to the continuous improvement of the proposed learning application and hope for continuation of the project with a second round of funding.

Employees working on the project:

- Dr. Julia Schnepf, Prof. Dr. Gerhard Reese (Psychology - Uni Koblenz/Landau)
- Dr. Martin Jatho (Biology, Education - AZN)
- Triinu Jesmin (Educational technology, game based learning - TLÜ)
- Prof. Dr. Jaanus Terasmaa, Maris Morel (Ecology, sustainability - TLÜ)
- Grete Arro (Educational and environmental psychology - TLÜ)
- Nora Hilland, Sarah Kreinbihl (Environmental Engineering - HSRM)
- Visar Januzaj, Prof. Dr. Andreas Zinnen (Computer Science, Education - HSRM)

Measures for the dissemination of project results

- Dissemination on WWW:
    - 5. MINTchallenge - STEM international
    - Projekttag Nachhaltigkeit mit „Junior-Ingenieur-Akademie“
    - HSRM - Aktuelles
    - Seemik - Tallinn University

- Dissemination in Newsletters:

SEEMIK uurimisgrupi koostöö Saksamaa kõrgkooliga

Oktoobris külastas Tallinna Ülikooli SEEMIK uurimisgrupi esindajad Triinu Jesmin ja prof Jaanus Terasmaa Saksamaa Rehmein Hochschulet ning nende laboratooriume. Delegatsioonile näidati nii biotehnoloogiate- ja veeanalüüsilaboreid kui ka muljetavaldaval tasemel tegutsevaid mikroplasti ning andmevisualiseerimise laboreid. Tegemist on ühega vähestest Saksamaa rakenduskõrgkoolidest, kellel on luba anda välja doktorikraade oma õpilastele, mis näitab nende teaduse kõrgetasemelisust. Koostöös Rehmein Hochshule kõrgkooliga valmib Tallinna Ülikoolis kliimateadlikkuse edendamisele suunatud mobiilirakendus ning viiakse läbi pilootuuring selle tõhususe testimiseks. Fotodel: paremalt delegatsioon ja vasakul laboreid avastamas.

Fig. 11 - News story in TLÜ newsletter

Preis für Projekt „MINT kann Klima retten"

Im Rahmen der MINT-Challenge „Kompetent für nachhaltige Entwicklung" wurde „MINT kann Klima retten" aus 56 Projekten für den zweiten Preis ausgewählt. Unter der Leitung von Prof. Dr. Andreas Zinnen entwickelten Studierende des Studiengangs Umwelttechnik eine Lern-App, die Gamification, Storytelling und Digitalisierung miteinander vereint, um mehr Studierende für MINT zu begeistern. Die Inhalte der App können darüber hinaus genutzt werden, um Schüler:innen für ein Studium im MINT-Bereich zu interessieren sowie die enge Verbindung zu Nachhaltigkeitsthemen aufzuzeigen und auch um Angehörigen entsprechende Themen anschaulich zu vermitteln.

AUSGEZEICHNET

MINT CHALLENGE®

Fig. 11 - News story in HSRM Environmental News

- Dissemination at schools and universities:
    - 100 students at Augustinerschule in Hesse
    - 24 students at Immanuel Kant Schule in Hesse
    - About 30 students in Tallinn
    - Concept to be used at more schools, Expansion of a laboratory for ESD at RhineMain University of Applied Sciences
    - Bachelor thesis in the field of environmental engineering: Evaluating gamification and storytelling in an app for teaching education for sustainable development.
    - Student projects in ESD as well as learning content creation and storytelling.
    - Paper submitted to: https://www.springer.com/journal/40573

Conclusion and Lesson Learned

Even though comprehensive studies were not possible due to the short time and small budget, the project led to the beginning of a promising cooperation between partners with different strengths. In the project itself, different approaches to ESD were tested and numerous findings were collected to be evaluated in projects.

Many citizens (students in the project) in both countries are aware of the problem of climate change. The challenge will be to encourage citizens to change their behavior and to explore technical solutions. Transfer, self-evaluation and problem-solving should be at the forefront of climate education to bring about activation regarding this important issue.

Interactive educational tools about climate change are very much needed and appreciated by the students. What needs to be done is make the application more attractive as well as deep learning enabled with more in depth discussions and cooperation between players and application. Depending on the educational system and the previous education of the students (especially in Germany), activation may only work if teachers monitor closely. User experience is paramount. Therefore, it is important to involve different disciplines from the beginning. The user experience needs to be upgraded and visuals supporting engagement with the application.

Cultural differences make a common cross-national approach challenging. The cross cultural differences in this project may be attributed to the fact that Estonian is considered a very digitally advanced country and their students are digital natives and performing as one of the best in the world (PISA, 2018). Estonian education system is very much digitalized and students are used to study on- and offline. Therefore, they have a lot of experience with different systems and applications and also have high expectations regarding these. Nevertheless, projects should try to test approaches beyond countries, as a solution to the challenge of climate change is only possible together. Germany in particular can benefit from the experience of its partners in digitization in education.

In summary, the project was enriching for all partners involved. The partners hope for a long lasting cooperation that combines different expertise and disciplines and thus can contribute to the management of climate change.

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