ENHANCING COMPUTER SCIENCE PROJECTS WITH REMOTE TEACHING ELEMENTS

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Abstract. The COVID-19 pandemic called for the ad-hoc implementation of many different types of remote teaching elements such as the use of particular methods and software. Entering the post-pandemic period, the acquired knowledge during this time of crisis can be used to enrich daily educational practice. In this paper, we introduce the *Digitechnikum*, a project in which students work on socially relevant computer science projects over the course of one school year. Based on the experiences made with various remote teaching elements during the pandemic, we discuss the use of these tools and methods for computer science projects in a school context in the post-pandemic era.

Key words: Computer science projects, Digitechnikum, remote teaching.

INTRODUCTION

Even before the COVID-19 pandemic, remote teaching concepts for everyday school life were developed and tested in many countries (Zeinz, 2019). Those concepts were attributed many hopes and chances, such as the large-scale availability of education (Sibirskaya et al., 2019), as well as the promotion of self-learning skills (Erhel & Jamet, 2013) and the quick creation of individual learning opportunities (Bondarenko et al., 2021). Then, with the COVID-19 pandemic, the largest conceivable test scenario for these concepts emerged from one day to the next - the abrupt and widespread home-schooling described as "emergency remote teaching" (Hodges et al., 2020). Teachers and students got particularly challenged by the sudden requirement of digital skills and technical prerequisites and, last but not least, by a drastic decline in motivation on part of the students (Barlovits et al., 2021). Nonetheless, the pandemic has also given a decisive boost to the digitization of the European educational sector (Cone et al., 2022). Now, in the post-pandemic period, we want to take a closer look at remote teaching elements used during the pandemic and their potential use at school in combination with computer science projects.

Computer science is a subject closely related to digital tools and elements. The experiences made during the pandemic can thus benefit this subject more than others. In this work, we want to take a closer look at long-term computer science projects at school during which students must also work at home, since the time to meet in person (e.g. as part of regular school lessons) is limited. Remote elements hold the potential to enhance this hybrid project setting, enabling students to productively collaborate from afar and merging their achieved work in in-person meetings, where understanding and coordination is crucial. In the context of computer science projects and in light of the recent events related to the pandemic, we take a closer look at the extracurricular computer science project *Digitechnikum*. This project had to suddenly be conducted in a pure remote format, like the majority of educational programs during the pandemic. In this article we want to outline which remote teaching elements used in the Digitechnikum have proven to be enriching to collaboratively work hybridly on a computer science project at school. This includes elements of professional software development (keyword "agile methods"), as well as different software solutions.

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The methods and software will be discussed based on our observations as well as evaluation data from the Digitechnikum in order to shed light on the following higher-level question:

How can remote teaching elements used during the COVID-19 pandemic prove worthwhile for computer science projects in the post-pandemic period?

THE DIGITECHNIKUM AND ITS REMOTE ELEMENTS

About the project

The Digitechnikum[1], a project originating in Frankfurt, Germany, aims at enriching the educational landscape by offering additional computer science learning opportunities on a local level (Wetzel & Ludwig, 2020). In this extracurricular program, selected students aged between 14 and 18 years, work in teams of four on a soft- or hardware project addressing a socially relevant problem in Frankfurt over the course of one school year. After an initial kick-off weekend where the students get to know each other, find teams and formulate their project ideas, students meet every two to four weeks in rooms at Goethe University Frankfurt to work on their project. These meetings resemble informal gatherings in a maker space, as students are provided with a space to work on their projects and all necessary materials such as computers, hardware components and 3D printers. The students are encouraged to solve problems by their own means but can always resort to the help of mentors with various technical backgrounds. The project is currently running in the fourth year. In the first three years, a total of 58 students participated working on 13 different projects. Software projects were predominantly designed in the form of a mobile app. An example from year 2 is an app for tracking one's own behavior and evaluating how sustainable it is based on what the team called "flower power score" taking into account different variables such as eating habits and the use of public transportation. In year 1, a team developed a 3D-printed box containing an Arduino equipped with two ultrasonic sensors that could be fixed to a bike. If a car comes too close posing a threat to the biker, the box gives out a warning in form of a blinking LED and a loud beeping sound (for more details on this project see Läufer et al., 2023).

Remote elements of the Digitechnikum

The Digitechnikum project, which started in October 2019, was meant to occur entirely live and in person apart from the phases in which student teams continue to work on their project tasks at home. However, the COVID-19 pandemic made this impossible from March 2020 on. Hence, the rest of year 1 was conducted in a remote manner, though with some difficulties, as no "remote plan B" had existed so far. Since it was unpredictable, when the pandemic situation would be over, we developed a concept for conducting the Digitechnikum remotely from year 2 on. Figure 1 gives an overview over the phases in which the Digitechnikum could be conducted in person and the remote phases between October 2019 and December 2022 (today). Apart from the kick-off weekend, year 2 was conducted completely in a remote manner. Year 3 could run longer in person, though winter also made it necessary to continue remotely. In spring, in-person meetings could be reinstated.

[1] The Digitechnikum (https://sptg.de/projekte/wissenschaft-und-technik/digitechnikum) is a collaborative project of Polytechnic Foundation Frankfurt and Goethe University Frankfurt, funded by Polytechnic Foundation Frankfurt.

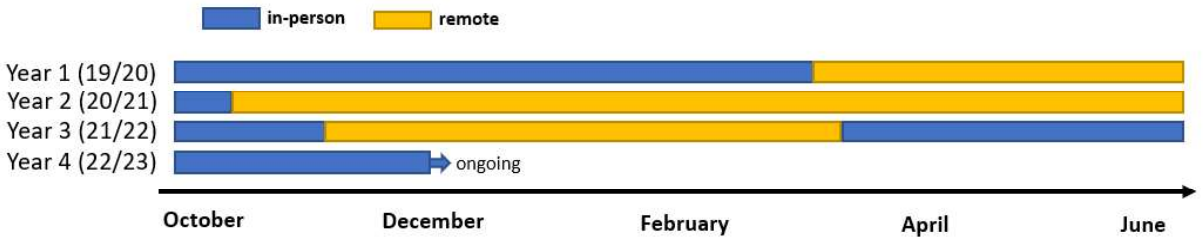

Figure 1: Overview of the phases in which the Digitechnikum could take place in-person and those in which it was conducted purely remotely.

The concept for the remote phases is built on different kinds of software and methods which are introduced in Table 1 specifying for each tool what it is and how it was used. Not all elements in this table can or must be used exclusively in a remote setting, however, they can enrich both hybrid and remote settings.

Remote element	Description
Video calls	Video calls enabled us to conduct regular project meetings during completely remote phases. We used software such as Zoom (https://zoom.us/) or the open-source alternative BigBlueButton (https://bigbluebutton.org/). These calls also enabled us to invite guests to give a digital presentation or workshop on a particular topic when meetings could not be held in-person. However, video calls can also be used in-between meetings for teams as a low-threshold means to discuss and collaborate. The format was enriched by using features such as screen sharing and breakout rooms. Breakout rooms give teams their own private space to work on their project. Screen sharing furthermore enables the team to discuss code, designs and more.
Kanban boards	Kanban boards aid in structuring each team's work by formulating user stories and tasks. User stories capture the key features of a project from a particular user's point of view with details about what the feature entails and what its purpose is. From each user story, many tasks can be derived which encompass the steps for the technical implementation of a particular feature. Kanban boards give an overview about what has to be done, what is currently being worked on and which tasks and user stories are already completed. Tasks are written on cards and assigned to a column, e.g., in the most basic form, "To Do", "In Progress" and "Done". If a team member takes on as task, this member's name is written on the card and the card is moved to the "In Progress" column. The board thus also provides insight into how work is distributed among the team members. A digital realization allows access from almost everywhere and thus facilitates staying up to date with the current state of the project. Digital Kanban boards were realized using WeKan (https://wekan.github.io/) on a server hosted by us, using Trello (https://trello.com/) or the built-in Kanban boards of NextCloud (https://nextcloud.com/).

Stand-up meetings	During a stand-up meeting, students stand together either live or virtually and report to each other in a few sentences what they have done for the project since the last time, if there were any problems and what next goals they aim to achieve. In the remote version of the Digitechnikum, a "big" stand-up meeting with the whole group took place at the start of a video call while "small" stand-up meetings within a team were realized via breakout rooms after the completion of the big meeting
Git	Git is a version control software used to store current and previous versions of code to facilitate collaboration especially when multiple features are developed simultaneously. Using it in school is uncommon, however, it is essential for a long-term project such as the Digitechnikum with potentially multiple coders, who – in a remote setting – all work on different computers. Git repositories can be set up e.g. on GitHub (https://github.com/) and every team member needs a GitHub account to contribute code to the project.
Online courses	Especially at the beginning of a year when students decide on the technology stack for their project, they need additional input to learn how to use certain languages or frameworks. Fee-based Udemy courses (https://www.udemy.com/) or free YouTube tutorials enable the students to e.g. learn new programming languages at their own pace at home using instructional videos.
Cheat Sheets	Cheat sheets are pdf documents containing useful links for a certain technology or topic such as "App programming with Flutter". They include links to official documentations, installation tutorials, forums etc. Students get these pdfs to independently acquire skills at home.

Table 1: Remote elements used in the Digitechnikum.

METHODS

To discuss the elements introduced in Table 1 in more detail, we rely on both, our observations and data from the end-of-year evaluations of the first three years of the Digitechnikum with $n_1 = 22$, $n_2 = 15$, and $n_3 = 15$ participants[2], respectively, which include 5-point Likert Scale (from 1 "Do not agree at all" to 5 "Completely agree") and open text items. These evaluations are not primarily focused on remote elements but the success of the Digitechnikum as a whole containing questions about the project structure, the students' experiences, teamwork, mentoring and more. In case of prior technical knowledge, students fill out a self-assessment of their skills when applying for the Digitechnikum (first time in year 2) with the same items reappearing in the end-of-year evaluation. Should no data about a remote element be derivable from the evaluation, we critically depict our subjective experiences.

[2] Due to the Covid-related restrictions, less students could participate in the Digitechnikum from year 2 on.

RESULTS – ENHANCING COMPUTER SCIENCE PROJECTS WITH REMOTE ELEMENTS

In this chapter we describe the results of the remote conduction of the Digitechnikum during the COVID-19 pandemic with respect to each remote element from Table 1 and propose how these elements can enhance computer science projects in school, especially those with a duration of several weeks or more.

The main and most indispensable element on which remote phases of the Digitechnikum relied are video calls to facilitate coordination, exchange and team coding. Meetings, both with the whole group and within the teams of four (via breakout sessions), could only take place virtually in remote phases, even though longer remote meetings "felt strenuous at times" (quote from year 2 evaluation). Nevertheless, video calls proved to be a practical tool and a low-threshold means for quick team consultations or longer discussions even during phases in which the Digitechnikum could take place in-person. In year 3, which took place both in-person and remotely, a direct comparison of these phases was possible. Even though the mean approval rate of the statement "I liked the remote meetings" was lower with M = 3,93 (SD = 0,96) than that of the in-person meetings (M = 4,67, SD = 0,62), the acceptance of the digital phases is still satisfactory. Screen sharing as part of these video calls is a useful tool to preset and get insight into the actual code base. Moreover, it facilitates decentralized work in modern program development. Screen sharing is also excellent for so-called code reviews. Here, the code of a specific new functionality is presented and thoroughly discussed with the whole group, which contributes particularly to the teaching of programming conventions, the removal of obstructive programming habits and the fortification of the ability to take criticism. Code reviews were not used in the first three years of the Digitechnikum but are currently being tested in the fourth year due to their great potential. In sum, there are many ways in which the self-regulated use of video calls and screen sharing in a school project context can enrich students' collaboration and communication outside of school and is, thus, worth being consciously motivated by the teacher.

Kanban boards were already an integral part of the Digitechnikum project before the COVID-19 pandemic. They belong to the selected agile methods introduced with the aim to improve teamwork and the advance of the project by highlighting values such as communication, feedback and simplicity. Aggregating the answers of all three years, the mean answer value to the statement "I think it's helpful that we use Kanban boards." is M = 3,52, (SD = 1,03, n = 53). The highest mean for this question was achieved in the almost all-digital run-through of the Digitechnikum in year 2 (M = 3,87, SD = 0,88), so Kanban boards seem to be at least equally helpful in a remote or hybrid setting. This impression is supported by open-text answers in year 2 to the question "What did you learn in the Digitechnikum?" where one student wrote that he used Kanban boards in the Digitechnikum for the first time and that they "are a very good tool to do work in a structured way". Another student wrote that Kanban boards are one of the things he liked most in the project. The Kanban boards are filled with user stories and tasks (see e.g. Brichzin et al., 2019). On the Kanban board, user stories and tasks are collected in a clear and structured manner. Students can independently assign themselves to tasks and move the cards to the respective column which facilitates remote work. In spite of its positive qualities, it takes students some time to get used to this method. In the evaluation of year 1, one student writes:

"We didn't have enough time during the meetings, actually we only had enough time to distribute tasks or move cards on the Kanban board from left to right (things which could be easily accomplished at home, we thus had only little time to intensively discuss ideas within our team)."

The quote demonstrates that meetings in-person are valuable for complex discussions and briefings. Moreover, the student emphasizes that Kanban boards can also be maintained at home. As such, they offer an opportunity to bridge in-person meetings and remote phases. Overall, we observed that some teams used their Kanban boards to their full potential until the end of the Digitechnikum, while other teams acted more independently of the board over time. Thus, an obligatory introduction of the Kanban board tool followed by a voluntary continuation appears to be a worthwhile compromise in a school context.

Stand-up meetings meant to bring all team members up-to-date before the next work session. They also proved to be valuable for the other teams and the mentoring team to get insights into the presenting team's current progress. After the "big" stand-up meeting with the whole group where everyone briefly summed up what they had been working on, the meeting was continued within the project team where the next steps and goals were discussed. In the remote periods of the Digitechnikum, stand-up meetings were realized via video calls and breakout rooms. In spite of these regular stand-up meeting within the whole group, some students wished for even more knowledge exchange across teams, as a quote from the year 3 evaluation depicts: "One could exchange more with each other or stimulate this exchange by mixing the groups at the project days.". Therefore, we would recommend practicing stand-up meetings live and remotely in school projects not only to involve all teams and team members in each project's progress, but also to use this format actively as a way to exchange knowledge.

The use of Git or other version control systems is invaluable in software development, allowing team members to productively code together and to integrate work done independently into the main code base. However, using version control systems efficiently is a complex matter to teach, especially since most students even at university level have no prior knowledge about it. We try to bridge this gap with designated Git-Workshops at the beginning of the Digitechnikum. In accordance with these, the evaluations show that Git is one of the topics students learned most about during the Digitechnikum: the self-reported skill-level increased from M = 1.87 to M = 3.67 in year 2 and from M = 2.1 to M = 3.73 in year 3 with Kanban boards being the only area where the self-reported data implied a higher increase. Still, due to the complexity of the topic it could be observed that students struggled to efficiently use the system to manage their project files. For an application at school, we appeal for a thorough and practice-based excursion on the basic usage of Git first, to empower the self-regulated remote usages by the students at home.

The need for more technical input in the Digitechnikum manifests in the mean answer value M = 3.95 (SD = 1.22) to the item "I would have preferred to get more technical input" (scale from 1 "Do not agree" to 5 "Completely agree") in the evaluation of year 1. However, we did not have the personal resources to give extensive technical workshops that lasted longer than a day. Additionally, one main goal of the Digitechnikum is for students to learn how to solve problems and to learn new things independently. The necessity for a remote conduction in year 2 helped us to find a solution to this problem by using online courses (see

Table 1). As long as they are didactically reasonable and designed to fit the currently taught topic, online courses make it possible to move entire topics to remote learning, presenting themselves as an opportunity for students to learn new technologies on their own – comparable to the flipped classroom concept. These courses proved to be successful for the autodidactic acquisition of new programming languages and environments: In year 3, one student writes "I learned most new things by completing the online Flutter course". We can also report a decrease in the voiced need for more technical input from M = 3.95 in year 1 to M = 3.07 in year 2 to M = 2.94 in year 3 with the decrease from year 1 to year 2 (where the online courses were introduced first) being statistically significant (two-tailed t-test, p = 0.05). Yet, we observed that some teams lost focus over in-detail courses and fell behind starting with their own project implementation. To support them, we created what we call "Cheat Sheets" with important links, online course chapters and videos to find orientation when working with a new technology. The impact of these cheat sheets is currently tested in year 4.

DISCUSSION

The use of remote elements in the classroom was taken to an extreme during the COVID-19 pandemic. Distance learning as a stand-alone way of education seems not desirable from a motivational point of view as first surveys with teachers during the emergency remote teaching phase suggest (Barlovits et al., 2020, Hodges et al., 2020). Nevertheless, the sudden widespread use of digital communication tools for teaching and learning environments has also created opportunities for advancing digitization in education. In this article, we have presented the Digitechnikum, a project for the development of non-profit computer science projects by students, which had to take place entirely online for long periods of time during the pandemic. Based on our experiences, we presented remote teaching elements used during the Digitechnikum to discuss the question "How can remote teaching elements used during the COVID-19 pandemic prove worthwhile for computer science projects in the post-pandemic period?".

A variety of remote was essential for the successful implementation of the remote Digitechnikum, as well as for the development of the individual projects in the student teams. Most essential were tools supporting communication such as video call software since they enabled a remote exchange and to teach content online with the use of practical features such as breakout rooms and screen sharing. These tools also facilitate more frequent team meetings in general, and hence, their use should be encouraged also in in-school projects. The same recommendation applies for stand-up meetings both live and remotely to foster progress and knowledge exchange across the teams. In turn, Kanban boards were observed to be a concept worth teaching which was also broadly accepted by the students. Yet, they suited some teams more than others. Therefore, we root for a voluntary continuation after a mandatory introduction of this agile method. Moreover, shifting the acquisition of some relevant topics to an autodidactically remote context in combination with online courses and cheat sheets is also in line with a sensible hybrid project setting. It should be emphasized that the right choice of remote learning content is crucial to not overwhelm the students and prevent them from starting with their actual project implementation.

Considering our initial question, our experience suggests that the use of many remote elements which we put to test in the Digitechnikum can also be suitable for a post-pandemic setting in the context of school-based computer science projects. However, this does not imply a desire for conducting a pure remote project, which becomes unmistakably clear from the many comments of the type *"the Digitechnikum would have been even better in-person"* in the complete remote run-through of year 2. Therefore, we appeal for the well-dosed use of remote teaching elements to enhance the teaching and learning experience in a school-based computer science project where part of the development is meant to be conducted at home.

References

Barlovits, S., Jablonski, S., Lázaro, C., Ludwig, M., & Recio, T. (2021). Teaching from a Distance—Math Lessons during COVID-19 in Germany and Spain. *Education Sciences, 11*(8), 406.

Bondarenko, T. G., Maksimova, T. P., & Zhdanova, O. A. (2021). Technology transformation in education: Consequences of digitalization. In S. I. Ashmarina, & V. V. Mantulenko (Eds.), *Current Achievements, Challenges and Digital Chances of Knowledge Based Economy* (pp. 659–666). Springer.

Brichzin, P., Kastl, P., & Romeike, R. (2019). *Agile Schule (E-Book): Methoden für den Projektunterricht in der Informatik und darüber hinaus*. Hep Verlag.

Cone, L., Brøgger, K., Berghmans, M., Decuypere, M., Förschler, A., Grimaldi, E., Hartong, S., Hillman, T., Ideland, M., & Landri, P. (2022). Pandemic Acceleration: Covid-19 and the emergency digitalization of European education. *European Educational Research Journal, 21*(5), 845–868.

Erhel, S., & Jamet, E. (2013). Digital game-based learning: Impact of instructions and feedback on motivation and learning effectiveness. *Computers & Education, 67,* 156–167.

Hodges, C., Moore, S., Lockee, B., Trust, T., & Bond, A. (2020). The difference between emergency remote teaching and online learning. *Educause Review, 27*, 1–12.

Läufer, T., Oehler, D.-X. K., Wetzel, S., & Ludwig, M. (2023). Mikrocontrollerprojekte: Unterrichtsrelevante Beispiele aus dem Digitechnikum. *MNU Journal 76*(2), 117–123.

Sibirskaya, E., Popkova, E., Oveshnikova, L. & Tarasova, I. (2019). Remote education vs traditional education based on effectiveness at the micro level and its connection to the level of development of macro-economic systems. *International Journal of Educational Management, 33*(3), 533–543.

Wetzel, S., & Ludwig, M. (2020). "Digitechnikum": A space to create meaningful CS projects. In T. Brinda, & M. Armoni (Eds.), WiPSCE '20: Proceedings of the 15th Workshop on Primary and Secondary Computing Education (pp. 34-1–34-2). ACM.

Zeinz, H. (2019). Digitalization and AI as Challenges and Chances for Future Teaching and Teacher Education: A Reflection. *Beijing International Review of Education, 1*(2-3), 427–442.