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Initiating the development of a pre-service teacher training course based on research on students' digital resource and teaching designs

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This paper reports an exploratory qualitative study conducted within the FLINK (German acronym for supporting learners for developing sustainable mathematics skills by using interactive materials) project in Austria. We present an overview of the study, its theoretical framework, initial findings from FLINK-based resource designs and the development of our TPACK-inspired professional development course focusing on assessing, designing, and implementing digital materials. Starting in the school year of 2021/22, all Austrian pupils in 5th and 6th grades will be equipped with digital devices. FLINK aims to support mathematics teachers in this digital transformation. In the pilot project, seven pre-service teachers participated in developing interactive, open-access learning and teaching resources for Austrian lower secondary mathematics courses, and initiated a design-based research project aiming to design a pre-service teacher training course within a masters program.

Keywords: Professional development, digital materials, technology integration.

Introduction

In Austria, digitalization in teaching and learning is becoming increasingly important especially due to impacts of the Covid-19 pandemic. The ministry of education reacted by providing a digital work environment for (lower) secondary schools (BMBWF, 2018). Since autumn 2021, most 5th and 6th grade students will be equipped with digital devices (laptops or tablets with a digital pen and keyboard). According to Clark-Wilson et al. (2020), one key issue for the successful integration of technology in mathematics classes is teacher training (TT). For example, in Uruguay *Plan Ceibal* (a government policy to provide a laptop for each student and teacher) revealed the need for TT programs to support teachers in the integration of digital devices for teaching and learning (Vitabar et al., 2019). However, identifying key factors for a sustainable TT, which have an impact on teachers' everyday lessons, is an ongoing research topic (Zehetmeier & Krainer, 2011).

The joint mathematics TT program at Johannes Kepler University (JKU) and colleges of education includes two courses on the use of technology in mathematics classes. However, these courses mainly focus on software skills, and they do not include the intense didactical feedback necessary to enable students' professional development in this field (Zehetmeier & Krainer, 2011). Research also suggests that it takes more time than often anticipated for teachers to gain enough confidence to use digital materials in teaching (Clark-Wilson & Hoyles, 2017). Supporting Austrian teachers' longer-term integration of digital materials into classroom teaching includes several phases of work. First, we aim to develop a pre-service TT course in our master program that focuses on designing and/or creating digital materials and the accompanying task design, which should enable students to select digital resources and plan for their use. The second important part of implementation into regular teaching will have to be addressed in a later phase as part of our long-term research plans.

Theoretical considerations

Technologies could support teachers' work in various ways, such as assisting the organization of teachers' work or offering new ways of communicating, connecting, sharing, and doing mathematics (Clark-Wilson et al., 2020). In this study, we focus on the role of technology as a new way to represent and learn mathematics and in particular on the digital materials to be used. With digital materials, we mainly utilize dynamic objects in GeoGebra that enable pupils to engage in dynamic interactions with the material and/or provide automated feedback. These objects are embedded in a GeoGebra-based online worksheet additionally comprising of further tasks or explanations for pupils. We chose this software as it: is an open-source mathematics software for educational purposes; allows an interactive combination of several semiotic representations of mathematical objects; and is widely employed in Austrian schools. Due to the age and grade of the pupils first equipped with technology and their limited experience with GeoGebra, we focus on material with pre-designed configurations.

After reviewing several possible alternative models, we selected Koehler and Mishra's (2009) TPACK model as the most appropriate framework. According to this model, teachers need to develop skills not only concerning technological, pedagogical, and mathematical knowledge but especially on the respective interactions of these themes. TPACK encompasses teachers' knowledge of challenges and changes in teaching when using technology, factors that make mathematical concepts easy or difficult to learn, ways to overcome learning difficulties by using technology, and the basis for a sound, meaningful teaching with technology (Koehler & Mishra, 2009). In the following, we interpret professional knowledge in the sense of the TPACK framework.

The TPACK model covers a wide variety of factors relevant for integrating technologies successfully into teaching, its latest version also includes teachers' knowledge *of* their sociocultural environments as contextual knowledge (Mishra, 2019). However, for designing pre-service TT, also sociocultural environments *in which* these skills are to be acquired should be considered. In terms of networking theories, we additionally utilize Goos' (2005) adaption of Valsiner's (1997) Zone theory to cover a broader range of possibly relevant factors to complement the TPACK model. Goos adapted the framework suitable for examining factors influencing teachers' use of technology in secondary mathematics classes. The zone of proximal development (ZPD) can be interpreted as the zone where (future) teachers can develop skills guided by more experienced persons, and the zone of free movement (ZFM) refers to environmental issues constraining a teacher's development (e.g., access to hardware). While the ZFM implies possible actions of future teachers, the zone of promoted action (ZPA) represents professional development (e.g., pre-service TT) which promotes their teaching practices. Considering the interplay of these zones, novice teachers' ZPA has to be within their ZFM, and promoted actions must be within a novice teacher's reach, that is within their ZPD (Goos, 2005). In sum, Zone theory and TPACK together provide a more holistic view on content-related, contextual, sociocultural, and individual factors relevant for implementing and researching a pre-service TT course focusing on technology integration in mathematics teaching.

FLINK – Digital materials design

Our exploratory study is situated within the FLINK project at JKU, which aims to provide mathematics teachers with digital materials to be used alongside mathematics textbooks. The pre-

designed interactive materials aim to support pupils' learning of mathematics and therefore focus on the following functionalities: (i) developing concepts and (ii) practicing skills (Drijvers, 2019). Teachers can implement specifically selected materials either during their lessons, or provide them for pupils' homework. A guiding objective in the design process is that each digital material offers a technology-added value compared to paper-and-pencil tasks, which means exploiting functionalities offered by technology such as: automated feedback; dynamic visualizations; or task randomization. For future materials, we also plan to examine the potential of technology for implementing more open-ended tasks, for instance tasks focusing on modelling or problem-solving.

Four mathematics teacher educators selected 18 high-achieving students (6th to 10th semester) enrolled in their university courses, seven of whom worked within FLINK project in July 2021 for an average of 28 hrs/week). These students designed digital materials for topics of grade 5 with a strong focus on the technology-added value. Their workflow is structured as follows: Firstly, students choose a particular small topic from the 5th grade curriculum. Then they work through a checklist (guided by an accompanying script), which requires students to summarize relevant information on their topic (e.g., literature research, learning goals, design ideas, and technology-added value). The script provides additional information for selecting and designing digital materials and for task design, in particular information about: the introduction of the mathematical topic in a learning sequence; the structure of finished materials; the use of language; and references to curriculum and mathematics educational literature. Students are required to analyse the chosen topic from a content-specific pedagogical perspective. Afterwards, they (re-)design digital materials and review their ideas together with an experienced teacher and teacher educator. This review and redesign process takes place two to three times. In parallel, the students discuss their ideas with an 'authoring team', which comprises those who implement their ideas in GeoGebra. Finally, the finished materials are reviewed again by another experienced teacher.

All materials currently completed can be found at www.geogebra.org/flink. One exemplary GeoGebra Book is *Fractions as part of a whole* (<https://www.geogebra.org/m/pge8d4x3>). Each book consists of digital materials for exploring mathematical concepts and practicing skills. The first part ('Entdecken') consists of interactive tasks about new concepts accompanied by guiding questions. The second part ('Üben') provides self-checking tasks with immediate responses, hints, prepared solutions, or new tasks at the push of a button. Figure 1 presents one task, where pupils must decide if a given fraction is coloured blue. They receive feedback (correct, false) and can choose the next task by pushing 'Neue Frage'. Furthermore, a counter displays the number of already correctly solved tasks.

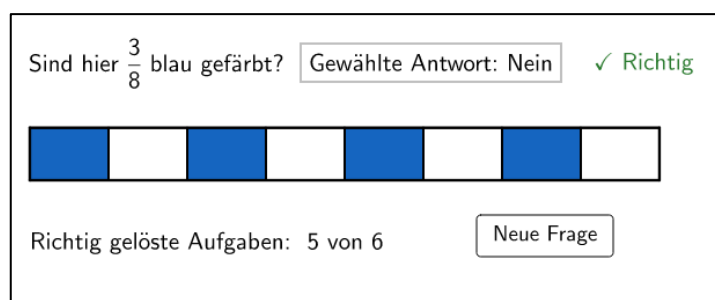


Figure 1: Task 'Can this be correct? – Level 2'

The project is framed by the following research questions: How can a pre-service TT course within a master program focusing on designing digital materials for lower secondary education support future teachers in (i) assessing the quality of digital materials, (ii) designing or (iii) implementing design

ideas with technology, and (iv) planning lessons integrating digital instructional materials? We concentrate on the master program because it offers opportunities for students to integrate their prior mathematical knowledge, mathematical content knowledge for teaching, pedagogical knowledge, and knowledge about technology integration acquired in their university courses and school internships. The above-described structure will be the starting point for the design of the TT course. Hereby, we currently have two major priorities: First, we consider it important to provide students with relevant literature-based information about technology-integration in school and to guide them in conducting an intensive literature research about the chosen topic in terms of relevant content knowledge for teaching (e.g., typical errors of pupils, options for visualizations). This should result in an awareness of relevant quality issues in the design and use of digital materials as for example outlined by Trgalova and Jahn (2013). Second, we want to implement a structural collaboration between students and more expert practitioners from mathematics education and technology implementation (Clark-Wilson & Hoyles, 2017).

Research design

From a long-term perspective, this study focuses on developing pre-service TT, thus integrating theoretical findings into practice. According to Cobb et al. (2003), design-based research (DBR) aims at developing domain-specific theories about learning with a designed learning environment and improving this environment by conducting an experiment in an iterative, hypothesis-driven way. DBR involves multiple cycles of hypothesis-based design of learning environments and aims at bridging the gap between practice and research. Therefore, DBR is suitable for our research questions.

For our first cycle, we selected an explorative qualitative approach (data collection by means of students' learning diaries and working notes). It aims to develop inductively a local theory about the development of the professional knowledge of the participating students, which should inform our deeper understanding of the processes involved, and relevant criteria for the design of a pre-service TT course - our *local theory* (Teppo, 2015). This first exploratory study of DBR intends to examine how the participants' self-assessed professional knowledge evolved according to the TPACK model. In addition, we plan to identify crucial – and missing – factors that are relevant for supporting students in assessing, designing, and creating digital materials with technology and thus important for designing a TT course. In this phase, we focus on the first three sub-questions of our research aim.

Preliminary results

In this section, we present exemplary analyses of data collected from FLINK project students' learning diaries over a period of approximately five weeks. Students were encouraged to self-assess the evolution of their TPACK knowledge over time, which factors were helpful and what additional kind of support they needed. Our data analysis followed thematic analysis coding procedures (Braun & Clarke, 2012), which revealed several themes. In this paper we concentrate on: evolving students' professional knowledge; supporting and constraining factors, and the changing beliefs of students.

Students' professional knowledge

The emerging themes span the TPACK model; however, the participating students highlighted especially their evolving knowledge in two fields: pedagogical content knowledge (PCK) and the

interaction between technological and pedagogical content knowledge (TPACK). This result also gives an account of the project structure, which focuses on students' intense work with mathematics educational literature.

Students' PCK includes: deepening understanding of PCK issues; how to enhance mathematical understanding for pupils; introducing mathematical topics in teaching; conceptualization in teaching, enhanced knowledge about typical pupils' errors and learning obstacles; topic-specific options for supporting pupils; and further topic-related themes. Most of the themes concentrate on a certain topic (e.g., typical errors when multiplying decimal numbers) but others cover more general aspects. Laura (all names are pseudonyms), for instance, noted:

Laura: Engaging with it [literature] opens new forms of conveying content. [21-08-16]

As the students' ideas are implemented in GeoGebra, one specific theme considers representation and visualization issues. Students discovered additional forms of representations (e.g., how to visualize rational numbers) and remembered rules for visualization (e.g., using various colours for visualizing a certain geometric object). Especially, they started to consider how related representations with technology and paper-and-pencil could interact; for example, Barbara's notes about possible representations of points or Flora's comment about the different representations of commas (in German as comma, in GeoGebra as dot).

Barbara: [Using] cross or point when constructing? Advantage of a cross: a compass can pierce it very accurately. Disadvantage of [using a] point: since it is quite large in GeoGebra, it could happen, that pupils draw thick 'dumplings' on paper. Therefore, ... points will be represented as a cross. [21-08-23]

Flora: GeoGebra does not recognize a comma as such, but one must enter a dot ... on paper, never dots but commas are made. [21-08-19]

Two further categories concerning PCK emerged from students' notes: language use and task design. We do not have space to expand on the theme task design, which obviously is an expected issue when designing materials. However, several comments revealed issues about language use, indicating the importance of this category, which included: the importance of formulating mathematically correct statements; using language precisely and sensibly; enhancing readability; and using inclusive wording (e.g., according to pupils' gender or cultural background). In addition, supported by an experienced teacher, students also evaluated inexact wording that occurs in schoolbooks. Here, one exemplary student comments about multiplication of decimal numbers, which reflects an expert's well-thought considerations:

Flora: Not the decimal point but the digits shift – [something] often described 'incorrectly' in schoolbooks. [21-08-06]

Finally, we discuss two technology-related knowledge categories: technology from a technical perspective and technology-related views on learning and teaching. The first category contains codes mainly concerned directly with the chosen software, its tools, and technical possibilities to implement students' materials ideas, which can be summed up as technology knowledge (TK) and technological content knowledge (TCK). The second theme relates to TPACK and mainly focuses on dynamic features and visualizations and especially on technology-added value (or limitations) of digital materials, which the following comments show:

Barbara: Dynamic visualization directly shows the effect of varying parameters. This can be very helpful for representations of solids or oblique projections. [21-08-05]

Julia: There are many tasks ... that can be carried out particularly well with digital technology because they contain direct feedback, solution paths, and new tasks. Also, the aspect of dynamic variation can be particularly helpful ... [21-08-03]

Furthermore, there are some tasks with more value if they are solved with non-digital means. For example, construction tasks in which children should use ruler and compass. [21-07-28]

Additionally, results reveal various themes representing quality issues for technology integration similar to those outlined by Trgalova and Jahn (2013) (e.g., design and presentation or technical aspects, didactical implementations), showing an increasing awareness of students towards quality aspects. To summarise, the data analysis results in a broad range of issues especially concerning students' PCK and TPACK, which indicates that the structure of FLINK project supports students' professional development and thus provides a profound starting point for organizing a TT course.

Supporting and constraining factors

Supporting factors most frequently mentioned are discussions with colleagues and reflecting and discussing their ideas with experienced teachers and teacher educators. Laura, for instance, wrote:

Laura: ... exchanging ideas with each other, being able to ask short questions. Sometimes, a short thought-provoking remark from a colleague is enough. [21-07-15]

Like Ida, all participating students highlighted the importance of discussing their ideas with experts:

Ida: I always find discussions with teachers ... particularly useful. It is helpful to discuss other thoughts, perspectives, and experiences on various topics. [21-07-29]

Further supporting factors are: studying schoolbooks and literature about mathematics education; researching existing digital materials; the provided accompanying script and checklist; and the students' prior knowledge. One student in particular mentioned that after reviewing content-specific literature, structuring her knowledge and ideas, proved to be helpful. This can be interpreted as one step of 'decompressing' mathematics to make it explicit for learners as mentioned by Clark-Wilson et al. (2020). These factors support elements of students' ZFM. As most of these factors – except student discussion – are already implemented in the structure of FLINK project, they also are part of their ZPA. A finding is that student discussions should be integrated in the planned pre-service course.

Finally, we discuss findings concerning the main constraints. As mentioned before, the participants mainly design digital materials and tasks and other students (authoring team) implement their ideas with GeoGebra (authors). While students find it supportive to discuss their ideas with the authors as suggested in the project structure, they highlight the need for earlier and more regular discussions:

Christina: To start planning digital materials, it would have been helpful to learn ... which ideas are implementable and which not, or what is particularly cumbersome and should be avoided, if possible, since I do not have so much experience with GeoGebra apart from basic knowledge. [21-08-04]

This theme indicates participants' missing TK and TCK, which only partly evolved in this project. Furthermore, it represents a constraining issue on students' ZFM, and there is a tension between students' ZPA and ZPD because designing the digital materials (promoted action) is not fully within

their reach (ZPD). Therefore, a further aim for designing a university course must be to provide a setting and structure to enlarge students' knowledge about implementing design ideas.

Beliefs and attitudes

Interestingly, before the project we did not consider how students' beliefs and attitudes may change in this project. Ida's comment about the value of intensive literature already indicates such change.

Ida: Before, I was not aware of how important it is to deal with mathematics educational literature to enable a topic for teaching to be prepared. [21-07-16]

In addition, Laura recorded after only two weeks:

Laura: The intensive study of digital implementation possibilities, its technology-added value, and, above all, the already implemented materials are constantly changing my mind and my attitude towards it. I can very well imagine using some of these materials in teaching myself. [21-07-15]

Data analysis revealed a change in: students' attitudes about how to approach a new topic for teaching; the value of the literature review to inform their PCK; and their beliefs about added value of technology integration in teaching. Furthermore, one student commented that she felt more secure about using digital materials in the classroom, even though she was yet to use them. From the perspective of Zone theory, beliefs and attitudes are part of the individual student's ZPD; therefore, such change is one factor for a possible successful technology integration in teaching and learning.

Discussion and conclusions

The results indicate that various factors implemented in the FLINK project's structure support students to develop their TPACK and thus provide a basis for a pre-service TT course. Supporting factors are among others: providing students with a checklist and script as guideline in the beginning; emphasizing literature review on the topic involved; and – most important – enabling regular discussions with experts (experienced teachers, teacher educators, and software experts). Based on these experiences, we could recommend common supervision by experienced teachers and mathematics educators, as they bring different perspectives into discussions: While students adopt the role of learners of technology used in teaching, the involved experts act as guides in the process of designing digital tasks. Furthermore, for each topic students should be encouraged to structure their ideas and knowledge about teaching mathematics (e.g., mathematical concepts, introductions, typical mistakes) and to formulate precise learning goals; the latter is something we introduced during the project as it helped students to focus on the intention of each digital material. One further major issue for us to consider in our study is how to deepen students' TK/TCK, possibly through collaboration with software experts. Finally, it seems crucial that the course structure enhances peer discussions, and it will be important how to embed these factors in a university course's time frame, which differs from this project in terms of structure and especially in the amount of time required.

Results indicate that students' knowledge mostly evolved concerning PCK and TPACK. Hence, it may be advisable to use the MPTK framework (Clark-Wilson et al., 2020) in our next research cycles as it takes a specific stance towards mathematics and also includes teachers' beliefs and attitudes. In addition, students' self-assessment of skills may not always correspond to their actual knowledge, a fact to be considered in the next phase. Furthermore, quality issues emerged during data analysis

implying that we already identified some crucial factors for a course design that supports students in assessing and designing digital materials and thus provides first answers to our research questions. Next we will concentrate on how to integrate the findings of this study into our master's program.

References

- Braun, V., & Clarke, V. (2012). Thematic analysis. In *APA handbook of research methods in psychology, Vol 2.* (pp. 57–71). American Psychological Association.
- Bundesministerium Bildung Wissenschaft und Forschung (BMBWF). (2018). *Masterplan Digitalisierung.* <https://www.bmbwf.gv.at/Ministerium/Presse/Masterplan-Digitalisierung.html>
- Clark-Wilson, A., & Hoyles, C. (2017). *Dynamic digital technologies for dynamic mathematics: Implications for teachers' knowledge and practice.* UCL Institute of Education Press.
- Clark-Wilson, A., Robutti, O., & Thomas, M. (2020). Teaching with digital technology. *ZDM Mathematics Education*, 52(7), 1223–1242. <https://doi.org/10.1007/s11858-020-01196-0>
- Cobb, P., Confrey, J., DiSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32(1), 9–13. <https://doi.org/10.3102/0013189X032001009>
- Drijvers, P. (2019). Head in the clouds, feet on the ground - A realistic view on using digital tools in mathematics education. In A. Büchter, M. Glade, R. Herold-Blasius, M. Klinger, F. Schacht, & P. Scherer (Eds.), *Vielfältige Zugänge zum Mathematikunterricht* (pp. 163–176). Springer.
- Goos, M. (2005). A sociocultural analysis of the development of pre-service and beginning teachers' pedagogical identities as users of technology. *Journal of Mathematics Teacher Education*, 8(1), 35–59. <https://doi.org/10.1007/s10857-005-0457-0>
- Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary Issues in Technology and Teacher Education*, 9(1), 60–70.
- Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *Journal of Digital Learning in Teacher Education*, 35(2), 76–78. <https://doi.org/10.1080/21532974.2019.1588611>
- Teppo, A. R. (2015). Grounded Theory Methods. In A. Bikner-Ahsbabs, C. Knipping, & N. Presmeg (Eds.), *Approaches to qualitative research in mathematics education* (pp. 3–21). Springer. https://doi.org/10.1007/978-94-017-9181-6_1
- Trgalova, J., & Jahn, A. P. (2013). Quality issue in the design and use of resources by mathematics teachers. *ZDM Mathematics Education*, 45(7), 973–986. <https://doi.org/10.1007/s11858-013-0525-3>
- Valsiner, J. (1997). *Culture and the development of children's action: A theory of human development* (2nd ed.). John Wiley & Sons.
- Vitabar, F., Lavicza, Z., & Hohenwarter, M. (2019). Developing professional development programmes with gamification for mathematics teachers in Uruguay. In U. T. Jankvist, M. van den Heuvel-Panhuizen, & M. Veldhuis (Eds.), *Proceedings of the 11th CERME* (pp. 3531–3538). Freudenthal Group & Freudenthal Institute, Utrecht University and ERME.
- Zehetmeier, S., & Krainer, K. (2011). Ways of promoting the sustainability of mathematics teachers' professional development. *ZDM Mathematics Education*, 43(6–7), 875–887. <https://doi.org/10.1007/s11858-011-0358-x>