



Volume 19, 2020

DESIGNING ONLINE LEARNING ENVIRONMENTS FOR FLIPPED APPROACHES IN PROFESSIONAL MATHEMATICS TEACHER DEVELOPMENT

Robert Weinhandl*	School of Education, Department of Mathematics Education, Johannes Kepler University, Linz, Austria	Robert.Weinhandl@gmail.com
Zsolt Lavicza	School of Education, Department of Mathematics Education, Johannes Kepler University, Linz, Austria	Lavicza@gmail.com
Tony Houghton	School of Education, Department of Mathematics Education, Johannes Kepler University, Linz, Austria	Ajh249@gmail.com

* Corresponding author

ABSTRACT

Aim/Purpose	Our research aims to explore which design elements and aspects of online learning environments are relevant for teachers when introduced to educational innovations such as flipped learning and, thereby, to enable facilitating the dissemination of these innovations.
Background	Integrating educational innovations from academic discourses or professional teacher development into teachers' classroom practices is challenging. Sustaining and reinforcing their effects on professional development is also difficult especially because of the lack of continuous support and inspiration for long term pedagogical changes. Online learning environments could facilitate such assistance, inspiration, and assist in developing supportive teacher communities. The current coronavirus pandemic and the associated homeschooling illustrate that supportive off- and online teacher communities and mutual support and inspiration of teachers will become increasingly significant, especially in virtual learning environments.

Accepting Editor Donna Jean Satterlee | Received: April 8, 2020 | Revised: May 30, June 8, 2020 | Accepted: June 9, 2020.

Cite as: Weinhandl, R., Lavicza, Z., & Houghton, T. (2020). Designing online learning environments for flipped approaches in professional mathematics teacher development. *Journal of Information Technology Education: Research*, 19, 315-337. <https://doi.org/10.28945/4573>

(CC BY-NC 4.0) This article is licensed to you under a [Creative Commons Attribution-NonCommercial 4.0 International License](https://creativecommons.org/licenses/by-nc/4.0/). When you copy and redistribute this paper in full or in part, you need to provide proper attribution to it to ensure that others can later locate this work (and to ensure that others do not accuse you of plagiarism). You may (and we encourage you to) adapt, remix, transform, and build upon the material for any non-commercial purposes. This license does not permit you to use this material for commercial purposes.

Methodology	To discover key elements and aspects of such learning environments, an online learning environment for flipped mathematics education was developed, and its application was investigated following design-based research principles.
Contribution	In this paper, specifications of design elements and aspects of our online learning environments for teachers embedded into flipped education and other educational innovations will be introduced.
Findings	The evaluation of the research data using grounded theory principles indicated that if online learning environments was to promote flipped approaches in mathematics education for teachers in our study the following categories were essential: (a) teachers want to be able to make decisions concerning online learning, (b) online learning environments should illustrate advantages of approaches/technologies as well as their practical relevance, (c) online learning environments should not lead to additional work for teachers, and (d) privacy and security of online learning environments.
Recommendations for Practitioners	Following results of our study, teachers should be provided with a variety of high-quality learning materials and opportunities for teachers to share their own learning materials through online learning environments in professional teacher development. However, when providing a variety of learning materials, course leaders should ensure not to overburden participants of professional teacher development.
Recommendations for Researchers	For researchers, it is necessary to verify results of our qualitative study quantitatively and to apply our results in other fields of online learning as well. Focusing on the contradictions between the visibility and dissemination of innovation through OLE and teachers' request for closed OLE could be fruitful.
Impact on Society	Results of our study could also have an impact on working lives as a whole, and not just schools or professional teacher development. The corona pandemic has increased the relevance of online working and related online learning for a growing part of our society. High-quality online learning environments could play important roles in this professional transformation.
Future Research	<p>Our consecutive research step will be, on the one hand, to explore how online learning environments and their elements could support teachers in their everyday professional lives and thus shifting our research focus from professional teacher development to teaching and learning mathematics in schools. On the other hand, our future research will focus on developing quality standards for learning materials for online learning environments.</p> <p>Furthermore, research should also be continued in regions and subjects with less favorable conditions. This enhancement of research setting should improve the generalizability of our results.</p>
Keywords	scaling-up innovations, professional teacher development, blended learning, mathematics teaching, online learning environments, flipped approaches

INTRODUCTION

Online learning environments (OLE) could become an important tool to facilitate the integration of educational innovations and 21st-century competencies into mathematics education. Seraji and Khodaveisi (2019) describe online learning environments as spaces created by using discursive,

adaptive, interactive, and reflective Internet tools. Goals of OLE include facilities to access numerous resources, to ease collaboration with other people, and to present ideas or learning outcomes more clearly. Furthermore, Robutti et al. (2016) summarized that online learning for mathematics teachers enables more in-depth face-to-face discussion, 24-hour support, and increased voluntary participation. In particular, the impact of COVID-19 on teaching and learning highlighted that these elements should be highly relevant for mathematics teachers in professional teacher development (PTD).

Flipped approaches (FA) are part of such educational innovations, and it has already been demonstrated that FA could have positive effects on mathematics education (Esperanza et al., 2016; Maciejewski, 2015). However, it was and still is questionable if access to educational innovations or technologies suffice to generate sustainable changes in everyday education (Artigue, 1998; Serdyukov, 2017). Hence, PTD could be crucial if educational innovations are to be integrated into learning and teaching in schools. Despite the potential of PTD, many experts (Amanatidis, 2014; Kuntze, 2006) criticize PTD for often having too short duration to produce sustainable changes in education, which could be especially true for mathematics and science education (Amedeker, 2018). To overcome these potential weaknesses of PTD, we have focused our study on using OLE in PTD courses. OLE provided an opportunity to extend the duration of our PTD and thereby might also increase potentials of educational innovations such as FA offer as well as lead to lasting changes in schools.

When combining OLE and PTD for FA in mathematics teaching in our study, we focused on teachers' needs concerning design elements of OLE. In this context, we focused our study on the following research questions:

- Which elements of OLE are crucial for teachers when they learn flipped approaches for their teaching?
- How should OLE be designed according to teachers' feedback to facilitate introducing flipped mathematics education to secondary teachers?

In order to classify the crucial design elements for OLE to enhance PTD for FA in mathematics teaching in our study, we will illustrate specifics of flipped approaches to learning and teaching mathematics as well as to professional teacher development.

FLIPPED APPROACHES IN MATHEMATICS EDUCATION

Education based on modern flipped approaches is a part of blended learning or more precisely a sub-model of the rotation model (Staker & Horn, 2012) and represents a synthesis of independent and technology-enhanced learning scenarios (Sureka et al., 2013). Learning and teaching according to flipped approaches is attracting increased interest both in schools and universities and in different disciplines (Muir & Geiger, 2016; O'Flaherty & Phillips, 2015), which is also reflected in associated scientific publications. (A GoogleScholar search on 21.01.2019 for the terms "Flipped Classroom" OR "Inverted Classroom" provided the following results: 2015: 5.400 - 2016: 6.900 - 2017: 8.290.) This interest in flipped education has not yet led to a uniform definition or description of flipped learning and teaching (Wolff & Chan, 2016), but some elements of flipped education could be found in most descriptions and definitions of this educational approach. According to Wasserman et al. (2015), flipped education has a characteristic so that direct instruction and passive learning happen outside of the classroom and in-class time is used for active and student-centered learning. Bergmann and Sams (2012), who can be seen as co-founders of 21st century flipped approaches, describe the functioning of flipped approaches by the following concept: "that which is traditionally done in class is now done at home, and that which is traditionally done as homework is now completed in class".

Galway et al. (2014) stated that when flipped approaches to education are utilized, lower levels of cognitive work take place in pre-class phases, and higher levels of cognitive work are tackled in in-class phases. These cognitively higher-level activities are often performed in lab-like environments according to Bergmann and Sams (2012) and can be described as inquiry or problem-solving activities. Consequently, teaching following FA principles requires that concepts of blended learning

should be considered and learning environments for self-learning (pre-class phase) and hands-on learning (in-class phase) should be developed by the teacher for students. For in-service teachers to develop knowledge and competencies to design such teaching and learning settings, specific forms of PTD could be beneficial.

Although flipped education can be considered much more than using video- or media-based learning (Tolks et al., 2016), additional modern technologies play an essential role in contemporary flipped education. There are often videos (García-Peñalvo et al., 2016; Muir & Geiger, 2016), e-books (Enfield, 2016) or other learning materials that are made available to students in pre-class phases of flipped education.

Another characteristic of FA requires active and knowledge-developing students (Bergmann & Sams, 2012; Galway et al., 2014), who also have a crucial role in modern mathematics teaching (Bell & Pape, 2012; Ngware et al., 2015). Active students, developing knowledge or using modern technologies when learning and teaching, also mean that the role of teachers should adapt to these circumstances. Lemmer (2013) and Butt (2014) describe the role of teachers in flipped education as coaches or guides in the classroom, who can support students when needed. Concerning mathematics education, Larsen (2017) and previously Tzur et al. (2001) stated that teachers are not just instructors, but the task of teachers should be to create learning environments and conditions so that students can practice mathematics fruitfully. Thus, extensive knowledge and competencies would be required for teachers to take on the role of guides or coaches providing tailored feedback or to take on the role of learning environment designers. To facilitate in-service teachers to learn and explore these diverse roles, OLE could be an appropriate supplement to face-to-face PTD. Regarding professional mathematics teacher developments for FA, Weinhandl et al. (2020) indicated in their study that learning by doing, sharing experiences, and expanding one's knowledge could be central activities in PTD courses. To facilitate implementing learning by doing, sharing experiences, and expanding one's knowledge in PTD, using OLE could be key. As explained by Seraji and Khodaveisi (2019) regarding online learning for teachers in general and summarized by Robutti et al. (2016) in relation to mathematics teachers, the specificities of OLE (simplified collaboration or increased participation) and PTD for FA (sharing experiences or learning by doing) could be a good match.

PROFESSIONAL TEACHER DEVELOPMENT

Selter et al. (2015) stress that professional teacher development (PTD) could be a crucial factor if innovations are to be integrated into everyday learning and teaching. However, not every PTD course automatically results in improved education, so it might be beneficial to consider the following aspects in PTD. For many years, experts (e.g., Amanatidis, 2014; Guo 2009; Kuntze, 2006) emphasized that each PTD course is attended by many teachers, and each teacher has rich knowledge and practical experiences. This knowledge of participating teachers should be seen as a promising basis of PTD courses and based on this, participating teachers should gain new knowledge and competencies in courses. However, integrating teachers' rich knowledge and practical experiences into PTD courses also requires a sufficient amount of time. Often, PTD courses are characterized as too short, so that teachers can neither contribute their own knowledge and experience nor benefit from knowledge and experiences of other colleagues. Therefore, our study sought ways to overcome potentially problematic lack of time. This overcoming of the time problem and thus facilitating collaboration among teachers could be especially critical for FA in PTD (Weinhandl et al., 2020). Following Seraji and Khodaveisi (2019), integrating OLE into PTD for FA that facilitates and fosters this collaboration between teachers could be highly beneficial.

Real and concrete educational problems, which occur in everyday teaching, are closely connected to the knowledge and practical experiences of participating teachers in PTD. According to many experts (e.g., Asikin et al., 2018; Maxwell, 2010; Weinhandl et al., 2020), such real and concrete problems should be an essential element of PTD courses. Real and concrete educational problems also imply that concrete examples of how to utilize technologies or educational approaches should be tackled in

PTD and that in this process the questions “how to use” and “why to use” new technologies or approaches should be addressed (Amanatidis, 2014; Kuntze, 2006). OLE are one way among others to integrate several resources and prototypical examples to FA in PTD (Seraji & Khodaveisi, 2019) and thereby address the questions posed above.

Kong et al. (2017) and Kramarski and Revach (2009) emphasized the significance of practical relevance and practice transfer at PTD for innovative and technology-enhanced learning approaches. In order to be able to integrate real and concrete educational problems and related concrete examples into PTD courses, one-off PTD courses should offer opportunities to use the concrete examples and to exchange experiences with colleagues regarding the real use of these examples. To facilitate this transfer of knowledge and competencies from theory to practice in PTD courses, this approach could be promising to enhance PTD courses.

In addition to practical applications of content taught in PTD courses, the duration and structure of a PTD could be decisive for the success of teacher education. With regard to the duration of PTD courses, it is noted that the courses are usually too short to produce noticeable and sustainable improvements in practice (Aldorf, 2016; Amanatidis 2014; Kuntze, 2006). Enhancing PTD by utilizing OLE could be one way to mitigate this time issue.

As OLE have the potential to improve PTD for FA in mathematics education, our study aims to explore how OLE should be designed, so that OLE could facilitate PTD courses in disseminating educational innovations and technology-enhanced approaches such as FA.

THEORETICAL BACKGROUND

As we aim to explore in our study how OLE should be designed to facilitate the dissemination of educational innovations, online teacher training and scaling-up are the two pillars of our theoretical background. The elements of the theoretical background also provide the framework for our research design and are therefore crucial to achieving our research goal.

ONLINE TEACHER TRAINING

Using OLE could have the potential to improve learning in a number of ways. For example, Gündüz et al. (2016) showed that combining active and problem-based learning and OLE have the potential to improve learning outcomes and confidence of learners. Evens et al. (2017) demonstrated in their study that using OLE in teacher education has a positive effect on developing or improving pedagogical content knowledge (PCK) and pedagogical knowledge (PK). PCK and PK could be of particular relevance in PTD for FA in mathematics teaching, as teachers should search or develop learning resources for individual learning periods and integrate these resources into a didactic framework. In addition, teachers should also develop in-class learning environments in which students can engage hands-on with new mathematical concepts. Online or digital education has a long tradition in professional teacher development (PTD) as it was first introduced in the 1990s. Online PTD was described as telematics-based learning in the 1990s and was considered a sub-area of lifelong learning (Kolos, 2002). Guo (2009) explains that teachers have a favorable opinion and attitude towards online PTD in general. Kamakari and Drigas (2010) add that teachers even prefer distance or online assisted learning over face-to-face learning. This positive description of online PTD is diminished by Potgieter (2004), explaining that online PTD has both positive and negative elements, but should not replace face-to-face training entirely. Kynigos and Kalogeria (2012) are more specific about positive and negative elements of OLE in PTD: A positive aspect of online PTD is that it is only slightly dependent on time or local circumstances. OLE for teachers could provide a variety of teaching and learning materials that could be accessed from almost anywhere. As far as disadvantages connected to online PTD are concerned, face-to-face learning might be reduced or entirely eliminated. However, this face-to-face learning time would be essential to build a community of teachers who participate in courses (Kynigos & Kalogeria, 2012). This importance of communities in PTD was also

highlighted by Czerkawski and Lyman (2016) and Weidlich and Bastiaens (2019) as a key design element of online distance learning. Interaction, cooperation, or feedback approaches as well as socio-emotional design aspects could be key to the success of online distance learning environments, but these design elements are often difficult to realize in practice.

Even though information and communication technologies are increasingly ubiquitous innovations that are used at all levels of education, it should not be forgotten when designing OLE that principles of learning and how to facilitate learning have not fundamentally changed (Evens et al., 2017).

A prominent design element of OLE is that learning materials can be used from different sources (Huda et al., 2017), and thus, multimedia-presented cases of content can be integrated into learning environments (vanOostveen et al., 2019). Here, vanOostveen et al. (2019) emphasized that OLE should not be only objectivistic, which would imply merely using more resources to deliver content. When integrating more resources and more technologies into OLE, Gündüz et al. (2016) emphasize using existing means that are familiar to participants to minimize an extra workload when using OLE.

The increasing amounts of resources and opportunities for OLE should enable participants to explore content (Huda et al., 2017) and also contribute to participants becoming active (Gündüz et al., 2016). Active participants imply, among other things, that tasks are solved, and, according to Evens et al. (2017), using authentic tasks and real-life cases could help to promote the integration of knowledge and skills in OLE. In order to improve the transfer to practice, vanOostveen et al. (2019) advocate that teachers should be enabled to use new pedagogical approaches in OLE. Through this use of new pedagogical approaches, learners of OLE (in our case teachers) become producers of knowledge and competencies. OLE should support the participants in this production of knowledge and competencies to collaborate, communicate, and debate, and thereby facilitate social networking.

The notion of teachers as knowledge producers and promoting social networking through OLE indicates that elements of constructivism and social constructivism are essential in designing and developing OLE. Following Euler (2001), Gräsel et al. (1997), and Koohang et al. (2009), learning by constructivist approaches intends that knowledge is developed through hands-on activities and that new knowledge depends on existing knowledge and experience and needs to be embedded into this network. When learning following constructivist approaches, it is vital that learning processes are triggered by real-world and, therefore, complex problems. Utilizing social constructivist approaches, this development of knowledge is particularly fruitful when it happens together with peers (Vygotsky, 1978) in a collaborative process of conjectures and refutations (Popper, 1963).

Thus, features of the design elements of successful OLE present a good match with online mathematics teacher development (Robutti et al., 2016) as well as with PTD for FA in mathematics (Weinhandl et al., 2020).

Our research focuses on investigating how OLE in PTD courses could exploit their best potentials while minimizing any negative side effects. In order to assess the potentials of OLE in PTD courses and to minimize side effects, we decided to consider OLE as an extension of PTD courses. Thus, our study aimed to examine how OLE should be designed as an extension of PTD courses for FA in mathematics teaching reflecting on teachers' needs and thereby facilitating disseminating educational innovations.

SCALING-UP THROUGH ONLINE LEARNING ENVIRONMENTS

Our online learning environment experiment contributes to the potentials to scale-up educational innovations like flipped education approaches. According to Cobb and Smith (2008), scaling-up educational innovations requires that educational innovations proved to be successful on a small scale and this success could be repeated on a larger scale, i.e., high number of classrooms.

Since Esperanza et al. (2016) could demonstrate that teaching and learning mathematics with FA could have a positive impact on students' achievements and student attitudes towards mathematics, flipped approaches in mathematics education qualify for a scaling-up process. According to Selter et al. (2015), it could be professional teacher development that supports educational innovations making their way into classrooms. However, Cobb and Smith (2008) highlight that PTD does not automatically lead to scaling-up of educational innovations. Therefore, PTD is often a necessary, but not sufficient condition for scaling-up. As educational innovations often involve changing teaching methods or the role of teachers, extensive PTD is required before educational innovations can manifest themselves in everyday school practices. This period could be supported by extending PTD with online learning courses.

According to Krainer et al. (2018), scaling-up is a complex process that could take place at the individual, local, regional, and national levels. Through our online learning environment experiment and through our digital extension of PTD, we focus on scaling-up at individual and local levels. According to Krainer et al. (2018), teachers should be given particular attention if learning and teaching are to be further developed. However, knowledge and competencies cannot easily be transmitted from teacher trainers or researchers to teachers, which applies, in general, to innovations in mathematics education (Krainer et al., 2018) and in particular to flipped mathematics education (Weinhandl & Lavicza, 2018).

Since teachers are at the center of innovation dissemination and motivated teachers are key to disseminate innovation in practice, there should be a balance to mix top-down and bottom-up approaches for educational innovation (Krainer et al., 2018). Our online learning environment should support teachers as they try to disseminate educational innovations in a bottom-up way.

In order to scale up or distribute innovations, Cobb and Smith (2008) stated that networks, shared vision, and mutual accountability should be established among stakeholders. Similarly, implementing a set of new tools or a set of coherent strategies, designed for practical use and adaptable to the framework of the respective educational settings, could be central to scaling up or distributing innovation in mathematics education (Cobb & Smith, 2008). Therefore, design elements of a fruitful OLE, as well as the specifics of online mathematics teacher development (Robutti et al., 2016) and PTD for FA in mathematics (Weinhandl et al., 2020), should provide a useful framework for scaling-up or distributing innovations.

Many of these strategies of scaling-up or distributing innovations can be traced back to Rogers (2003) and his five characteristics of adaptation rates of innovations. Of these five characteristics of innovation adoption rates, three characteristics are of particular importance for OLE in PTD and, therefore, of particular relevance for our study: *Relative advantage*, *Trialability*, and *Observability*. *Relative advantage* includes advantages perceived through innovations, *Trialability* implies that innovation can be tested, and *Observability* implies that innovations that are visible to other people and institutions are more likely to be accepted.

According to Kuntze (2006), the first implementations of an educational innovation into teaching are crucial, as the first implementations of new approaches or technologies could lead to a decline in the performance of teachers and students. In this crucial and at the same time vulnerable phase of innovation dissemination, teachers would need special support until a higher level of competencies and familiarity with innovation is reached.

RESEARCH DESIGN AND METHODOLOGICAL FRAMEWORK

In order to explore our research questions, an online learning environment was developed, piloted, and utilized in practice. All these research steps have been investigated following grounded theory approaches offering findings on key elements and crucial design principles of OLE in PTD.

RESEARCH DESIGN AND SAMPLE

To discover how to design online learning which could enhance professional development, an online learning environment for flipped approaches (FA) in mathematics education was developed to support teachers who would like to conduct flipped education experiments. The first design of our online learning environment was based on current literature (see Theoretical framework, Online teacher training). From the completion of our online learning environment, our online learning environment was made available to teachers for review and piloting. Teachers participating in this phase of our study were informed that interviews would be conducted after the review period.

When selecting teachers for reviewing our online learning environment, only those teachers were considered who had positive attitudes towards teaching and learning with new technologies. Teachers with positive attitudes towards using technologies in mathematics teaching were defined as those who had participated in advanced PTD courses for mathematics teaching, who were members of networks utilizing technologies in mathematics teaching, or teachers in whose schools had technology focus and who had leading roles in this respect. By considering teachers with positive attitudes towards education with new technologies, we were aiming to ensure that teachers' feedback on our online learning environment related to individual elements of the learning environment and did not fundamentally question technologies in education.

In order to increase the number of participants in our online learning environment experiment, a snowball system was used. Thus, participating teachers named other colleagues whose attitude towards technologies in education was considered similarly positive. Since the goal of using a snowball system was to find teachers to review our pilot phase, only a few cycles of the snowballing were utilized. By applying this system, a total of 12 teachers participated in our online learning environment experiment as critics and reviewers of our online learning environment.

Our semi structured interviews focused on the following: (1) Which elements of our online learning environment are supportive if one wants to get information about flipped approaches in mathematics teaching? (2) Which elements of our online learning environment are troublesome if one wants to get information about flipped approaches in mathematics teaching? (3) Which elements of our online learning environment are practical and could be easily and quickly integrated into everyday teaching? and (4) Which elements are missing in our online learning environment so that transferring of online learning environment's contents into school practice would be made possible or facilitated? Interviews lasted from 12 to 31 minutes and were conducted at teachers' workplaces or in private environments or online.

After developing and initially piloting our online learning environment by in-service teachers, our online learning environment was utilized in professional teacher development courses and *educational practice* (EP) courses. In Austria, beginning teachers must attend courses in subject didactics, general didactics and school law during their first year of service. This set of courses is called EP courses. In PTD and EP courses, our online learning environment was used in the courses supplementing lectures and presentations as well as before courses for teachers to prepare themselves. Our online learning environment was also available to teachers participating in PTD or EP after the courses, which was communicated to the participating teachers at the beginning of the training. Teachers in PTD as well as in EP courses were included into our study so that perspectives of experienced (PTD) and beginning (EP) teachers could be taken into account in identifying vital design elements for online learning environments (OLE) for FA.

After the courses, participating teachers were asked to provide written or oral feedback on our online learning environment. In order to encourage teachers to participate in the feedback process and thus obtain substantial feedback received, the guiding questions were kept general and open: (1) What was positive about the OLE and helped while learning or working? (2) What was negative about the OLE and made learning or working more difficult? and (3) What additional elements or features of the OLE could facilitate your learning process?

A total of 12 teachers participated as reviewers of our online learning environment, 78 teachers participated in our four educational practice courses, and 46 teachers in three PTD courses. Among the reviewers there were five women and seven men; the youngest was 27 years old, and the oldest was 51 years old. The majority of the teachers in the EP courses were between 24 and 26 years old. Three beginner teachers, for whom it was their second professional career, were over 30 years old. There was a female dominance among the beginner teachers in EP courses: almost 70% of the EP course participants were female, slightly more than 30% were male. Teachers in the PTD courses were between their early 30s and early 60s and thus covered the entire age spectrum of teachers. There was a concentration of teachers in their 50s, which corresponds to the overall demography of teachers in Austria (Bildungsbericht 2018, 2019). Out of the participating teachers in PTD courses, 28 were women and 18 men.

Excerpts from the interviews and feedback in the *Results* section were translated from German into English.

RESEARCH TOOLS

Design-based research (DBR) was applied as our research was situated in real educational contexts, and real problems and desires of individual teachers were investigated; many experts (e.g., Anderson & Shattuck, 2012; Barab & Squire, 2004; Cobb et al., 2003) consider utilizing DBR to be appropriate. Another reason for using DBR is that teaching and learning are highly complex activities for which to create reproducible laboratory conditions (Reinmann, 2005), which could become even more challenging when integrating technologies.

Another reason for choosing design-based approaches is that according to Reinmann (2005), a central question of DBR is how to adopt new possibilities to a given context and how to develop and improve new insights through this adaptation process. Generating knowledge through an adaptation process is one of the aims of our research and certain elements of OLE could be changed quickly and separately. Since our research activity lasted 16 months, investigating the effects of our adaptations of elements of our online learning environment was facilitated. According to Annetta et al. (2013), by applying and studying our online learning environment design over a more extended period, we should be able to both improve our online design and develop and improve related learning theories.

In order to improve our design and to develop learning theories about OLE for PTD courses, we continuously collected and evaluated data and implemented results into the design of our online learning environment (see Figure 1). According to McKenney and Reeves (2013) and Reinmann (2005), this small-step approach to adapt design elements and generate knowledge is intended to facilitate achieving practical and theoretical insights, improve the design, and sustain it in real educational contexts.

Phases of OLE design with different elements of each phase

Pilot phase

General information and information regarding pre-class phases and in-class phases regarding flipped classroom teaching are provided in written form.

Videos by other researchers and teachers are used to present general information about the flipped classroom method.

Lesson plans for flipped mathematics lessons are made available for download in written form as a pdf.

Participants can add their experiences to individual contributions via the commentary function.

The PTD instructor can be contacted via e-mail and telephone.

First application and modifications or extension to the pilot phase

General information and information regarding pre-class phases and in-class phases flipped classroom regarding flipped classroom teaching are subdivided into more detailed sections. Each information contribution is divided into two parts: Short initial information box about a topic is always visible on the website, on-demand this information box can be extended.

Subpages are created for -) general information, -) pre-class phases and -) in-class phases.

The number of information videos is extended from three to seven.

Second application and change or extension to the first application

A collection of educational videos and other online learning resources for pre-class phases is made available through the website; subdivided by grade level.

Information videos on Flipped Classroom teaching are created by the researchers / PTD instructor - these videos replace the videos of the pilot phase. The new learning videos address the specific features of the educational setting of our study.

The number of lesson plans is expanded, and links to online learning resources are also provided. Slack is integrated into the online learning environment as a communication tool. Teachers can access a Slack room for communication and sharing of their examples.

Third application and modification or extension to the second application

There is a finer division of the learning videos. The videos for pre-class phases are structured by grade level (second application) but now also by topic.

The number of lesson plans is extended, and the lesson plans are available for teachers to download as pdf and MS Word documents. This allows teachers to change the lesson plans and adapt them to the conditions of their school location.

The slack room is closed for the public (only accessible via password,) and one new slack room is opened per PTD course.

Last application and change or extension to third application

Learning videos for pre-class phases are structured and hidden per grade level and then per topic. Only by clicking on the grade and then on the topic, the videos become visible.

The number of lesson plans is increased, and lesson plans are structured and hidden per grade level and then per topic. By clicking on the grade and then on the topic, the lesson plans become visible.

Standards for independently selecting learning materials are developed and made available in written form and via video.

Figure 1. The different phases of our online learning environment

The framework conditions – i.e., using an online learning environment and instructional approach in courses – were maintained during each cycle of our design-based experiment and research, contributing to generalizability of our results (Barab & Squire, 2004; Baumgartner et al., 2003; McKenney & Reeves, 2013). Collecting and evaluating data in our design-based research consisted of several methods (design-based research, action research, and grounded theory approaches) and research tools and techniques (open and closed written feedback, interviews, and observations). According to numerous experts (e.g., Anderson & Shattuck, 2012; Hakkarainen, 2009; McKenney & Reeves, 2013) utilizing a

variety of methods and research tools should contribute to better analyses of data and more in-depth findings.

RESEARCH PROCEDURES

When analyzing our data and thus designing the teacher-centered aspects of OLE for FA mathematics teaching, we utilized principles of grounded theory (GT). We followed constructivist GT approaches (Charmaz, 2006). Constructivist GT approaches presume that the research and results depend on researchers of a study and backgrounds and beliefs of researchers. This interpretation of GT was necessary for our study because the initial design of our online learning environment and then its further development also depended on our experiences as secondary and university teachers and PTD course instructors. While generating the teacher-centered aspects of OLE for FA mathematics teaching, we used the coding principles of GT, namely, open coding, axial coding, and selective coding. In coding our data and generating the central aspects, we followed the theoretical and practical contributions of Charmaz (2006), Mey and Muck (2011), and Breuer et al. (2009).

Table 1. Codes of the coding process and essential aspects of OLE

initial open codes	open codes of a higher level of abstraction	essential aspects of OLE
Deterrence • <i>concerning online materials</i> • <i>concerning student-driven approach</i> Materials on the OLE • <i>meta-info</i> • <i>ready to use</i> • <i>quality</i> • <i>quantity</i>	Deterrence of the new Adjustability of materials on the OLE Concrete examples Online collaboration and confidence	teachers want to be able to make decisions concerning online learning online learning environments should illustrate advantages of an approach/technologies as well as their practical relevance
Text • <i>of explanatory video</i> • <i>on the learning environment</i> • <i>quantity</i> • <i>language</i>	Means for students' assessment Collection of material for use Highlighting benefits for teachers	online learning environments should not lead to additional work for teachers
Theory • <i>mathematics</i> • <i>practice / everyday teaching</i> • <i>technologies</i>	Practical relevance of technologies / approach Technical language	privacy and security of online learning environments

The open coding aimed at breaking up the newly collected data and generating first units of meaning. In order to generate the first units of meaning, the questions *what*, *how*, and *why* were asked of the data. The initial open codes (Table 1, left column) were then compared in terms of definitions, descriptions, and concrete text passages of the data and similar initial open codes were combined and provided with new keywords. This merging of first open codes led to open codes of a higher level of abstraction (Table 1, middle column). These codes of a higher level of abstraction were then used for axial coding. The axial coding was intended to re-establish a synthesis of the fragmented data. In order to achieve this synthesis of the fragmented data, open codes of a higher level of abstraction were arranged according to the tripartition *cause*, *activity*, and *consequence* around one central *phenomenon* (see Figure 2). First central aspects could be derived by paying particular attention to the codes of the area of activity and combining these codes.

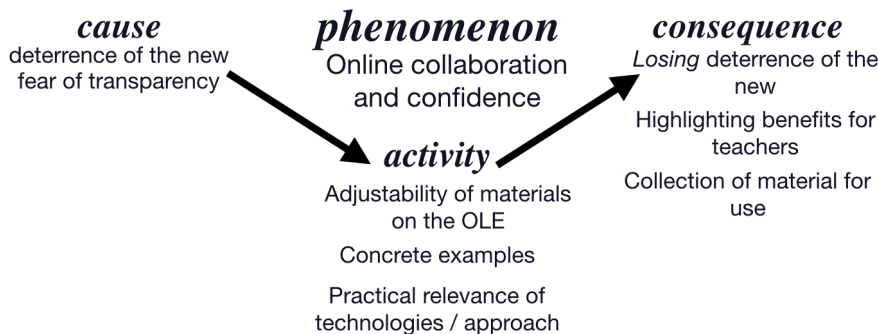


Figure 2. Prototype procedure for axial coding

These first central aspects were then connected during selective coding, and dependencies and properties of the central aspects were developed. Selective coding led to the aspects discussed in the Results section.

RESULTS

The analysis and elaboration of our data indicate that four aspects of OLE for flipped mathematics education are essential to teachers – namely, (a) teachers want to be able to make decisions concerning online learning; (b) online learning environments should illustrate advantages of an approach/technologies as well as their practical relevance; (c) online learning environments should not lead to additional work for teachers; and (d) privacy and security of online learning environments. In the following sections, the individual categories are described in more detail. The quotes from teachers' feedback given in the *Results* section is accompanied by the information whether the feedback was given in the pilot phase [P] or the application phase [A], whether the feedback was given in writing [w] or orally [o] and whether the teachers were experienced [E] or beginners [B].

TEACHERS WANT TO BE ABLE TO MAKE DECISIONS CONCERNING ONLINE LEARNING

Making decisions refers, on the one hand, to how to receive information and theory and, on the other hand, how to work with examples and practices.

When conveying information and theory, it was vital for teachers that the core of our online learning environment – flipped mathematics education – could be quickly and easily recognized. Recognizing the core of OLE means that users of OLE are informed concisely about the goals concerning the presented content and how these goals should be achieved.

[P-o-E] *The good thing about the videos [on our online learning environment] is that there is no long pedagogical blah blah and that he [the designer] gets right to the point*

When information and theory is presented on OLE, it becomes apparent in general that teachers want to choose their information transfer channel. This is particularly the case when a first contact is made about theoretical aspects. Teachers cited videos or texts (see Figure 3) as their preferred media when the first information about new content is provided.

[A-o-B] [...] *I rather like watching videos and let it [content] be told to me*

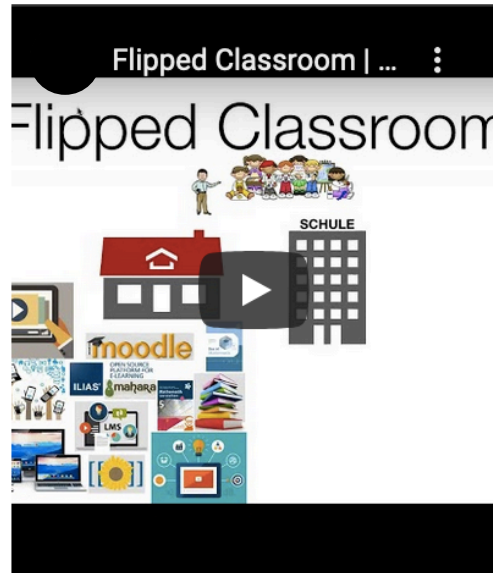
[A-o-B] [...] *I prefer text because I can jump to the interesting sections and skim the other ones*

Flipped Classroom | Wie funktioniert das?

Die eine oder die richtige Definition des Flipped Classroom Unterrichts gibt es nicht – aber folgende Charakteristika finden sich in den meisten Beschreibungen und Anwendungen der Flipped Classroom Methode: Die Schüler/innen eignen sich selbstständig Basiswissen mithilfe von Lernmaterialien bereits vor den Präsenzeinheiten an. In der Klasse, sprich im Klassenverband, wird dieses Wissen angewendet und vertieft. Hierdurch entsteht eine Lernspirale, die zu nachhaltigem sowie flexibel anwendbarem Wissen und Kompetenzen führen soll.

Flipped Classroom | Wie funktioniert das?

Video | Flipped Classroom, aber wie?



**Figure 3. Extract from our OLE for FA:
Teachers can decide whether to consume information via text or video**

For both videos and texts, it was important for users to get to the point quickly and easily. Getting to the point quickly and easily means that both videos and texts use a simple language and that the information packages are clear and complete.

[A-w-E] Videos were not too long and above all understandable –you did not have to google every second word

Another aspect that was relevant to users of our online learning environment in the category “Teachers want to be able to make decisions concerning online learning” is further information about theoretical elements of online learning environments’ content (see Figure 5). It is important to the teachers participating in our research that if there is interest, they can quickly obtain additional information on selected parts of the theoretical content of our online learning environment.

[A-w-E] It was good that there were also links to other sites you could have a look at

The category “Teachers want to be able to make decisions concerning online learning” refers not only to theoretical elements of our online learning environment, but also to practical elements and concrete examples of flipped mathematics education. Concerning concrete examples on OLE, research data indicated that the number of examples was double-edged and a considerable challenge (see Figure 4). On the one hand, teachers wanted a manageable and small number of examples to be made available so that teachers were not overwhelmed. On the other hand, teachers wanted a rich and varied range of examples so that they could decide for themselves which examples they wanted to explore and use.

[P-o-E] You open it [collection of material], and you are slain.

[A-o-E] I find the collection of material and the examples are very successful and helpful – really impressive

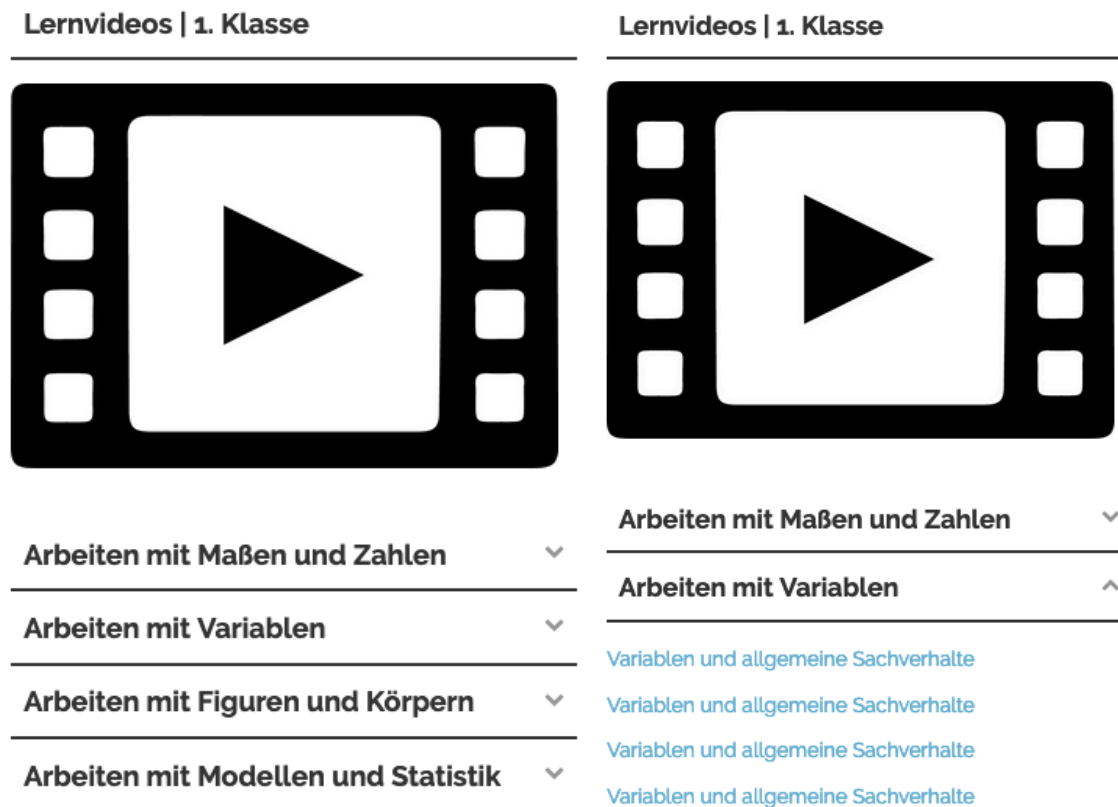


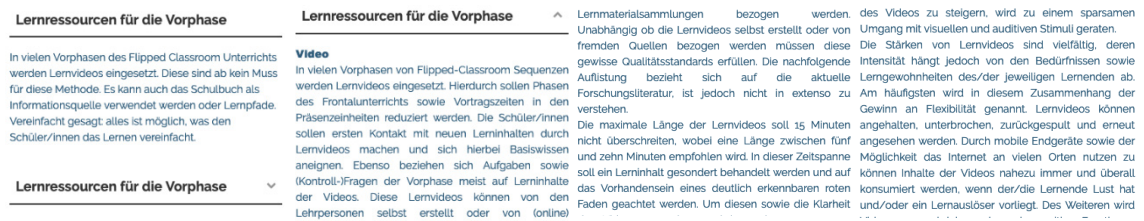
Figure 4. Thematic overview (left) and, after clicking on a topic, links to tutorial videos (right)

In addition to the amount and choices of examples, it was important to teachers of our research that the offered examples or parts of examples could be changed and exchanged. Changeable examples imply that teachers wanted elements of teaching materials for pre-class phases (videos, texts, or tasks) and in-class activities (to be calculated examples or real-world problems) to be adaptable to teaching situations and frameworks of their school or classes.

[A-w-E] It is good that you can also change certain things [about the examples] and so you are able to try them out [in lessons]

The last aspect that concerned with the category “Teachers want to be able to make decisions concerning online learning” was the navigation of OLE. Analyzing the data indicated that different teachers had different approaches to OLE and therefore to new content. The different approaches could be divided into two categories: from theory to practice or through practice to theory. Regardless of the approach chosen, it was important to teachers that they could freely move back and forth between the elements of our online learning environment and that our learning environment did not dictate either the learning path or the learning intensity.

[A-o-B] If you want you can also read through the long text [fold-out text after a summary] and if not, then you could also move on immediately



**Figure 5. Left: Short summary of the topic and link to more information
Middle and right: Excerpts from detailed information after clicking on the link**

ONLINE LEARNING ENVIRONMENTS SHOULD ILLUSTRATE THE ADVANTAGES OF AN APPROACH/TECHNOLOGIES AS WELL AS THEIR PRACTICAL RELEVANCE

According to our data analyses, a crucial factor for the success of OLE could be that, after a short time of using OLE, teachers could realize benefits of the presented content and how learning and teachers could benefit from the content. The benefits should be conveyed both in a theoretical or general manner (through videos or texts) and in a particular manner (through examples). The explanations of the advantages should not only be general but should also refer to the subject (mathematics).

[P-o-E] [...] to emphasize the subject orientation, this is important – that the reference to mathematics is clear

If advantages of presented content are conveyed concretely through examples, it is of great importance, according to the teachers of our research, that top examples and materials are used. Top examples and materials mean that examples are “ready to use” and could be incorporated immediately into everyday teaching. By using examples of OLE in everyday teaching situations, OLE should also facilitate teachers to link theory and practice of to be learned content.

[P-o-E] [For the designer of an OLE] it is important to pay attention to the quality of the materials – only choose materials that are really top quality, and that could be used in class.

In addition to demonstrating the benefits of an approach or technologies through OLE, it could also be crucial that teachers quickly and effortlessly recognize which and how many benefits have already been reached through OLE. In order to quickly and easily identify a user’s progress in OLE, teachers from our research have argued that OLE should provide a tool that reflects which elements of OLE have already been covered or resolved and which elements are still to be discovered. This tool for reflecting learning progress could also increase teachers’ motivation.

[A-o-B] I appreciate at other pages that you can see what you have already done – when you have one of those bars that fill up more and more.

PRIVACY AND SECURITY OF ONLINE LEARNING ENVIRONMENTS

Security of OLE was also an important concern of teachers who participated in our research, and in many cases security was cited as a crucial factor which could influence whether or how OLE would be used in everyday school life. Security of OLE could be divided into two aspects. (1) It was important for teachers to know who has access to the content and examples provided. The critical question was whether parents or students could also access the content of our online learning environment.

[A-o-E] The first question for me would be, is this platform basically open for teachers only or can pupils access it, too?

(2) An essential aspect regarding the security of OLE is concerned with the communication between users and sharing of their own teaching materials. In general, many teachers had advocated opportunities for interaction and sharing of experiences and examples in OLE when security could be provided.

[A-w-E] It would be great to have a folder where we, those who are in practice, can exchange our flipped classroom lesson plans.

Concerning sharing of experiences and examples, it was even more important for teachers of our research to know who the members of OLE were and therefore knowing people who could participate in communication and had access to shared content. According to users' feedback, it might facilitate sharing content if you know the other users of closed OLE personally.

[A-o-B] somehow it would be strange sharing your own teaching materials with strangers

Both in the area of general access to OLE and terms of communication and sharing of examples, we discovered that the smaller the number of people participating and the better members of OLE know each other, the more comfortable many teachers feel.

ONLINE LEARNING ENVIRONMENTS SHOULD NOT LEAD TO ADDITIONAL WORK FOR TEACHERS

It should be remembered that OLE was often utilized in PTD courses or other continuing education contexts. Professional teacher development or training also involved additional work in teachers' private and professional everyday lives. For this reason, it was important to teachers in our research that OLE did not give impressions of additional workload.

[A-w-B] You see the page – so many materials, so much work, and you do not know where to start.

Additional workload in OLE was related to both the content and the design of OLE. Concerning the design of OLE, it was vital to the users of our research that the first impression of OLE did not suggest extra work and that navigation and orientation did not cause additional effort.

[P-o-E] [...] and if you then click on a link, you are on another page, and it takes a long time until you are back again [there where you started]

Teachers wanted a straightforward design and OLE that quickly got its message across.

[A-o-E] [...] good that you can see on the pages [of the OLE] what it is all about

Although feedback from teachers of our study regarding the design of our online learning environment was not explicitly focused on mathematics education or flipped approaches, the frequency of the feedback and emotionality associated with design and related additional work of our online learning environment indicated that design principles are critical elements of OLE which are used in professional teacher development.

DISCUSSION

Our research aimed to discover crucial elements and design principles of OLE for flipped approaches in mathematics education and, thereby, facilitate the dissemination of educational innovations. One crucial element of OLE for teachers participating in our research was that they could decide for themselves how information was to be consumed. The type of information consumption refers to the fact that teachers could choose whether or not to use videos or texts or both as information resources. Benefits of a variety of teaching and learning materials had already been explained by Kynigos and Kalogeria (2012), Huda et al. (2017) and vanOostveen et al. (2019). However, our research indicates that not only the type of teaching and learning materials (video or text) is vital, but, above all, the extent and intensity of the teaching and learning materials. Thus, it could be concluded

that one advantage of OLE is that types of materials are diverse and adaptable. Adaptation of material type and adjusting the amount of information of materials could be seen as a precise specification of individual tailoring of a learning environment, which is, according to Kamakari and Drigas (2010) and Tan et al. (2011), an advantage of OLE. In addition to selecting types of media (e.g., video or text) and intensity of information, it was also significant for teachers that information resources had high practical relevance. In order to deliver a high practical relevance of information resources in an OLE, PTD leaders needed to have an advanced level of knowledge about the needs and the professional lives of the teachers participating in the PTD courses. Furthermore, the practical relevance of information resources implies that PTD leaders have a filtering or production function. Thus, PTD leaders select from the wealth of information resources those that are specifically relevant to participants of the PTD courses. If such resources are not available, the PTD leader should also produce information resources in different formats and with various information intensities. The practice relevance and practice transfer (Kong et al., 2017; Kramarski & Revach, 2009) thus depends on the knowledge of the PTD leader about specific needs of the teachers and their educational frameworks.

The amount and personal choice of concrete teaching examples were also in line with the explanations given by Kynigos and Kalogeria (2012) regarding a variety of teaching and learning materials in OLE. However, our research suggests that the diversity of teaching and learning materials should not be interpreted only positively, since too many teaching and learning materials could overburden teachers and thus lead to disadvantages. Our research could add to the scientific debate that the quality of each and every one of the teaching and learning materials is just as important as their quantity. In order to ensure the quality of the materials, profound knowledge of PTD leaders about the specific needs of teachers in the PTD courses and their educational frameworks is essential.

Kamakari and Drigas (2010) and Tan et al. (2011) stated that a wide range of teaching and learning materials makes it easier for teachers to tailor a learning process. However, OLE offer teachers an opportunity to learn to customize a learning process on a larger scale, suggesting that teachers can choose the learning approach themselves through OLE – from theory to practical examples or from practical examples to theory.

Kramarski and Revach (2009), Valente (2003), and Mugimu and Nabadda (2009) emphasize the importance of a practice transfer and an interplay of theory and practice in professional teacher development in general. According to our research, a practice transfer of PTD content could be facilitated by “ready-to-use” examples which represent a significant element of OLE. Ready-to-use materials require that PTD leaders have a detailed knowledge of educational environments in which the materials should be used.

Long-term PTD courses (Aldorf, 2016; Breckwoldt et al., 2014) and follow-up activities of PTD courses (Ramatlapana, 2009; Yan & He, 2011) could lead to greater success of PTD courses. Secure environments for exchanging experiences and concrete examples in OLE could help extend PTD time beyond the end of the course. Teachers of our research stated that there is a primary interest to share examples with other teachers even after the end of a PTD course and thus be part of a community. However, in order to share examples in OLE, it would be important for teachers to know and trust the members of OLE and that OLE are closed. Sharing examples and experiences in a closed OLE could also facilitate a better integration of in-depth knowledge from participating teachers into PTD courses, which would be essential according to Amanatidis (2014), Guo (2009), and Kuntze (2006). Also, Czerkawski and Lyman (2016) and Weidlich and Bastiaens (2019) emphasized the importance of communities in OLE. Cobb and Smith (2008) identified the existence of networks as a central aspect of disseminating innovations in mathematics education. Results of our study indicate that the importance of communities or networks is also present in OLE for PTD for FA mathematics teaching. In addition, feedback from teachers in our study illustrated that communities and networks only develop under certain conditions. The essential framework condition for teachers was that OLE were closed and that members of OLE were known to each other. The closedness of OLE

could have reduced its *Observability* (Rogers, 2003) which in turn could make it more challenging to distribute innovations.

CONCLUSIONS, FURTHER CONSIDERATIONS AND LIMITATIONS

OLE could be a beneficial extension of professional teacher development courses if utilizing OLE facilitates teachers in choosing a learning approach themselves and if OLE emphasize benefits and practical relevance of an approach or technologies. Here, preventing unnecessary workload by using OLE, as well as privacy and security of OLE could be vital design elements of OLE which should extend PTD courses.

An interesting insight of our research is that teachers considered the visual design and the first impression of OLE highly important. It was important for teachers of our research that the design and first impression of OLE did not give the impression of additional work, even though professional teacher development is an essential element of teachers' working environment.

Another remarkable aspect of our research is that there is a high heterogeneity of teacher opinions regarding essential and significant elements of OLE. Teachers' opinions at times greatly differed or were contradictory so that even finding common ground became difficult or sometimes impossible.

Although our research took a large number of teachers into account and thus covered a wide range of age and teaching experiences, it was interesting that no trend or tendency between age as well as teaching experience and attitudes as well as expectations regarding OLE could be deduced. No trend or tendency between age as well as teaching experience and OLE means that we could not identify patterns or preferences of teachers concerning OLE that could be explained by age or teaching experience.

In summary, OLE could be a helpful tool in PTD and thus contribute to disseminating educational innovations if key elements of design and implementation are followed and satisfied.

Results of our study obviously have limitations as it was carried out under favorable conditions in terms of location and teaching subject. As our study was conducted with teachers from Austria, conditions concerning hardware availability for teachers and schools were above average (Breit et al., 2019). In addition, there had been nationwide initiatives and legal requirements (e.g., School 4.0 or digital basic-education) which could have improved the framework conditions for OLE in PTD for technologies and educational innovations (Breit et al., 2019). Concerning the combination of OLE in PTD for technology-enhanced and student-driven approaches to learning, as is the case when using FA, mathematics as a teaching subject offers particularly fruitful framework conditions in Austria. However, on the one hand, using technologies have become mandatory in the written school exit examination, and all students in secondary schools have to take this examination. On the other hand, there are also technological initiatives (e.g., GeoGebra) which are particularly implicit in the teaching of mathematics and have its origins in Austria.

The next step for our research initiatives will be to explore how OLE and elements of OLE could support teachers in their everyday professional lives and thus shift our research focus from professional teacher development to teaching and learning mathematics in schools. Furthermore, future research should also investigate what design elements of OLE for PTD for educational innovations are required when studies are to be conducted in less favorable environments. This further development of research could, therefore, contribute to improving the generalizability of the results of our study.

REFERENCES

- Aldorf, A.-M. (2016). Untersuchungsgegenstand [Object of investigation]. In A.-M. Aldorf (Ed.), *Lehrerkooperation und die Effektivität von Lehrerfortbildung* [Teacher cooperation and the effectiveness of in-service teacher training] (pp. 87–96). Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-11677-4_4

- Amanatidis, N. (2014). An in service training course, (INSET) on ICT pedagogy in classroom instruction for the Greek primary school teachers. *Education and Information Technologies*, 19(2), 307–326. <https://doi.org/10.1007/s10639-012-9215-y>
- Amedeker, M. K. (2018). Caring relationships in the environment of changing teacher professional development. *African Journal of Educational Studies in Mathematics and Sciences*, 14, 185–198.
- Anderson, T., & Shattuck, J. (2012). Design-based research. *Educational Researcher*, 41, 16–25.
- Annetta, L. A., Frazier, W. M., Folta, E., Holmes, S., Lamb, R., & Cheng, M.-T. (2013). Science teacher efficacy and extrinsic factors toward professional development using video games in a design-based research model: The next generation of STEM learning. *Journal of Science Education and Technology*, 22(1), 47–61. <https://doi.org/10.1007/s10956-012-9375-y>
- Artigue, M. (1998). Teacher training as a key issue for the integration of computer technologies. In D. Tinsley & D. C. Johnson (Eds.), *Information and Communications Technologies in School Mathematics: IFIP TC3 / WG3.1 Working Conference on Secondary School Mathematics in the World of Communication Technology: Learning, Teaching and the Curriculum*, 26–31 October 1997, Grenoble, France (pp. 121–129). Springer US. https://doi.org/10.1007/978-0-387-35287-9_15
- Asikin, M., Junaedi, I., & Cahyono, A. N. (2018). The INNOMATTS: A model of mathematics teacher training management. *Journal of Turkish Science Education*, 15(Special), 76–86.
- Barab, S., & Squire, K. (2004). Design-based research: Putting a stake in the ground. *Journal of the Learning Sciences*, 13(1), 1–14. https://doi.org/10.1207/s15327809jls1301_1
- Baumgartner, E., Bell, P., Brophy, S., Hoadley, C., Hsi, S., Joseph, D., Orrill, C., Puntambekar, S., Sandoval, W., & Tabak, I. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32, 5–8, 35. <https://doi.org/10.3102/0013189x032001005>
- Bell, C. V., & Pape, S. J. (2012). Scaffolding students' opportunities to learn mathematics through social interactions. *Mathematics Education Research Journal*, 24(4), 423–445. <https://doi.org/10.1007/s13394-012-0048-1>
- Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. International society for technology in education. <https://doi.org/10.1177/073989131401100120>
- Bildungsbericht 2018. (2019). In *Bundesinstitut bifie*. https://www.bifie.at/wp-content/uploads/2019/03/NBB_2018_Band1_Indikator_B.pdf
- Breckwoldt, J., Svensson, J., Lingemann, C., & Gruber, H. (2014). Does clinical teacher training always improve teaching effectiveness as opposed to no teacher training? A randomized controlled study. *BMC Medical Education*, 14(1), 6. <https://doi.org/10.1186/1472-6920-14-6>
- Breit, S., Eder, F., Krainer, K., Schreiner, C., Seel, A., & Spiel, C. (2019). *Nationaler Bildungsbericht Österreich 2018*. Band 1. <http://doi.org/10.17888/nbb2018-1.4>
- Breuer, F., Dieris, B., & Lettau, A. (2009). *Reflexive grounded theory: Eine einföhrung für die forschungspraxis* [Reflexive Grounded Theory: An Introduction for Research Practice]. VS Verlag für Sozialwissenschaften.
- Butt, A. (2014). Student views on the use of a flipped classroom approach: Evidence from Australia. *Business Education & Accreditation*, 6(1), 33–43.
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis* (1st ed.). SAGE Publications Ltd.
- Cobb, P., Confrey, J., Disessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher*, 32, 9–13. <https://doi.org/10.3102/0013189x032001009>
- Cobb, P., & Smith, T. (2008). District development as a means of improving mathematics teaching and learning at scale. In K. Krainer & T. Wood (Eds.), *International handbook of mathematics teacher education: Vol. 3. Participants in mathematics teacher education: Individuals, teams, communities and networks* (pp. 231–254). Brill Sense. https://doi.org/10.1163/9789087905491_012
- Czerkawski, B. C., & Lyman, E. W. (2016). An instructional design framework for fostering student engagement in online learning environments. *TechTrends*, 60(6), 532–539. <https://doi.org/10.1007/s11528-016-0110-z>

- Enfield, J. (2016). The value of using an e-text in a flipped course. *TechTrends*, 60(5), 449–455. <https://doi.org/10.1007/s11528-016-0100-1>
- Esperanza, P., Fabian, K., & Toto, C. (2016). Flipped classroom model: Effects on performance, attitudes and perceptions in high school algebra. In K. Verbert, M. Sharples, & T. Klobučar (Eds.), *Adaptive and Adaptable Learning: 11th European Conference on Technology Enhanced Learning, EC-TEL 2016, Lyon, France, September 13-16, 2016, Proceedings* (pp. 85–97). Springer International Publishing. <https://doi.org/10.1007/978-3-319-45153-4>
- Euler, D. (2001). Manche lernen es - aber warum [Some learn it - but why]. *Zeitschrift Für Berufs-Und Wirtschaftspädagogik*, 97(3), 346–374.
- Evens, M., Larmuseau, C., Dewaele, K., Van Craesbeek, L., Elen, J., & Depaepe, F. (2017). The effects of a systematically designed online learning environment on preservice teachers' professional knowledge. *Journal of Digital Learning in Teacher Education*, 33(3), 103–113. <https://doi.org/10.1080/21532974.2017.1314779>
- Galway, L. P., Corbett, K. K., Takaro, T. K., Tairyan, K., & Frank, E. (2014). A novel integration of online and flipped classroom instructional models in public health higher education. *BMC Medical Education*, 14(1), 181. <https://doi.org/10.1186/1472-6920-14-181>
- García-Peñalvo, F. J., Fidalgo-Blanco, Á., Sein-Echaluce, M. L., & Conde, M. Á. (2016). Cooperative micro flip teaching. In P. Zaphiris & A. Ioannou (Eds.), *Proceedings of Learning and Collaboration Technologies: Third International Conference, LCT 2016, Held as Part of HCI International 2016, Toronto, ON, Canada, July 17-22, 2016* (pp. 14–24). Springer International Publishing. https://doi.org/10.1007/978-3-319-39483-1_2
- Gräsel, C., Bruhn, J., Mandl, H., & Fischer, F. (1997). Lernen mit Computernetzen aus konstruktivistischer Perspektive [Learning with computer networks from a constructivist perspective]. *Unterrichtswissenschaft*, 25, 4–18.
- Gündüz, A. Y., Alemdag, E., Yasar, S., & Erdem, M. (2016). Design of a problem-based online learning environment and evaluation of its effectiveness. *Turkish Online Journal of Educational Technology-TOJET*, 15(3), 49–57.
- Guo, W. (2009). From an online training course to a “virtual” teacher training academy—Design and implementation of Peking University asynchronous online teacher training program. In F. L. Wang, J. Fong, L. Zhang, & V. S. K. Lee (Eds.), *Hybrid learning and education* (pp. 365–377). Springer. https://doi.org/10.1007/978-3-642-03697-2_34
- Hakkarainen, P. (2009). Designing and implementing a PBL course on educational digital video production: Lessons learned from a design-based research. *Educational Technology Research and Development*, 57(2), 211–228. <https://doi.org/10.1007/s11423-007-9039-4>
- Huda, M., Haron, Z., Ripin, M. N., Hehsan, A., & Yaacob, A. B. C. (2017). Exploring innovative learning environment (ILE): Big data era. *International Journal of Applied Engineering Research*, 12(17), 6678–6685.
- Kamakari, A., & Drigas, A. (2010). Video conferencing and knowledge management in in-service teacher distance lifelong training and development. In M. D. Lytras, P. Ordonez De Pablos, D. Avison, J. Sipiior, Q. Jin, W. Leal, L. Uden, M. Thomas, S. Cervai, & D. Horner (Eds.), *Technology Enhanced Learning. Quality of Teaching and Educational Reform: First International Conference, TECH-EDUCATION 2010, Athens, Greece, May 19-21, 2010. Proceedings* (pp. 610–619). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-13166-0_85
- Kolos, V. (2002). National strategy for teacher training in new ICT use. In D. Passey & M. Kendall (Eds.), *TeLE-Learning: The challenge for the third millennium* (pp. 101–104). Springer. https://doi.org/10.1007/978-0-387-35615-0_14
- Kong, S.-C., Looi, C.-K., Chan, T.-W., & Huang, R. (2017). Teacher development in Singapore, Hong Kong, Taiwan, and Beijing for e-Learning in school education. *Journal of Computers in Education*, 4(1), 5–25. <https://doi.org/10.1007/s40692-016-0062-5>
- Koohang, A., Riley, L., Smith, T., & Schreurs, J. (2009). E-learning and constructivism: From theory to application. *Interdisciplinary Journal of E-Learning and Learning Objects*, 5(1), 91–109. <https://doi.org/10.28945/66>

- Krainer, K., Zehetmeier, S., Hanfstingl, B., Rauch, F., & Tscheinig, T. (2018). Insights into scaling up a nationwide learning and teaching initiative on various levels. *Educational Studies in Mathematics*. <https://doi.org/10.1007/s10649-018-9826-3>
- Kramarski, B., & Revach, T. (2009). The challenge of self-regulated learning in mathematics teachers' professional training. *Educational Studies in Mathematics*, 72(3), 379–399. <https://doi.org/10.1007/s10649-009-9204-2>
- Kuntze, S. (2006). Teachers' beliefs on teacher training contents and related characteristics of implementation—The example of introducing the topic study method in mathematics classrooms. *ZDM*, 38(6), 456–463. <https://doi.org/10.1007/BF02652782>
- Kynigos, C., & Kalogeria, E. (2012). Boundary crossing through in-service online mathematics teacher education: The case of scenarios and half-baked microworlds. *ZDM*, 44(6), 733–745. <https://doi.org/10.1007/s11858-012-0455-5>
- Larsen, S. (2017). A review of *How to teach mathematics* 3rd edition, Steven Krantz. (2015) American Mathematical Society. *International Journal of Research in Undergraduate Mathematics Education*, 3(1), 243–246. <https://doi.org/10.1007/s40753-016-0050-1>
- Lemmer, C. A. (2013). A view from the flip side: Using the inverted classroom to enhance the legal information literacy of the international LL.M. student. *Law Library Journal*, 105, 461–491.
- Maciejewski, W. (2015). Flipping the calculus classroom: An evaluative study. *Teaching Mathematics and Its Applications: An International Journal of the IMA*, 35(4), 187–201. <https://doi.org/10.1093/teamat/hrv019>
- Maxwell, B. (2010). In-service initial teacher education in the learning and skills sector in England: Integrating course and workplace learning. *Vocations and Learning*, 3(3), 185–202. <https://doi.org/10.1007/s12186-010-9045-2>
- McKenney, S., & Reeves, T. C. (2013). Systematic review of design-based research progress. *Educational Researcher*, 42(2), 97–100. <https://doi.org/10.3102/0013189X12463781>
- Mey, G., & Mruck, K. (2011). *Grounded theory reader* (2nd ed.). VS Verlag für Sozialwissenschaften.
- Mugimu, C. B., & Nabadda, R. (2009). The role of pre-service and in-service teacher training (PITT) programmes in preparing teachers for HIV curriculum integration. *PROSPECTS*, 39(4), 383–397. <https://doi.org/10.1007/s11125-009-9130-1>
- Muir, T., & Geiger, V. (2016). The affordances of using a flipped classroom approach in the teaching of mathematics: A case study of a grade 10 mathematics class. *Mathematics Education Research Journal*, 28(1), 149–171. <https://doi.org/10.1007/s13394-015-0165-8>
- Ngware, M. W., Ciera, J., Musyoka, P. K., & Oketch, M. (2015). Quality of teaching mathematics and learning achievement gains: Evidence from primary schools in Kenya. *Educational Studies in Mathematics*, 89(1), 111–131. <https://doi.org/10.1007/s10649-015-9594-2>
- O'Flaherty, J., & Phillips, C. (2015). The use of flipped classrooms in higher education: A scoping review. *The Internet and Higher Education*, 25, 85–95. <https://doi.org/10.1016/j.iheduc.2015.02.002>
- Popper, K. (1963). *Conjectures and refutations: The growth of scientific knowledge*. Routledge.
- Potgieter, C. (2004). The impact of the implementation of technology education on in-service teacher education in South Africa (Impact of technology education in the RSA). *International Journal of Technology and Design Education*, 14(3), 205–218. <https://doi.org/10.1007/s10798-004-2270-y>
- Ramatlapana, K. A. (2009). Provision of in-service training of mathematics and science teachers in Botswana: Teachers' perspectives. *Journal of Mathematics Teacher Education*, 12(2), 153–159. <https://doi.org/10.1007/s10857-009-9101-8>
- Reinmann, G. (2005). Innovation ohne Forschung? Ein Plädoyer für den Design-Based Research-Ansatz in der Lehr-Lernforschung [Innovation without research? A plea for the Design-Based Research Approach in teaching and learning research]. *Unterrichtswissenschaft*, 33(1), 52–69.

- Robutti, O., Cusi, A., Clark-Wilson, A., Jaworski, B., Chapman, O., Esteley, C., Goos, M., Isoda, M., & Joubert, M. (2016). ICME international survey on teachers working and learning through collaboration: June 2016. *ZDM*, 48(5), 651–690. <https://doi.org/10.1007/s11858-016-0797-5>
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- Selter, C., Gräsel, C., Reinold, M., & Trempler, K. (2015). Variations of in-service training for primary mathematics teachers: An empirical study. *ZDM*, 47(1), 65–77. <https://doi.org/10.1007/s11858-014-0639-2>
- Seraji, F., & Khodaveisi, S. (2019). Teachers' professional development through online learning environment: A phenomenological study. *Interdisciplinary Journal of Virtual Learning in Medical Sciences*, 10(4), 40–53.
- Serdyukov, P. (2017). Innovation in education: What works, what doesn't, and what to do about it? *Journal of Research in Innovative Teaching & Learning*, 10(1), 4–33. <https://doi.org/10.1108/JRIT-10-2016-0007>
- Staker, H., & Horn, M. B. (2012). *Classifying K-12 blended learning*. Innosight Institute. <https://www.christensen-institute.org/wp-content/uploads/2013/04/Classifying-K-12-blended-learning.pdf>
- Sureka, A., Gupta, M., Sarkar, D., & Chaudhary, V. (2013). A case-study on teaching undergraduate-level software engineering course using inverted-classroom, large-group, real-client and studio-based instruction model. *ArXiv Preprint ArXiv*. 1309.0714. <http://arxiv.org/abs/1309.0714>
- Tolks, D., Schäfer, C., Raupach, T., Kruse, L., Sarikas, A., Gerhardt-Szép, S., Kllauer, G., Lemos, M., Fischer, M. R., Eichner, B., Sostmann, K., & Hege, I. (2016). An introduction to the inverted/flipped classroom model in education and advanced training in medicine and in the healthcare professions. *GMS Journal for Medical Education*, 33(3), Doc46. PMC. <https://doi.org/10.3205/zma001045>
- Tzur, R., Simon, M. A., Heinz, K., & Kinzel, M. (2001). An account of a teacher's perspective on learning and teaching mathematics: Implications for teacher development. *Journal of Mathematics Teacher Education*, 4(3), 227–254. <https://doi.org/10.1023/A:1011493204582>
- Valente, J. A. (2003). In service teacher development using ICT: First step in lifelong learning. In C. Dowling & K.-W. Lai (Eds.), *Information and Communication Technology and the Teacher of the Future*: IFIP TC3 / WG3.1 & WG3.3 Working Conference on ICT and the Teacher of the Future January 27–31, 2003, Melbourne, Australia (pp. 97–108). Springer. https://doi.org/10.1007/978-0-387-35701-0_10
- vanOostveen, R., Desjardins, F., & Bullock, S. (2019). Professional development learning environments (PDLEs) embedded in a collaborative online learning environment (COLE): Moving towards a new conception of online professional learning. *Education and Information Technologies*, 24(2), 1863–1900. <https://doi.org/10.1007/s10639-018-9686-6>
- Vygotsky, L. S. (1978). *Mind in society: Development of higher psychological processes* (Revised ed.). Harvard University Press.
- Wasserman, N. H., Quint, C., Norris, S. A., & Carr, T. (2015). Exploring flipped classroom instruction in calculus III. *International Journal of Science and Mathematics Education*, 15, 545–568. <https://doi.org/10.1007/s10763-015-9704-8>
- Weidlich, J., & Bastiaens, T. J. (2019). Designing sociable online learning environments and enhancing social presence: An affordance enrichment approach. *Computers & Education*, 142, 103622. <https://doi.org/10.1016/j.compedu.2019.103622>
- Weinhandl, R., & Lavicza, Z. (2018). Introducing teachers to a technology-supported flipped mathematics classroom teaching approach. *Proceedings of the 5th ERME Topic Conference MEDA 2018. ERME Topic Conference 'Mathematics Education in the Digital Age'*, Copenhagen.
- Weinhandl, R., Lavicza, Z., & Houghton, T. (2020). Mathematics and STEM teacher development for flipped education. *Journal of Research in Innovative Teaching & Learning*. <https://doi.org/10.1108/JRIT-01-2020-0006>
- Wolff, L.-C., & Chan, J. (2016). Defining flipped classrooms. In L.-C. Wolff & J. Chan (Eds.), *Flipped classrooms for legal education* (pp. 9–13). Springer. https://doi.org/10.1007/978-981-10-0479-7_2
- Yan, C., & He, C. (2011). Enhancing part-time in-service teacher training programmes to facilitate rural teacher development in China. *PROSPECTS*, 41(4), 553–566. <https://doi.org/10.1007/s11125-011-9211-9>

BIOGRAPHIES



Robert Weinhandl is a postdoctoral researcher at the Linz School of Education in the field of STEM didactics. Robert is a member of the GeoGebra Community and Origin Lab team as well as a staff member of the MINT Learning Center at the Linz School of Education. Robert's research focuses on integrating real-world problems into mathematics teaching and professional mathematics teacher development. In this research, flipped mathematics learning plays a central role. Furthermore, Robert teaches mathematics as well as mathematics didactics at a secondary school, a teacher training college, and a university of applied sciences.



Zsolt Lavicza has worked on several research projects examining technology and mathematics teaching in classroom environments in Michigan and Cambridge. In addition, Zsolt has greatly contributed to the development of the GeoGebra community and participated in developing research projects on GeoGebra and related technologies worldwide. Currently, Zsolt is a Professor in STEM Education Research Methods at Johannes Kepler University's Linz School of Education. From JKU he is working on numerous research projects worldwide related to technology integration into schools; leading the doctoral program in STEM Education; teaching educational research methods worldwide; and coordinates research projects within the International GeoGebra Institute.



Tony Houghton is Visiting Professor Linz School of Education, Johannes Kepler University, Educational Development Director at CCITE Cambridge Centre for Innovation in Technological Education and Visiting Professor University of Essex Computer Science and Electronic Engineering. His STEAM work on Creative Collaborative Problem Solving is with teachers and schools worldwide on the BT Global Hothousing and Educational and Social Inclusion Community of Practice programs, with organizations such as Microsoft, Tesco, CISCO, Pepsico, DHL, Essex County Council, Nationwide and Sony. He has worked on STEAM projects with HP, IET, University of Cambridge and most recently was UK Project Leader KIKS (Kids Inspiring Kids in STEAM) EU ERASMUS+.