

RESEARCH ARTICLE

Participatory Action Research in the Development of Higher Education with Digital Media

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The digitalisation of higher education has versatile potential for students and especially for pre-service teachers. Unfortunately, this potential is insufficiently used in higher education institutions. This article displays a project focusing on developing university teacher education with digital media. For this purpose, the applied model of Participatory Action Research for Higher Education will be illustrated, reflected, and discussed to share the findings and experiences of the process and facilitate future development projects. Furthermore, conditions for success, challenges, and recommendations based on this project are provided.

Keywords: Science Education, Educational/Instructional Technologies, Technological Pedagogical Content Knowledge, Action Research

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Introduction

The potential of digitalisation for education has created new teaching opportunities but also placed new demands on schools and universities. Nowadays, as part of digitalisation, information and communication technologies (ICT) shapes the everyday reality of people, and therefore digital competencies are a necessary cultural skill in the (future) information society, especially for the current students in school and university (Döbeli Honegger, 2016). Furthermore, for educational institutions using ICT can make organisations more efficient and promote better learning in class (Döbeli Honegger, 2016). But this potential can only be realised if these technologies are used in appropriately designed didactic learning concepts and digital infrastructure.

Based on this, the education policy in Germany demands (KMK, 2019) that educational institutions should consistently use the possibilities of digitalisation to develop higher education teaching. Furthermore, educators and researchers should develop research-based and practice-oriented opportunities for the design of teaching with digital media (KMK, 2019).

However, various studies show that digital media has so far only been insufficiently used in German universities (Dittler & Kreidl, 2018; Schmid et al., 2017). Reasons for this are the absence of digital strategies and infrastructure as well as the insufficient utilisation of the available ICT by educators (Biehl & Besa, 2021). Educators predominantly use presentation software (e.g., PowerPoint) and learning management systems (e.g., moodle) to provide digital text documents (Schmid et al., 2017). This means educators do not utilise digital media's full potential. Especially teacher training towards media literacy seems to be insufficient and does not meet the requirements of the KMK (Maxton-Küchenmeister & Meßinger-Koppelt, 2020). The Covid-19-pandemic significantly accelerated the digitalisation of higher education institutions in Germany, as, within a few weeks, teaching had to be converted to online teaching (Schwabl & Vogelsang, 2021).

For pre-service teachers, learning systematically with digital media in higher education could be one successful way of educating pre-service teachers in media literacy. Following the model of the social cognitive theory (Bandura, 1977), in experiencing digital media in their learning, students can build up technological, pedagogical, and content knowledge (TPACK) and positive beliefs regarding digital media in their future class (Schwarzer & Jerusalem, 2002; Westmeyer, 2005). Teachers need this knowledge and beliefs to use digital media successfully in their future teaching in school (Cetin-Dindar et al., 2018; Guzey & Roehrig, 2009).

Theoretical Background

There is a great variety of innovative didactical concepts, which educators could use next to presentation software and learning management systems. It is reported that social and collaborative learning (Hernández-Sellés et al., 2019), simulations and games (Vlachopoulos & Makri, 2017) and learning with videos (Wolf, 2015) are already used successfully in university teaching. Also, innovations like augmented reality (AR), virtual reality (VR) (Radianti et al., 2020) or artificial intelligence (AI) (Baker et al., 2019) are researched towards their potential in learning processes. One of the most promising and, therefore, popular concepts with digital media in higher education is flipped classroom (Al-Samarraie et al., 2019). The flipped classroom uses the advantages of learning at home and in class. At home, students learn content individualised asynchronously. The learning material has different formats, such as educational videos, texts, podcasts, quizzes, and illustrations (Bergmann & Sams, 2012; Strayer, 2012). In class, learning activities are collaborative, interactive, and student-centred (Strayer, 2012). Research shows the potential of the flipped classroom concept in supporting specific learning outcomes, e.g., engagement, attitude, understanding, metacognition, performance (Strayer, 2012), and self-efficacy (Al-Samarraie et al., 2019).

Overall, studies show that these didactical concepts can make higher education more attractive, effective, and flexible (Dittler & Kreidl, 2018; Xu & Xu, 2019). Studies show that using digital media in education has various positive effects on teaching and learning (e.g., Hillmayr et al., 2017). In well-designed digital learning environments, learning can be individualised and differentiated (Tulodziecki & Herzig, 2004). Further, digital media in teaching positively

influences learning performance and learning efficiency (Kalyuga & Sweller, 2005; Ma et al., 2014) and reduces the required learning time (Çakir, 2019). In science education, research shows great potential regarding process and model visualisation, experimentation, and exploratory learning (e.g., Hogarth et al., 2006; Meßinger-Koppelt et al., 2017).

In digital media, the positive effects on learning are achieved using the concepts of multimedia (Kerres, 2013), adaptivity (Schmidt & Küsel, 2021) and interactivity (Küsel & Markic, 2021; Niegemann & Heidig, 2019; Sosa et al., 2011). Interactivity refers to a dynamic process between learners and a medium in which learners react to the actions of the learning system and vice versa (Domagk et al., 2010). The interactivity of digital learning media is assigned great importance because it promises individualised, motivating, and multimedia learning (Niegemann & Heidig, 2019). A medium can achieve interactivity if it enables the selection and presentation of content that optimally fits the learner. Therefore, the interactive media should consider interests and individual needs (Sosa et al., 2011). The motivating character of interactivity is explained by the inclusion of learners in the learning process (Haack, 2002; Niegemann & Heidig, 2019), as the presentation of content in interactive scenarios is an effective way for learners to become active recipients (Niegemann & Heidig, 2019). Furthermore, interactivity has positive effects on learning success in small groups (Nussbaum et al., 2015) and blended learning scenarios (Castaño-Muñoz et al., 2014).

Goals

Based on the displayed demands and research, the aim of the project presented here is first to develop the university education towards a concept with digital media, and second this teaching should contribute to the development of pre-service science teachers' competence regarding digital media. To reach these goals, the Participatory Action Research for Higher Education is used (Tolsdorf & Markic, 2018). This model is employed because it promises a successful change in teaching practices and professionalises the participating educators (Eilks, 2018).

Participatory Action Research for Higher Education

Participatory Action Research is an established strategy in the educational and social science fields that helps to promote practical curricular development research. Curricular development research is systematically related to practice, and educators are to be integrated into the process with their knowledge and experience. This cooperation should lead to the educators' professionalization (Eilks & Ralle, 2002). In addition, curricular research should be more strongly oriented towards empirical teaching and learning research and justify the relevance and importance of new concepts. Furthermore, the documentation and dissemination of the new concepts should be an integral part of the research.

Tolsdorf and Markic (2018) adapted this Participatory Action Research model for university teaching, in which educators form teams that further develop science education courses in a communicative exchange. A central difference compared to Eilks and Ralle (2002) is an extended composition of the team, which should consist of different experts, like educators, teachers, and students, depending on the characteristics of the development. The development process results

are new teaching materials, media, and methods for university teaching (Tolsdorf & Markic, 2018).

The Participatory Action Research is organised in a step-based communicative, cyclical process (see **Figure 1**). This process consists of (1) problem analysis, (2) team building, (3) development, (4) testing in practice, (5) evaluation and (6) reflection and revision. In this cooperative development, an interdisciplinary team work together on a topic. This team play an important role because the team is compiled according to the problem and the skills needed to solve it. Furthermore, the information gathered after each test, the practical experiences of the educators, and the successes and failures in teaching are considered in the further cyclical development process. In addition, other research questions regarding the learning media are included in this evaluation step. As a result, possible changes can contribute to new questions and approaches, and generalisable insights into teaching and learning processes at universities can be gained.

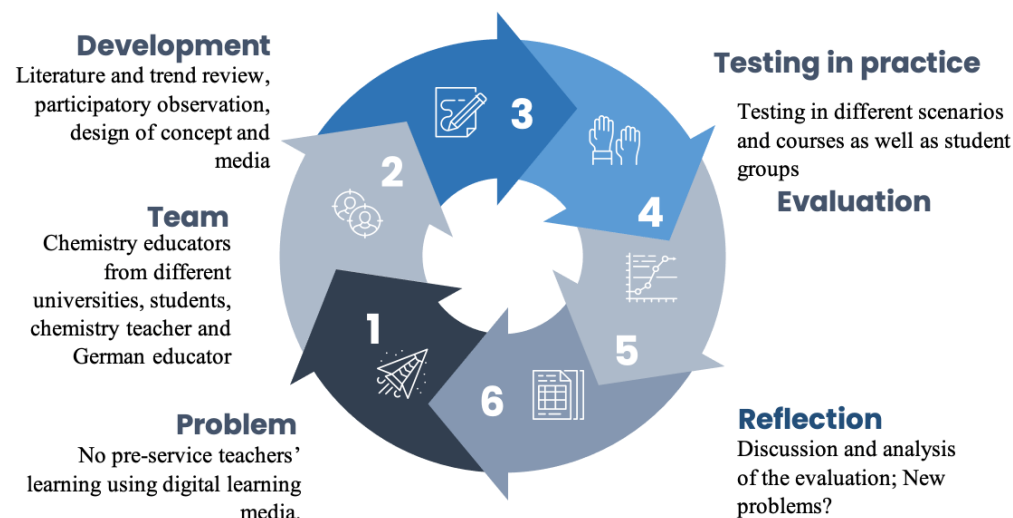


Figure 1. Cyclical development using the model of Participatory Action Research - oriented on Tolsdorf and Markic (2018).

This model of Participatory Action Research is used to develop the lecture "Introduction to science education". The following section describes the steps of the Participatory Action Research in detail.

4.1 Problem

First, as already portrayed, digital media provides diverse possibilities for higher education. So far, the authors identified that this potential is not used in their courses, especially in the lecture "Introduction to science education". Further, there was only little experience in teaching with digital media, so a need for professionalisation is seen.

Second, the pre-service science teachers lack technological, pedagogical and content knowledge (TPACK) and positive beliefs regarding the use of digital media in their future teaching (Küsel & Markic, 2020; Küsel et al., 2020; Küsel et al., submitted;). Their TPACK and beliefs can be influenced by practical experiences with digital media (Bandura, 1977). Therefore, by enriching the teaching with digital media, an improvement regarding the students' TPACK and beliefs is intended. This way, they will be better prepared to teach with digital media.

Thus, the problem in the sense of the Participatory Actions Research is how to develop the lecture "Introduction to Science Education" with digital media, first, resulting in effective pre-service science teachers learning and second contributing to the development of students' experience with digital media, potentially increasing the TPACK and improving the beliefs of pre-service science teachers regarding digital media. A literature and trend research shows that the defined problem required a development effort on two levels:

1. The didactical concept had to be changed to address the presented problem. Here areas of application in teaching are defined, i.e., in which topics and activity it could be particularly worthwhile to use digital media. Especially the concept of the flipped classroom seemed promising regarding the problem.
2. Suitable digital media are needed for this didactical concept, which supports learning through multimedia, adaptivity and, most crucial, interactivity.

4.2 Team

In order to deal with this problem, a core team is formed consisting of two chemistry educators who are specifically responsible for the lecture. In addition, other science educators (chemistry education as well as physics education) from the Leuphana University Lüneburg and the University of Vienna are approached to provide feedback in the development process and to support testing, evaluation, and reflection. A valuable part of the team are scholars of media didactics, especially experienced in online learning from the USA, which enabled insightful international comparison research. Also, a chemistry teacher and a German educator are part of the team to provide other perspectives, especially concerning ease of use and language sensitivity. An essential part of the team is further the pre-service science teachers, which primarily tested and evaluated the newly developed concept and media. In each of the four cycles, approximately 75 pre-service science teachers participated in the lecture "Introduction to science education", resulting in around 300 students being part of the Participatory Action Research. Overall, they are aged 19 - 59 ($M = 23,08$), and 84.9 % are female, which is typical for teachers' study programmes in Germany. The students attend one German university and are pre-service science teachers (with their major either in mathematics or German and their minor in chemistry, physics, biology, history, technology, geography, political science or economics) in their third or fourth study semester, becoming primary school teachers. Accompanying studies done for diagnostic purposes show, that pre-service teachers have little experience in learning with digital media (Küsel et al., submitted; Küsel & Markic, 2020).

The selection of the team members followed a pragmatic approach, as team members are chosen based on who are already working with the authors in other projects and thus, the project's success is considered likely. However, the focus is on the addition of experts' competences and knowledge. Communication is organised partly through email, online meetings, and face-to-face meetings.

4.3. Development, Testing, Evaluation and Reflection in four cycles

Following the model of Participatory Action Research for higher education (Tolsdorf & Markic, 2018), the development, testing, evaluation, and reflection are organised in four cycles (see **Figure 2**). Each cycle corresponds to the cyclical development of Participatory Action Research for higher education and lasts one semester (see **Figure 1**). This means that the concept and the digital media are further developed in every cycle based on the previous testing, evaluation, and reflection. The evaluation is conducted using a variety of quantitative and qualitative questionnaires for the pre-service teachers at different times and with different focuses, e.g., regarding usability (Brooke, 2016), concept, methods (Küsel & Markic, 2020) and media (Küsel & Markic, 2021). Expert assessments and support from the team members are gathered at different stages. In the reflections after each cycle, the evaluation is analysed, and findings are discussed in the team. Based on this, problems in the concept and digital media are identified, which the team then addressed further in the development in the next cycle. In addition to the evaluation of the concept and the digital media in each cycle, research focusing on pre-service teachers' learning, their knowledge of and beliefs towards ICT is conducted. The findings from this research lead directly to changes and adjustments in the development process of the concept and digital media.

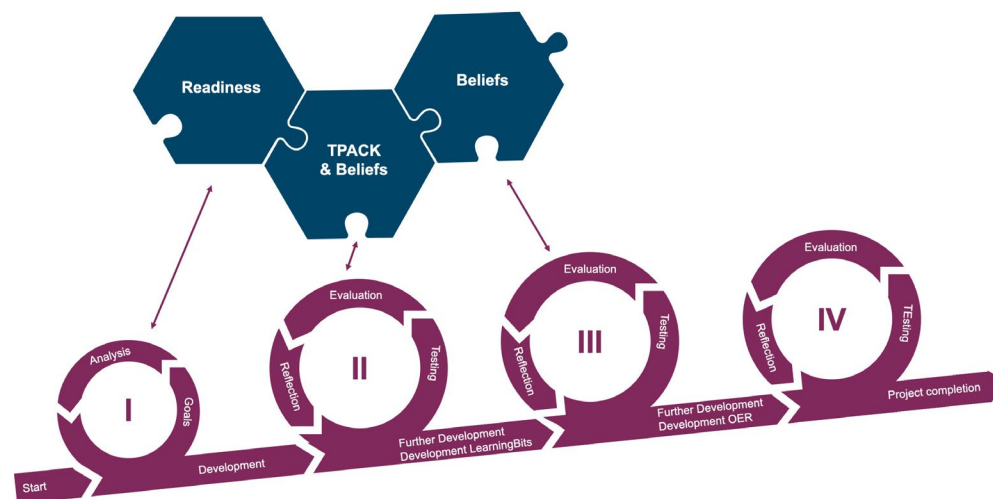


Figure 2. Project design

4.3.1. First cycle (I)

In the first cycle of the project, the goals are defined, and a trend and literature analysis is carried out, finding the flipped classroom as a promising concept for the lecture. In addition, for the purpose of initial diagnostics, the readiness of students to learn with digital media is evaluated (Küsel et al., 2020). This evaluation reports that the pre-service teachers are basically prepared to be able to learn with digital media during their studies. They assess the necessary skills as generally important for their learning. However, they are unsure whether they can acquire these skills.

Further, the team conducted a participatory observation of the lecture in the original form in the first cycle. Thus, one team member is present in each lecture and creates notes on the potential for improvement and areas of application of new methods and digital media. These notes are discussed throughout the team.

4.3.2. Second cycle (II)

Based on the trend and literature analysis, the research and the observation results, the first version of the new didactical concept is developed at the start of the second cycle. A didactical concept using the flipped classroom with various digital media like educational videos, digital papers and quizzes is designed. This concept is then implemented and evaluated by pre-service teachers. In addition, as a part of the evaluation, pre-service teachers' TPACK and beliefs regarding digital media in teaching are assessed (Küsel & Markic, 2020). The investigation of the TPACK shows that pre-service science teachers are undecided about the extent to which they have the relevant knowledge to use digital media in their future teaching. Regarding the beliefs, digital media are considered to have some vague value for their future teaching. These insights are discussed and incorporate the further development.

4.3.3. Third cycle (III)

The insights gained from the evaluation reflection and the research of the second cycle led to the further development of the didactical concept. To improve the usability and learning for the target audience, explanations for the use of digital media like educational videos are integrated. The tasks and digital media of the lecture are edited based on students' evaluation, and the lecture schedule is modified to ensure a good fit of the assignments.

In addition, the development of new digital media, the so-called LearningBits, began in the third cycle. LearningBits are interactive, adaptive, and oriented towards game-based- and story-based learning. The team reviewed and improved this media in multi-stage processes before the first trial. In this way, many technical errors and improvements are eliminated before the first actual use and thus lead to a better quality.

Since the third cycle, the LearningBits have been used as digital media in the adapted didactical concept and evaluated by pre-service science teachers using a short questionnaire with closed and open questions. This is done for every single learning media. As a result, any identified technical errors are fixed, and overly complex tasks are changed to easier ones or amended with content hints. Also, the design of the LearningBits is improved, and some are extended to cover more content (Küsel & Markic, 2021).

In addition, pre-service teachers' beliefs regarding selected digital media are researched (Küsel et al., submitted). The selected digital media are generally seen as somewhat to relatively important and supportive for the students. In comparison to pre-service teachers from the USA, German one's rate digital media as significantly less important and less supportive as well as rating themselves as significantly less competent. Based on these insights, the concept of the lecture incorporated as many variety of digital media as possible to influence these beliefs, without overburdening the pre-service science teachers.

4.3.4. Fourth cycle (IV)

In the fourth cycle, the concept needed to be modified because of the mandated switch to digital teaching due to the Covid-19-Pandemic. The concept and LearningBits are also evaluated positively by pre-service teachers in online teaching. An essential adaptation in the LearningBits is the advanced learners' tracking so that the learning management system could show the individual learners' progress in synchronous and asynchronous learning environments. Also, the concept of the lecture and the LearningBits is continued to be tested on pre-service teachers resulting in further improvements.

Additionally, in this cycle, the science educators from other universities implemented and evaluated the LearningBits in different scenarios and learning contexts. In cooperation with these educators, these media are expanded, improved, and specialised for the individual context of use.

Furthermore, the development of a website-based Open Educational Resource (OER) started, where other science educators outside of the project could integrate the developed concept and LearningBits in their teaching.

4.3.5. End of the project and dissemination

By the end of the project, a tested and evaluated didactical concept and various LearningBits have emerged, as well as a means of disseminating them (www.nw-didaktik-digital.de). The quantitative evaluation of the lecture shows that the pre-service teachers liked the variety of methods and the interactive design of the lecture. They stated that they felt they learned a great deal and recognised a useful structure of the lecture. In the qualitative part of the evaluation, the students emphasised that working with various digital tools in this lecture is new and fun. A majority is sure that they learned more successfully in the flipped classroom setting than in traditional lectures. They also stated that the usage of digital media provided them a good overview over the possibilities as well as inspiration and knowledge for their own future teaching. This is supported by a study that shows a significant increase in the pre-service teachers' TPACK (Küsel & Markic, 2020). The concept and the mentioned research are described in detail in Küsel and Markic (2020). Research on the LearningBits shows that for the pre-service science teachers, the LearningBits support individual learning, independent revision, and reflection, as well as illustration and consolidation of content. The LearningBits are seen as entertaining, easy to use, well designed and to have good usability (see also Küsel and Markic (2021)).

Discussion and Conclusion

First, a successful didactical concept for a lecture is developed and continuously improved by using Participatory Action Research. This concept is positively evaluated by pre-service teachers and published in the research community. Second, learning in this concept, the TPACK of the pre-service science teachers improved significantly. Third, new interactive digital media has been developed, evaluated, and continuously improved. This media supports students in their learning and can be used in various learning activities and university courses (Küsel & Markic, 2021). This research could also contribute to the development of other interactive media. Forth, a small network of educators across different universities and teaching domains emerged based on good cooperation in the project team. Altogether, the defined goals are reached.

Subjects and departments or faculties inside one university work differently based on (research) traditions and habits. This difference can be a vital resource to be used in development projects. For the two chemistry educators who are specifically responsible for the course, the cooperation with teachers from other subjects is a valuable opportunity to get insights and new perspectives. The work with science educators from other universities helps to improve the developed didactical concept and the LearningBits. In line with similar Participatory Action Research projects (Eilks & Markic, 2011; Mamlok-Naaman & Eilks, 2012), it can be assumed that professionalisation is achieved among the participating educators.

The participating students had the opportunity to be part of a development process as part of their studies. In this process, they could achieve ownership of their learning by taking responsibility for the progress of their university teaching. This student ownership enables greater active participation and engagement in the learning process and better performance (Crowe & Kennedy, 2018). This experience could influence their future teaching in school, in which feedback from students could be seen as valid and essential.

However, this project using the model of Participatory Action Research for higher education shows that it takes time to work and organise the development of university teaching with digital media. Moreover, finding other suitable members for the project team can be a challenge, as well as the organisation and cooperation with a team of several educational institutions and disciplines (e.g., Burmeister & Eilks, 2013). Nonetheless, this project shows that it is worth investing this time and effort. For a future development of teaching, using the Participatory Action Research for higher education is seen as beneficial.

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