Chapter 2
The Blended Learning Concept e:t:p:M@Math: Practical Insights and Research Findings

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Abstract The chapter outlines the key ideas of the blended learning concept e:t:p:M® and its further development in the field of Higher Mathematical Education. e:t:p:M@Math aims to integrate digital technologies and face-to-face interactions to simultaneously allow personalized and high-quality learning. Both practical teaching experiences as well as research findings will be discussed. One focus is on the description of the self-developed and designed e-Learning environment, its possibilities and further development. Another focus is on the reflection of the practical implementation into everyday teaching, especially the integration with face-to-face seminars. In addition, first research insights will be presented and explained.

Keywords Blended learning · E-learning · Distance learning · Learning analytics

2.1 Introduction: Challenging Trends in Higher Education

In the winter term 2014/2015, the Federal Bureau for Statistics of Germany counted 2.7 million university students—a milestone in the history of the Federal Republic of Germany (SB, 2015). Given that only ten years ago there were far less than 2 million students (Bildungsbericht, 2014), the magnitude of this increase becomes even more significant. Many universities have adopted "bulk-instruction" with heterogeneous student groups and an unfavorable student-to-instructor ratio (Himpsl, 2014). In particular, high-demand introductory courses suffer under these problematic circumstances. Therefore, the quality of education is lacking and the need for reforms is apparent (Asdonk, Kuhnen, & Bornkessel, 2013).

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Since this situation is unlikely to change in the foreseeable future—neither nationally nor internationally (Dräger, Friedrich, & Müller-Eiselt, 2014; Maslen, 2012)—innovative teaching and learning concepts are necessary. In contrast to widely-discussed MOOCs, one very promising approach involves integrating regular class sessions with the opportunities of digital (Internet-) technologies (see Carr, 2012). One specific model that specifically aims at the integration of both class sessions and digital content is e:t:p:M®.

2.2 The Blended Learning Concept e:t:p:M®

e:t:p:M®[1] was developed as an introductory course in education in the winter term 2012 at the University of Education in Karlsruhe by Timo Hoyer and Fabian Mundt. Detailed information about the project and its theoretical framework can be found in Hoyer and Mundt (2014, 2016). The acronym, which indicates the individual parts of the project, are described in depth below.

2.2.1 "e" for E-Learning

The core of the e-learning content consists of 11 studio recorded *online lessons* that have been post-produced according to a creative framework. The lessons are all between 20 and 30 min long and are comprised of a speaker as well as info boards, images, animations and quotations. Additionally, the lessons are structured through so called "Fähnchen" (thematic headlines). The students can access the content via an especially for the e:t:p:M® project developed *responsive web-app* (Fig. 2.1).[2]

Personal annotations can be added to every "Fähnchen" and then downloaded as a PDF-file (Fig. 2.2). Furthermore, the web-app grants access to additional materials (texts, exercises etc.) and does not only contain general information about the class but also an extensive FAQ-area and the possibility to get in touch with the lecturers directly. The web-app also provides the user with a differentiated module for analysis that enables the teacher to track the students' interactions.[3]

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[1]Project website: http://etpm.ph-karlsruhe.de/demo/ [13.12.2016].

[2]The web-app was developed with the open-source frameworks Laravel, Vue.js, Semantic UI and Video.js.

[3]As a tool for analyzing the interaction, an adjusted version of the open analytics platform "Piwik" is used. All collected data is anonymized. The tracking function can be deactivated from inside the web-app, which is highlighted for the users.

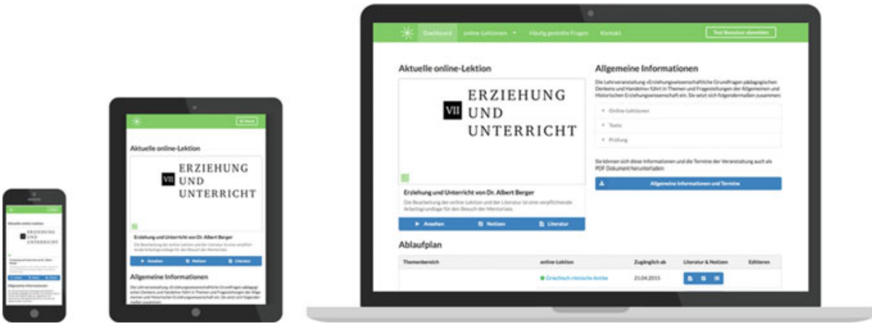

Fig. 2.1 The responsive web-app (original version)

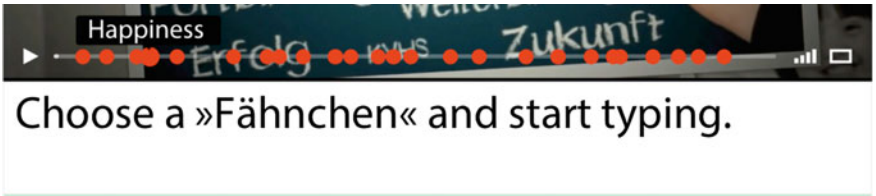

Fig. 2.2 The annotation function of the web-app

2.2.2 *"t" for Text and Theory Based*

Alongside every online lesson, the students are provided with a text that deepens the content (primary as well as secondary literature). In addition to suggested approaches to the text, the file contains questions that will be dealt with during the attended seminar. All texts are formatted uniformly and have been edited for the use in a seminar.

2.2.3 *"p" for Practice-Oriented (and Attendance-Oriented)*

The e-learning content of e:t:p:M® aims at a high personalization of the learning content as well as its integration into the seminars. The latter are comprised of information sessions (lecturers), FAQ-sessions (lecturers) and weekly mentoring sessions (student mentors) (Fig. 2.3).

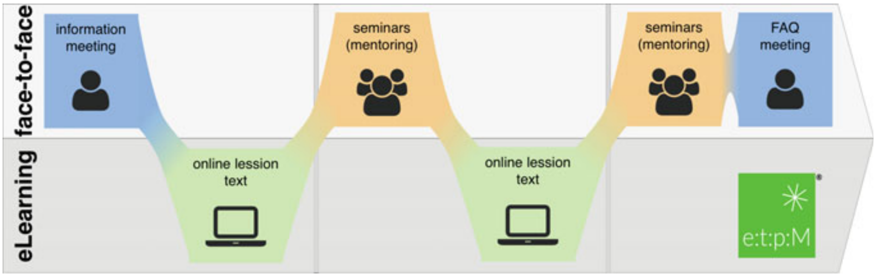

Fig. 2.3 The e:t:p:M® concept

2.2.4 *"M" for Mentoring*

Especially in the beginning of studies at university, the support and care for beginners is of high importance. In addition to subject-specific competences, the students need to acquire a sense to navigate the foreign academic world. In e:t:p:M® the class is separated into smaller groups who will be mentored by a tandem of older students during the semester. The mentors are trained in a specifically designed workshop and receive a certificate after completion.

The program received an award for extraordinary teaching methods in 2013 and was evaluated positively several times.[4]

2.3 Using e:t:p:M® in an Introductory Course in Mathematics

Based on the previously explained challenges for teaching at university and the very positive feedback towards the project e:t:p:M®, the concept is being adapted for other subjects outside the realm of pedagogy. At the moment, the authors work on applying the program to an "Introduction in Mathematics" course, which started in the winter term 2015 (Mundt & Hartmann, 2015). The current evolution of the concept is presented below. Since the contents are more historical and theory oriented, the application of e:t:p:M@Math requires adjustments. The online lessons and web-app, in particular, are being revised extensively to meet the requirements of mathematical learning.

The adaptation is informed and guided by "design-based research methodology" (Wang & Hannafin, 2005). Specifically, it is situated in a real educational context (mathematics introduction) and is focusing on the design and testing of significant interventions (e:t:p:M@Math concept) (see Anderson & Shattuck, 2012). As part of the design process, we refer to contemporary findings in the field of Higher

[4]http://etpm-dev.ph-karlsruhe.de/etpm-evaluation/ [13.10.2015].

Education eDidactics (Ertl, 2010; Kerres, 2013) with a special focus on mathematical learning in digitally supported environments (Aldon, Hitt, & Bazzini, 2017; Juan, 2011) and "User Experience Design" (Meyer & Wachter-Boettcher, 2016; Walter, 2011). In this text, we are concerned with the extensions of the web-app.[5] For this reason, we also include a review of existing blended-learning specific tools.

2.3.1 Existing Tools and e:t:p:M@Math Web-App

A review of the current literature and software shows that there are many blended learning concepts in the field of Higher Education, but only few explicit tools. Besides well-established Learning Management Systems like *Moodle*, *OpenOLAT* or *ILIAS* there are some more recent MOOC related platforms like *edX*. A more detailed overview of these and similar resources can be found in Spring et al. (2016) and Ma'arop and Embi (2016). All these solutions offer functionality for blended learning scenarios. Often, these tools require special plugins or add-ons (Kumari, 2016). They also often lack both a good user experience design and context-specific needs (e.g. for mathematics teaching), which goes hand in hand with the overwhelming functionality of the software (Persike & Friedrich, 2016). Hence, it is no surprise that there are also a variety of special and often well-designed tools in addition to the all-embracing systems. These range for example from applications which enable the creation of interactive videos (H5P[6]), deliver the opportunity to brainstorm online (MindMeister[7]) or create entire learning lessons easily (TES Teach[8]).

In contrast to this situation, the e:t:p:M@Math web-app is a blended learning-specific software. This means it integrates modern technologies and ideas, e.g. creating rich interactive video content, with the pedagogical aspects of the e:t:p:M® concept and context specific needs in mind. One example might be personalized annotations optimized for seminar use (see Fig. 2.2) or instant exercise feedback for teachers as outlined below. The web-app can be seen as a continuously developing framework in the sense of the design-based research, where interventions are repeatedly added, evaluated and improved. The web-app itself can also be seen as a research tool.

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[5]The web-app is developed in the sense of "Agile Software Development" (Dingsøyr, Dybå, & Moe, 2010), which fits perfectly with the design-based research methodology.

[6]https://www.h5p.org [10.7.2017].

[7]https://www.mindmeister.com [10.7.2017].

[8]https://www.tes.com/lessons [10.7.2017].

2.3.2 Research Questions

The review of the current literature and software showed that there is a lack of a well-designed blended learning specific software that integrates modern technologies in a tight didactical way and is also open for further research-based development. Out of this, our focus is on the following overarching question: *How can modern technology enabled options be implemented in the mathematical adaptation of e:t:p:M®?* The following sub-foci organize our discussion of our broad research focus:

(a) How can *interactive content* be integrated in the web-app?
(b) How can *discussions*—a key element of teaching and learning mathematics—be integrated in the web-app?
(c) How can *exercises and tests* be implemented?
(d) How can the teachers *modify and generate content*?
(e) How can student activities be tracked and reported for *continuous evaluation and improvement*?

2.3.3 Series of Interactive Content (Sub-focus a)

An online lesson is not only comprised of just a single video, but contains a series of shorter videos and interactive learning applications. This series of interactive content enables a more differentiated structure of the more abstract, mathematical learning contents. The interactions make it possible for the user to comprehend complex correlations on their own. Current versions of the video environment are shown in Figs. 2.4 and 2.5.

At present, we are considering about at least three different content types:

- Interactive videos
- Exploration exercises
- Test exercises

As you can see in Fig. 2.4 the video environment integrates these new ideas in the existing application. In addition, the concept of “Fähnchen” can be used in both the shorter videos and in exercises. In case of the exercises, the concept has to be adjusted, particularly through structuring each interactive exercise around several tasks. Each of these tasks can be visually and functionally highlighted by one “Fähnchen”. Thereby individual notes can be taken while solving the tasks.

To implement interactive exploration and test exercises the open-source software CindyJS[9] is used. CindyJS is a JavaScript implementation of the well-known interactive geometry software Cinderella (Richter-Gebert & Kortenkamp, 2012).

[9]http://cindyjs.org [13.12.2016].

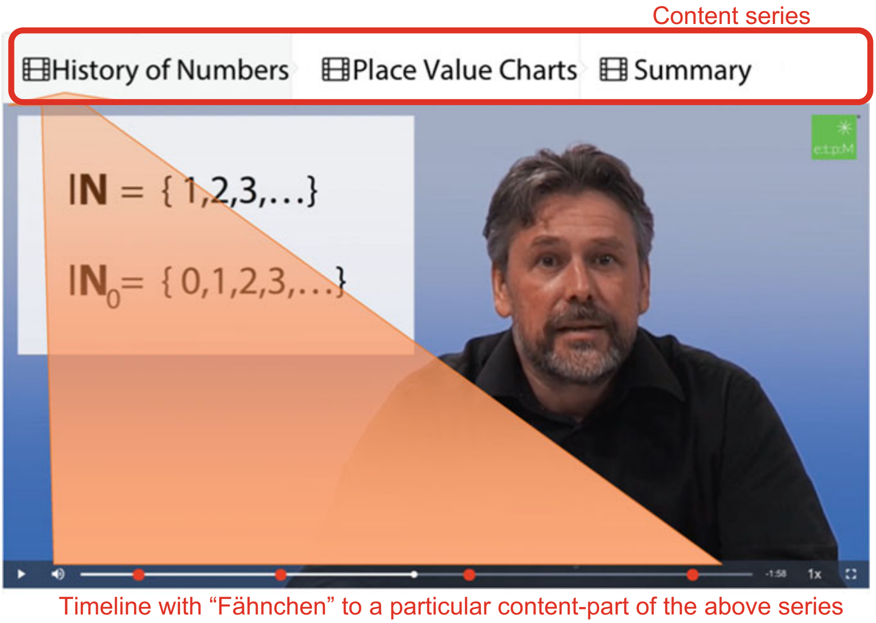

Fig. 2.4 Implementation of content series

The software is mainly used to connect with existing content. However, a modern JavaScript-framework also makes is possible to optimize the learning environment for modern devices, which is very important in the mobile world. Furthermore, it is possible to develop an intuitive content editor, which allows for quick and easy editing of the exercises (Sect. 2.3.4).

2.3.4 Discussions (Sub-focus b)

Especially in mathematics, controversial discussions facilitate learning and create a lot of questions. Hence, the annotations and the series of interactive content are supplemented by discussions. In the discussion forums, which are based on traditional online discussions, students can post questions and answers tailored to the corresponding "Fähnchen". Additionally, the students can 'like' the posts, and lecturers can highlight relevant questions or interesting postings. To keep matters clear, irrelevant postings will be faded out after a while.

Since 2016, we have been testing several forms of in-app discussions. Following the iterative implementation and evaluative paradigm of the design-based research approach we present here both, a first draft (Fig. 2.5) and the current version

Fig. 2.5 First draft of “discussions”-extension

(Fig. 2.6). As you can see in Fig. 2.6 we are using the popular disqus™ service at the moment. By using an existing service, we gain valuable insights for our own implementation. In addition to technical challenges, it seems important to develop a discussion format which integrates very well with the existing parts of the blended learning concept, particularly the interlink to the face-to-face seminars.

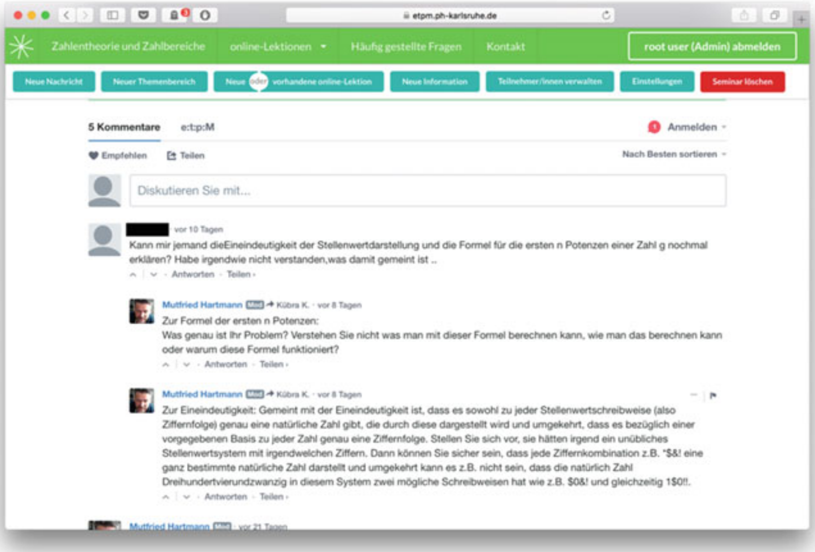

Fig. 2.6 Implementation of discussions (native web-app screenshot, see Fig. 2.8 for translated interface)

2.3.5 *Playground (Sub-focus c)*

Every online-lesson contains a summarizing event called “playground”. The playground consists of practice final exercises and interactions that can be scored in terms of understandability. Through that, a feedback loop is created that enables a focused learning process. Furthermore, a dynamic script can be generated. If desired, the personal annotations and discussions from the forum can be included at the respective place in the script, before it can be downloaded as a PDF (Fig. 2.7).

2.3.6 *Content Editor (Sub-focus d)*

In addition to functions that deal with teaching content, the easy creation and revising of online materials is an important point. Especially in the context of mathematical settings, where abstract ideas and their representation are focused, content production can become very intensive.

For this reason, we are working to extend the web app with an “editor mode”, which makes it possible to create rich learning content quickly and easily. On the one hand, this includes the possibility to add “Fähnchen” and interactive areas (links, graphs, pictures etc.) to video content. An elaborate postproduction is

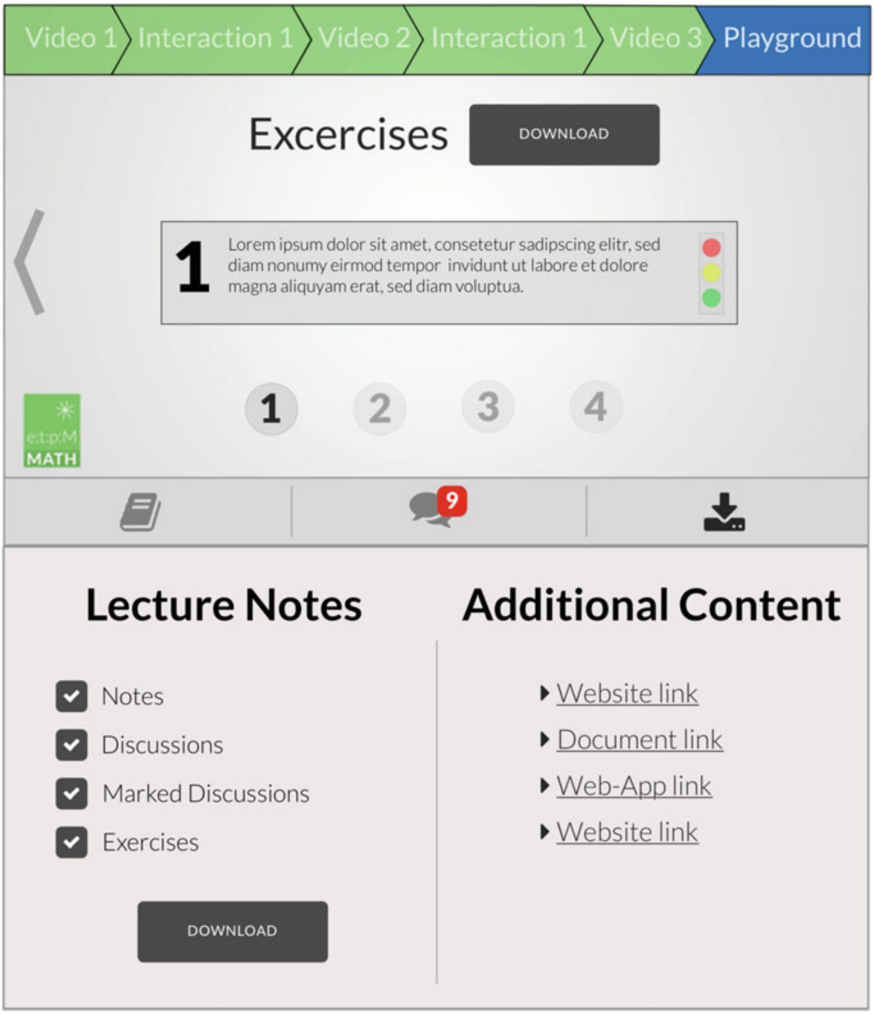

Fig. 2.7 First draft of the "playground"-extension

thereby reduced to the essential and the video content can be changed more easily. A great advantage is also that the teachers can do this by themselves. On the other hand, the interactive applications (exploration and test exercises) will be editable as well.

In this way, the web-app offers teachers the opportunity to create a comprehensive and modern learning environment, which reflects both the requirements of the mathematical subject and those of the learners.

Figure 2.8 shows the current development of the content editor.[10] We are trying to integrate the editor features seamlessly within the user interface. Teal-colored buttons highlight interaction possibilities, and the main features are bundled in the secondary menu bar. Following the agile development paradigm, we are implementing extensions continuously. At the moment we have implemented the following "main features":

- news message system
- FAQ system
- seminar management
- rudimentary online lesson management
- discussion system
- user management
- user role system
- integration in the university ecosystem through LDAP support
- integration of the open analytics platform Piwik (see footnote 3)

In other words, teachers are able to create and manage their own seminars. This includes the possibility to arrange existing online lessons or add new ones, manage seminar participants, upload documents, write news messages and manage discussions through a disqus™ service integration. Further, they can receive statistically prepared live analytics and configure the system setup.

Unfortunately, it is at the moment not possible to create new high-level online lessons without technical knowledge. The next step will be to develop the previously explained online lesson editor based on the already mentioned CindyJS and H5P frameworks.

2.3.7 Continuous Evaluation Strategy (Sub-focus e)

The series of interactive content, the discussions, the playground and the content editor mark the current state of the further development of the e-learning content of e:t:p:M@Math. At the moment, the program—in particular, the discussions and their integration with face-to-face seminars—is being implemented and evaluated. In addition to continuous web-based interaction analysis, we have planned an extensive survey in 2017, when more parts of the introduction course are implemented according to the blended-learning concept. Because we can relate both tools of our analytical framework—which is called "Blended Evaluation" (Mundt & Hoyer, 2017)—we expect to identify detailed learning profiles. In fact, we hope to obtain a solid empirical basis for further design-based decisions. In the following sections, we share some initial results, which focus the web-app interactions.

[10] The web-app project, called "Synthesise", is published under the MIT Open Source license. The code is available on GitHub: https://github.com/inventionate/Synthesise. Participation is welcome.

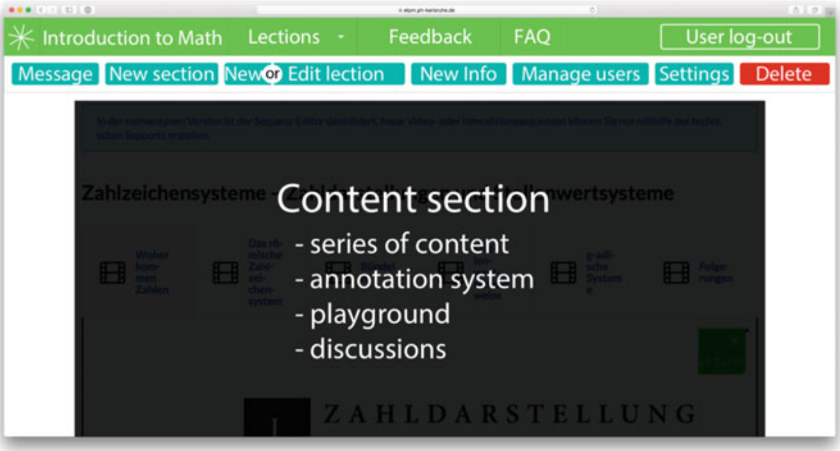

Fig. 2.8 First implementations of the content editor (web-app screenshot, translated)

2.4 First Insights of the Use in Winter Semester 2015/2016

The first three sessions of an "Introduction in Mathematics" course (October 2015 to November 2015) were organized in the e:t:p:M® format. Altogether, there were 168 students who attended the course. In this section, we will present some statistical analysis of the web-app interactions using *Learning Analytics*, which is described as "an educational application of web analytics aimed at learner profiling, a process of gathering and analyzing details of individual student interactions in online learning activities" (NMC, 2016). We are focusing on the web-interactions for two reasons. First, the introduction course is at this time only partly adapted. A comparative analysis, which allows conclusions on the student performance is therefore very difficult. As already said, this is methodically prepared as well as planned for future semesters (see Mundt & Hoyer, 2017). Second, the evaluation of web-interactions (Learning Analytics) provides important information for our agile development and design-based research process.

2.4.1 Evaluation Strategy and Questions

We begin by interpreting some core web-analytics data provided by our Piwik (see footnote 3) installation. Based on these singular insights we apply a more elaborate multivariate approach—the so called Multiple Correspondence Analysis (see Sect. 2.4.3 for additional details and references)—to visualize entangled relationships. In the sense of our design-based research methodology, we seek to identify indicators of particularly effective interventions and developments. In this context, two main questions are addressed:

a. How do students use the web-content?
b. Can web-interactions be condensed into interaction-profiles?

2.4.2 Usage of Web-Content (a)

Figure 2.9 shows the visitors of the web-app form October to November. After a period of initial curiosity, the tool has been used continuously. In particular, one day before the weekly seminars (mentoring), the online lessons were intensively watched.

More important than the number of visitors over time are their content interactions (clicks, movements, typed characters). For example, how long and how often videos were played seems to make a difference. In our case, the average playing time was more than 30 min per online lesson and they were often played multiple times (3–4 times). These data may indicate that there was much ‘done’ with the videos—and hopefully much learned.

Additional data also supports the conjecture regarding active student engagement. Overall, the online lessons were played more than 45,000 times, almost as often as they were paused. Nearly 35,000 times the students skipped parts of the video by using some “Fähnchen”. At least 14,500 annotations were made by most of the students.

Apart from traffic and interaction data there is some other interesting information. Looking at the above-mentioned challenge of digitization, it is appropriate to analyze the devices which have been used by the students. In the case of “Introduction in Mathematics”, 80% used ‘traditional’ desktop or laptop computers to access the web-app. 20% used ‘modern’ smart devices—10% used smartphones and 10% tablets.

Overall, it can be stated that the students have used the web content extensively. Even if no information about the performance of the students could be integrated, the amount of web-interactions, the time spent and the continuity of usage leads to meaningful insights for further research.

However, research methods which focus on the relationship between those particular aspects of content usage are even more useful. They enable the reconstruction of interaction-profiles, which allows well-informed didactical interventions as they are intended by the referenced design-based research methodology.

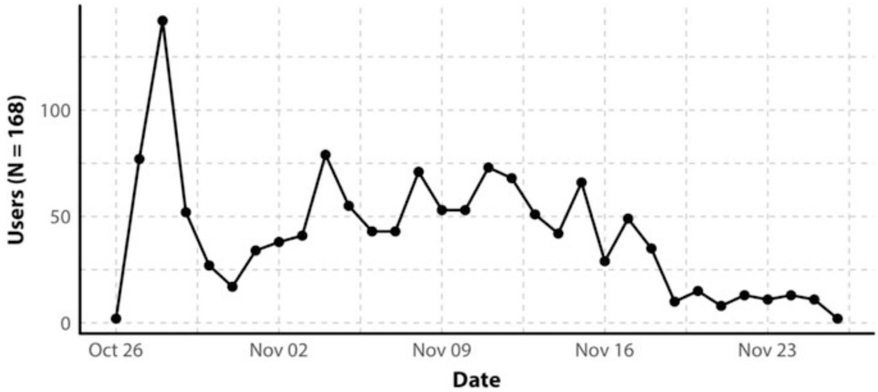

Fig. 2.9 Web-app users (October 2015 to November 2015)

2.4.3 Reconstruction of Interaction-Profiles (b)

In order to reconstruct rich interaction-profiles, we applied a *Multiple Correspondence Analysis (MCA)*. This is a multivariate statistical method, which belongs to a framework known as "Geometric Data Analysis" (Le Roux & Rouanet, 2010). In contrast to popular methods, e.g. Factor Analysis, geometrical methods are exploratory oriented, which is concerned with the construction of "social spaces". That is, an individual level is observed throughout the whole geometrical modeling process (see ibid). Especially in the case of a "Blended Evaluation," this property is of great advantage. It allows both the analysis of the position of each student as well as the reconstruction of group profiles (see Mundt & Hoyer, 2017). Within this chapter, we can only provide brief insights.

2.4.3.1 Dataset and Analysis Toolkit

The analyzed data refer partially to the previously mentioned values. Overall, the correlations between 12 interaction-variables are evaluated. These can be grouped under three headings:

1. Duration of web-app interactions overall (2 variables)
2. Amount of web-app interactions overall without video (5 variables)
3. Amount of video interactions in particular (5 variables)

All variables were categorized in order to be able to carry out an analysis which is as meaningful as possible. The two temporal variables (first heading) were divided into four categories: *very short* (0–7 h), *short* (8–13 h), *long* (14–23 h), *very long* (24–60 h). Likewise, the five web-app counting variables (second heading) as well as the five video counting variables (third heading) were divided in four categories. Web-app interactions are, as already mentioned above, mouse clicks, mouse movements and keyboard input. They were categorized in: *very few* (0–800 interactions), *few* (801–2000 interactions), *many* (2001–4000 interactions), *very many* (4001–20000). Video interactions (playback, pause, jump, speed change) were categorized in: *very few* (0–600 interactions), *few* (601–1800 interactions), *many* (1801–3300 interactions), *very many* (3001–9700 interactions). In total, the dataset consists of 12 columns (one per variable), 168 rows (one per student) and 48 categories (12 variables multiplied by 4 categories).

A standard MCA was performed on this dataset using the free statistical environment R (R Core Team, 2017). To be more specific, the Geometric Data Analysis related packages "FactoMineR" (Lê, Josse, & Husson, 2008) and "factoextra" (Kassambara & Mundt, 2017) were used. In the sense of open and reproducible science, all analysis scripts are available online.[11]

2.4.3.2 MCA Results and Interpretation

Figure 2.10 visualizes the MCA results as a biplot. Both the categorical locations as well as the corresponding positions of the students (grey points) are recognizable. This two-dimensional MCA solution clarifies 86.6% variance, which underlines the significance of the analysis. Usually, solutions over 70% are considered sufficiently meaningful (see Le Roux & Rouanet, 2010). In order to obtain the greatest possible overview, only the barycenters of the variable headings are mapped. For example, the position of "Amount of video interactions: many" results from the positions of the corresponding categories of the five variables of this heading and so on.

Looking at Fig. 2.10 it is striking that the location of the four categorical barycenters of all three headings are always arranged approximately the same. By connecting the points, a kind of parabola becomes visible. As a matter of fact, this effect is a well-known methodological artefact. It reflects the ordinal structure of the variables under investigation (Le Roux & Rouanet, 2010).

In terms of content, the so called "horseshoe-effect" (ibid.) makes clear that students who have a lot of interaction with the web-app and videos also have visited the app significantly longer than the other students. The respective categories are distributed ascending from left to right.

Reflecting the corresponding positions of the students (grey points) four more or less separated interaction-profiles can be identified. These profiles are linked to the temporal intensity and frequency of web-app interactions. Hence, it is almost impossible that people work considerably more with the video elements, but interact rather less with other elements of the web-app. Furthermore, it is noticeable that in particular the less-intense-user-profile is separated sharply (down left). This refers to approximately 25% of the students who have used the web content rarely, which can be interpreted as an indication of a skeptical attitude towards the concept. In contrast, there is a less clearly separated spread of approximately 75% positions

[11]https://github.com/inventionate/learning-analytics [11.07.2016]; especially file "mca_mathe.R".

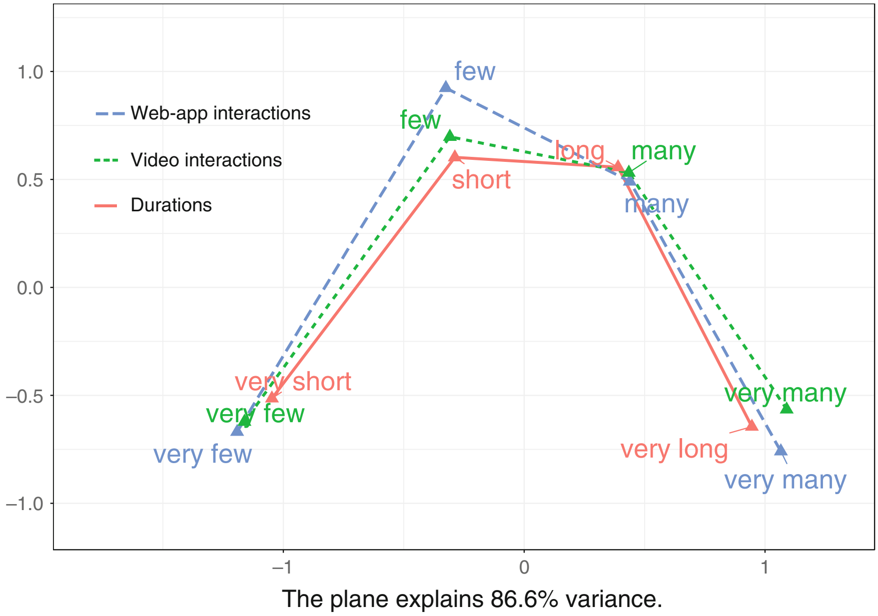

Fig. 2.10 MCA biplot on web-app interactions

along the other three categories (short/few to very long/very many). We have begun to outline three additional interaction-profiles, which can be attributed to a positive attitude towards the concept, and are related to a gradual distribution of the interaction intensity. These three interaction profiles appear to be fluid and permeable. Additional research is underway to further analyze the interaction profiles and their impact.

On the one hand, this analysis confirms the altogether intensive use of the web-app, which has been already discussed in the previous section. On the other hand, a more detailed description and understanding of this initial observation became possible through the Geometric Data Analysis.

2.5 Conclusion

Based on the results presented above, we argue that the high adoption progress clearly signifies the potential of the online system. Particularly, it indicates the potential of the mathematical adaptation of the established blended learning software. In combination with the previously gained experiences with the original e:t:p:M® concept and the ongoing optimization, we are very optimistic to be able to offer an outstanding mathematical learning environment, and especially one that allows for interesting empirical insights in mathematical learning processes. Our work continues, with currently research focusing on further analysis and evaluation, particularly of successful mathematical learning and its relation to the interaction profiles. Results of this work is forthcoming.

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