Co-Design and Use of Open Online Materials for Mathematics and Science Didactics Courses in Teacher Education: Product and Process

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1 Introduction

The design and use of online materials for learning have been in the spotlight of educational development over the last decade. Notions of blended learning (Bonk, & Graham, 2006) and flipping classrooms (Nwosisi, Ferreira, Rosenberg, & Walsh, 2016; O'Flaherty, & Phillips, 2015; Tucker, 2012) have given rise to an immense growth of online educational resources, that in many cases are the product of processes of co-design in teams of teachers, designers or researchers. These resources facilitate online learning, which is claimed to provide opportunities for increased educational quality, and for more flexible and effective learning (Garrison, & Kanuka, 2004; O'Flaherty, & Phillips, 2015).

To our experience, online learning is particularly gaining momentum with respect to courses that concern subject knowledge, such as courses on calculus in applied mathematics curricula, or on statistics for social science studies. With respect to didactical courses, however, we consider the potential of online and blended learning to be underused. This is probably the case because the transfer between didactical theory and teaching practice, so crucial in didactics courses, makes the design of such a course more complex and subtle. Also, the learning goals of didactical courses often include a mixture of skills, knowledge and attitudes, a mixture that is difficult to address in an online setting. A first challenge of the study presented here, therefore, is to address this complexity and subtlety through designing online learning units that

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facilitate the transfer from theory to practice, in this case for pre-service mathematics and science teachers.

A second challenge when designing online learning units is the time and energy needed to really produce them, particularly if the target group is relatively small and the budget and time for creating materials are limited. For courses in mathematics and science didactics in the Netherlands, teacher education is relatively small scale, and educators in many cases work in isolation and deal with high time constraints. Despite the existence of a successful cooperative network of Dutch STEM teacher education centres (ELWIeR-ECENT[1]), we observe that the development of the education of STEM didactics is under pressure and that new initiatives in this field are more than welcome (Verhoef, Drijvers, Bakker, & Konings, 2014). As a consequence, it seems logical to try to collaborate with different institutions when it comes to the design of online learning units. The second challenge addressed in the study, therefore, is how to enhance the co-design of online learning units for STEM teacher education across different teacher education institutes.

In this chapter, we address these two issues. First, how do we cope with the challenge of designing online learning units on mathematics and science didactics for pre-service teacher education? How are online learning units for pre-service teacher education for secondary mathematics in a blended learning context designed, implemented and evaluated? Secondly, besides these product-oriented questions, we are also interested in the ways collaboration took place: How can the process of co-design between teacher educators from different institutes be enhanced? To address these questions, we will describe the design, use, and evaluation of two online learning units for pre-service teacher mathematics education, one on mathematical thinking and the other on statistics didactics, as well as the co-design process. As a result, we identify transferable design heuristics and process model characteristics.

2 Theoretical Framework

The theoretical framework that guided this study includes two main lenses, one on online and blended learning, and the other on the co-design of learning units. We will outline them now, and next phrase the study's research questions.

2.1 Online and Blended Learning

Obviously, it is the responsibility of teacher education institutes to ensure that their students, being prospective mathematics and science teachers, not only master the domain knowledge, but also have the skills to adequately teach it. For instance, prospective teachers should be able to exploit the potential of information and com-

[1] See https://elbd.sites.uu.nl/ (in Dutch).

munication technology (Hegedus et al., 2017). In teacher education, the possibilities of online learning and blended learning in the domain of didactics nevertheless remain largely unexplored.

When addressing this responsibility, blended learning comes into play. Roughly speaking, blended learning means blending face-to-face education with online learning activities. Nowadays, more than twenty-five years after the introduction of the worldwide web as part of the internet (Berners-Lee, 1989), a staggering amount of digital resources for the teaching and learning of mathematics is available online. This leads educational designers and teachers to selecting, re-designing and arranging resources to orchestrate their students' learning (Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010). For the case of teacher education, however, and for courses on domain-specific didactics in particular, the affordances of blended learning remain largely unexplored.

In higher education, blended learning has been on the rise since the early 2000's. With respect to terminology, quite a few buzz words came along. In fact, one might wonder if educational goals have fundamentally changed since researchers from the University of Illinois in 1960 utilized a mainframe computer with work stations for their students for computer assisted learning, which they called Programmed Logic for Automatic Teaching Operations [PLATO, see Woolley (1994)]. Terminology evolved from computer-assisted (or-based or-supported) learning to intelligent tutoring systems (Anderson, Corbett, Koedinger, & Pelletier, 1995), E-learning (Clark, & Mayer, 2008), with blended learning as a popular teaching approach nowadays (Bonk, & Graham, 2006). In retrospective, all terminology boils down to roughly the same issue, i.e., how to arrange the educational resources—including information and communication technology—into an educational design that optimizes learning? What we appreciate in the term 'blended learning' is that it explicitly points at the fact that there is more than one medium to be addressed when designing instruction.

From the perspective of learning theory, scientific insights have evolved as well: from the behaviourist view on human learning (Skinner, 1954), suitable for computer assisted mastery learning (Skinner, 1958), to the nowadays accepted social constructivist view, as initiated by Vygotsky (1962), which can be supported by a more open learning environment. Blended learning is a technological paradigm that suits this view on learning and teaching.

A major didactical issue with respect to blended learning is how to arrange the interplay between online, web-based activities (Tolboom, 2004) and face-to-face activities, and how to design such arrangements. In the case of small-scale courses in mathematics and science didactics, it is important to keep in mind that position of such courses, content, size, and approach differ between the teacher education institutes. Also, each educator wants to be able to add a particular focus or flavour to it. Therefore, the online parts of the blended courses should be very flexible and offer opportunities to function as building blocks for adaptation to a particular course in a particular institute.

2.2 Co-design of Online Learning Units

Pre-service teacher education in mathematics and science takes place in different teacher education institutes in the Netherlands, and in many cases have a limited number of students. Besides this, the national curricula and pedagogical culture complicate the use of international materials. For these reasons, is seems beneficial that educators from the different institutes engage in a process of co-design to develop online learning units. Some researchers report persistent tensions in co-design teams (Kvan, 2000; Penuel, Roschelle, & Shechtman, 2007), but others point at good practices in other fields than education and formulate design guidelines for successful teams (Coburn, & Penuel, 2016). As is more often the case with new phenomena, there is some terminological confusion about what precisely co-design, or co-creation, or research-practice partnerships consist of. In this study, we are pragmatic in choosing the term 'co-design', and read it as 'a collaborative effort of a team of mathematics teacher educators in designing and developing learning units'. Some Dutch experiences with the co-design approach have turned out to be effective, such as the co-design of the handbooks of mathematics didactics (Drijvers, Streun, & Zwaneveld, 2012) and science didactics (Kortland, Mooldijk, & Poorthuis, 2017) and a series for bachelor teacher education (van den Bogaart, Daemen, & Konings, 2017). Also, a limited collection of online materials was designed and stored, and made available online as the Knowledgebase Mathematics (Staal, 2006). Co-design of online learning units, however, seems to become more common in higher education in the Netherlands (Baas et al., 2017), and connects to the phenomenon of co-creation in vocational education (Butter, & Schamhart, 2017).

The above experiences have shown that the co-design of educational materials can overcome its challenges and indeed may lead to high-quality didactical materials. As an important side-effect of engaging in a co-design process, we would like to point out the professional development reported by the participating teacher educators. The constructive, in-depth discussion of educational content and didactics, that is inherent in the co-design process, leads to increasing knowledge and skills among the participants, and to more coherent views on teacher education across the different institutes. As such, a co-design team may act as a community of practice (Wenger, 1998), in which knowledge and experiences are co-created and shared.

2.3 Research Questions

The challenges identified in the introduction and the above theoretical lenses lead to three research questions that the study presented here would like to answer.

1. Which features can be identified in the online learning units on mathematics and science didactics produced for teacher education?
2. How can a process of co-design, in which teacher educators design such online learning units, be organized?

3. How do educators and students experience the use of the online learning units that result from the design process?

3 Methods

3.1 Research Context

In 2013, new curricula in upper secondary education (grades 9–12) were implemented in the Netherlands for the natural sciences, and the mathematics curricula followed in 2015. These revised curricula included some new overall perspectives: for science, micro-meso-macro thinking was highlighted, whereas mathematical thinking was an overarching new element in the mathematics curricula. More specifically, in the mathematics curricula for pre-social science students, new approaches to statistics education were introduced, based on large data sets made available through the use of ICT. The crucial factor in curriculum innovation, however, is to make these innovations impact on classroom practice (Anderson, 1997; Fullan, 2007) and teachers play an important role in it. Therefore, teacher education institutes needed to reconsider their curricula as well. Also, most institutes for higher education in the Netherlands were considering forms of blended and online learning. From these perspectives, the study was the right thing to do at the right moment. It was a small, fourteen month project granted by the Dutch ministry of education and supervised by SURFnet, the collaborative organisation for ICT in Dutch education and research.[2]

3.2 Research Design

To address the three research questions phrased in the previous section in the available time frame, the project had the character of a design study with one cycle, consisting of three phases: an initial design phase, a field test phase, and a revision and conclusion phase.

In the initial design phase, participants were twelve teacher educators, six in mathematics and six in science teacher educations. Four design teams were set up. Each design team consisted of three teacher educators: one from the HU University of Applied Sciences, one from Utrecht University, and one from another teacher training institute in the Netherlands. The latter would facilitate dissemination and bring in a wider view. Most of the designers were experienced teacher educators, who had only limited experience with (the design of) blended learning resources. Within the design teams, some colleagues knew each other and others didn't.

[2] See https://www.surf.nl/en/innovationprojects/customised-education.html.

At the start of the project, it was decided to focus on two themes in the didactics of mathematics in secondary education that were relevant in the light of the curriculum reform: a more generic one on mathematical thinking and a more specific one on the didactics of statistics. Something similar was done with respect to science teacher education: as a general theme, we chose for micro-meso-macro thinking, needed to understand and use the relations between the observed scientific phenomena at the macro level, the models of the invisible particles at the micro level, and the intermediate meso level. As a specific theme in science, we chose the concept of warmth. Experiences with these co-design trajectories are out of the scope of this chapter.

As each of the designers had limited time for the project (about 40 h over the whole one-year period), the coordinating team—this paper's authors—decided to organize short, intensive collaborative "boot camp" design sessions. During the fall of 2016, three of such one-day boot camps were organized, during which the design teams engaged in their co-design, but informal exchange between teams was also possible. Camera teams were available, as well as tools such as light boards for the production of video clips. During the design process within the design teams, the educators brought in the materials they used in their own teacher education and collected freely available materials, as to build up a shared body of resources.

During these boot camp days, the different teams discussed overarching topics, such as learning unit layout and structure, and possible guidelines for use by teacher educators. During the design process, design heuristics and decisions were monitored. To address the first research question, design heuristics and decisions were observed, and the design process was monitored by this chapter's authors, as to evaluate the process of co-design and its organization. These experiences form the basis for answering the second research question. To facilitate ongoing collaboration and co-design in between the boot camp design meetings, a collaborative online design environment was set up.

Based on these criteria, we chose to use the Dutch online platform Wikiwijs,[3] an open platform for educational resources. Wikiwijs also offers extensive search options based on standardised metadata, which is expected to support the dissemination and use of the designed learning units. This ICT environment was hosted by Kennisnet, a Dutch semi-governmental organisation for ICT in education. In this way, a blended design approach was made possible.

Altogether, data in the initial design phase included the first versions of the online learning units, and field notes of the design process made by the researchers.

In the field test phase, the online learning units were field-tested in didactics courses by teacher educators all over the country, including co-designers and educators not involved in the design. Participants included fourteen educators, nine of whom actually field-tested (part of) one or more units, and their students. Out of the fourteen, nine were mathematics educators and five science educators, so mathematics is slightly overrepresented. To monitor these field-tests, the educators filled in an online questionnaire beforehand, to assess their intentions and ideas. After the field

[3] See https://www.wikiwijs.nl.

test, they received a second questionnaire to assess their appreciation of the units as well as the ways in which they used them in practice.

The pre-questionnaire focused on the educator's goals, impressions and expectations, whereas the post-questionnaire focused on their experiences and those of their students (see Appendix for the questionnaires). Initially, some more educators reacted to the emails, indicating that they were not able to pilot the learning units. Therefore, they have not been included in the data; in the meantime, such reactions show the educators' interest and the viability of this approach. The responses to the questionnaires were the main data source that were analysed to answer the third research question. To do so, the responses were coded with respect to the categories mentioned in the questionnaire itself, in a bottom-up, open approach. As the number of reactions was limited and the format was rather open, we were unable to carry out a confirmative coding process or to carry out an interrater reliability.

In the third phase, the revision and conclusion phase, the units were revised by the design teams, based on the feedback from the educators who field-tested them, as well as on the input by an external expert committee. Furthermore, the results were disseminated through different means (workshops, journal papers, and online media) and conclusions were formulated.

4 Results

In this section, we will discuss the study's results according to the three research questions.

4.1 Features of the Online Learning Units

The designed learning units for each of the four themes were published online under a *creative commons* license,[4] which implies that they are freely available for use.[5] For the design process, this required some care in using already existing materials or materials featuring persons not directly involved in the project, for example video data in which students are filmed.

A first important design heuristic that emerged during the design process concerned the way in which the learning activities were arranged and elaborated. To enhance their use in teacher education, we felt the learning units should not be standalone materials for individual use by the student, but rather should provide the teacher educator with autonomy and opportunity—as is the case when using a textbook—to include them in a teaching arrangement that does justice to the teacher educator's

[4] See https://creativecommons.org/licenses.

[5] The learning units are accessible from https://elbd.sites.uu.nl/2017/11/13/open-online-betadidactiek.

didactical expertise and intended role. This implies that the units should offer the possibility to easily incorporate (parts of) the materials into the learning management system used in the teacher educators' own institution. Also, the materials should allow for use in the arrangements the type of interactions preferred by the educator, such as in blended, face-to-face or online teaching formats.

As a consequence, the designed learning units do not provide ready-to-use and fixed learning trajectories, but instead suggest activities that teacher educators can use as building blocks for activities to be carried out with or by their students. As such, the online units serve two target groups: the pre- and in-service mathematics teachers, but in particular their educators, who have their own ideas for their courses but still need input to further improve them. The online available video materials and literature primarily aim at the former target audience, whereas the suggested activities are meant to serve the educators' needs.

For each of the four themes, the learning units share the same structure. For example, each unit contains a part entitled "For the educator", in which suggestions are provided for the use of the materials in a teacher training context, and a part called "Further reading", in which main literature resources on the topic of the unit are collected and made accessible to students through some annotations and reading guidelines.

Apart from the two overarching features of the learning units, namely the building block character and the shared overall structure, we wanted to provide the four design teams with as much freedom as possible to make their own design choices, also in the light of the project's explorative character. To give an impression of the resulting learning units, we will now briefly describe the two mathematics units.

4.2 Unit 1: Mathematical Thinking

The first case we describe concerns an open online unit about didactics for fostering mathematical thinking. Attention to this topic is evident in the international research community (Devlin, 2012; Schoenfeld, & Grouws, 1992) and was invigorated in the Netherlands by recent curriculum developments in Dutch secondary education. As one of the design team members also developed and taught a course on mathematical thinking as in-service training for teachers, there were already some materials and experiences that could serve as points of departure. As a result, the outlines of the online unit were quickly decided on. The unit was planned to consist of several self-contained student activities divided into three topics: (i) designing classroom tasks that stimulate mathematical thinking, (ii) supporting such classroom tasks in the classroom, (iii) assessing proficiency in mathematical thinking.

For the first topic's inspiration was sought in a key article by Swan, Van 't Hooft, Kratcoski and Unger (2005). This resulted in a set of materials, including a video clip, and a guide for teacher educators how the material could be used. An example from this set is a 'speed date activity' were students are asked to discuss in class differences

Fig. 1 An impression of the learning materials on mathematical thinking

between standard school book exercises and exercises specially designed to stimulate mathematical thinking and then to reflect on this activity in an online message board.

The second topic featured three series of three video clips, labelled A, B and C. Clip A showed two team members discussing the exercise before it was used in practice (see Fig. 1). They tried to predict what kind of thought processes the question would evoke in pupils. Clip B was filmed inside a school building. A pupil was asked to work on the set question, and was then interviewed about the strategies he or she had used. Clip C showed the team members again, but now they reflected on their experiences with the pupils. The film projects were placed on the website together with suggestions for use in teacher education. The suggestions involved a choice for the teacher educator. He could either just use the clips B together with digital copies of the exercises, or use the whole series of clips modelling how to discuss potential thought provoking questions. In the former case, his students can predict and reflect on the quality of the exercises in a whole-class discussion. In the latter case, students can be given the task to try it out themselves with other (e.g., self-designed) exercises in their own classrooms.

Besides these series of video materials, the second topic contained other resources such as several interviews with teachers and an expert about mathematical thinking in the classroom. The third topic centered around authentic pupil's materials, taken from high school assignment.

In retrospective, the most salient feature of this unit is the way in which the secondary school students played a role in the video recordings: for pre-service teachers, it is very important to acquire insight into the way students think, in contrast to their own thinking. Video materials and hand-written student work can be very

useful for that, combined with additional analysis and design tasks for the teacher-students. This provides us with a third important feature of online units for teacher education.

4.3 Unit 2: Statistics Didactics

Based on general ideas on exploratory data analysis (Tukey, 1977) and the analysis of large data sets through the use of ICT, the Dutch statistics curricula have been reformed recently. Therefore, statistics didactics is an issue in teacher education and this explains the choice for this topic.

It was noticed that many mathematics teachers, due to their education, only have limited knowledge about statistics and the new approach to it. Therefore, content knowledge should be added to the learning units, intertwined with pedagogical and didactical lenses. Similar considerations were acknowledged in other design teams, and have led to the fourth feature of the learning units: it is important to take into consideration the specific content knowledge that is a prerequisite for a didactical approach, and to include opportunities for teacher students to extend their knowledge by adding knowledge components to the learning units that are essentially not didactical in character.

With this characteristic as point of departure, the design team decided to focus on two key aspects of statistics education, which on the one hand are expected to be beneficial to teachers' content knowledge, and on the other hand involve didactical challenges while teaching. The first focus is called Describing data and concerns data visualization, measurement levels and statistical literacy. The second focus is called Beyond data and concerns answering questions about a population based on a sample. Topics addressed here include correlation and causality, the interpretation of significance, and the meaning of confidence intervals.

In the design process, a mix was made of existing resources such as video clips, text books, research papers, and newly designed resources such as tasks for teacher-students and guidelines for the teacher educator, and dedicated video clips. On the one hand, it made sense to make use as much as possible from existing resources. On the other hand, the need was felt to have dedicated resources that fit well to the specific Dutch situation and curriculum. Figure 2 shows a still from a new clip on measurement levels made with light board technology. Figure 3 shows an extract of a dialog between Dutch mathematics teachers' Facebook group on a particular problem, which is used in the online learning unit to enhance discussion between students during the face-to-face part of the blended course. As an overall approach, misconceptions and confusion with respect to statistical and probabilistic issues served as interesting contexts to address content knowledge and didactics in this domain.

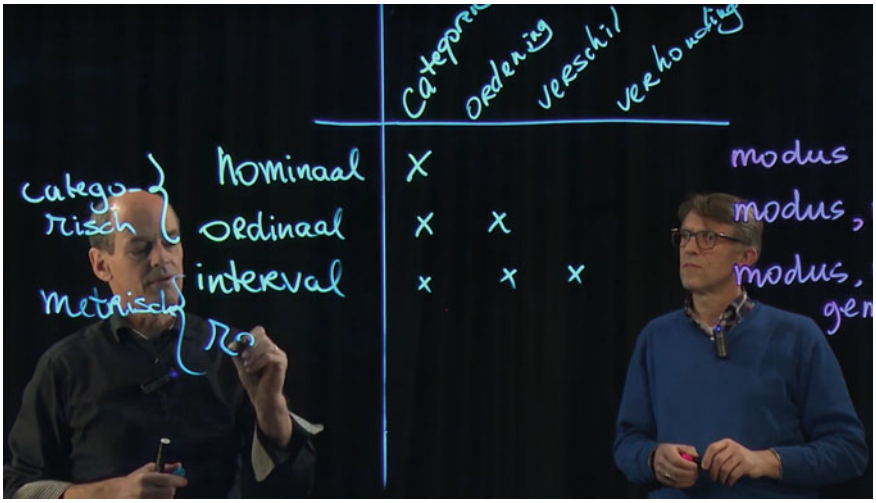

Fig. 2 Still from a video made with light board technology

Discussion starter: A
A question:
In a text book test, an item is: estimate the standard deviation, chose between 0.4, 1.4, 2.4, 3.4. The mean is 2.13. The corresponding graph is skewed to the right.
Can somebody explain to me why the answer is 1.4?
Response B: Just the information that the graph is skewed to the right does not justify one of the 4 responses. One has to see more in the graph, so please add the figure.
A: This is the part of the graph that should be used (out of a bigger picture)

Fig. 3 Screen dump of a dialog on the Dutch mathematics teachers' Facebook group

4.4 The Process of Co-design

The members of the design teams were acquired through an invitation letter to teacher training institutes. Teacher educators who reacted were contacted to align the purpose and goals of the project and the practical arrangements. As a next step, the authors formed design teams for each of the four topics, each consisting of four designers from different institutes.

To facilitate the co-design beyond face-to-face meetings, and to prepare for the online publication of the learning units, an important choice needed to be made with respect to the online platform to use (Tolboom, 2004). Different requirements played a role for the different target groups. A first requirement for the platform with respect

to the end users was that it would make the content freely available without any obstacles. In addition, it should present the multimedia content in an accessible and user-friendly way. Also, it should allow for online collaboration by the design teams. For optimal use for teacher educators, it should allow easy export to specific web-based learning environments (WLO) used in the different teacher training institutes, as well as adaptation within these WLOs. From the financial perspective, finally, we wanted to have a service without any costs, as to increase shared ownership, also beyond the participating teacher training institutes.

In an oral debriefing meeting, the educators indicated that taking part in the design teams had been a personal learning experience, both with respect to their knowledge of the subject matter and the didactics, as to the skills needed to design online learning units for blended learning, including the design of video materials. A limitation of the composition of design teams with members from different institutions, however, was the time needed to get to know each other and to develop a shared view on the topic of and the approach to the learning units. In short, the experiences show that the organization of the design process in small-size design teams of experienced educators enabled them to design rich online learning units, and, through their participation, to engage in a process of professional development. A pitfall may be that much time needs to be spent to developing an overall approach and too little to the actual design.

An important element in the design process was its organization in the boot camp days. During these days, the design teams intensively collaborated, with some plenary, cross-design team meetings to synchronize approaches. The design teams were themselves responsible for their style of working and were technically supported by video technicians. In this way, the design teams on the one hand were quite autonomous, which they appreciated, and in the meantime were encouraged to spend three full days outside of their regular working place to work on the project. Even though it was difficult to schedule these days in this extra-institutional environment, they seemed to be an important organizational factor. In short, the experiences show that the organization of the design process in sessions in which the design teams can collaborate intensively with full attention for the learning units is an efficient and fruitful way to design online units. The attendance of technical support lowers the barriers for the production of video materials.

4.5 Experiences from Teacher Education Practice

The main sources for the experiences with the learning units in teacher education practice are the educators' reactions to the pre- and post-field test questionnaires.

The reactions to the pre-test questionnaire show that there was greater interest in the learning units for mathematics than for science, which may be explained by the higher response from mathematics educators. The educators' first impressions of the learning units were positive: the subjects were considered relevant and the presentation was perceived as attractive. The video resources seemed to be the most

interesting content. It was appreciated that the units were flexible in that they could also be partially integrated in existing courses. As critical notes, some educators found the units too extensive, both in terms of content and of study load for students. Also, questions were raised on how to really "make a course out of the building blocks", and on the usefulness of the materials for teacher education for lower secondary level. Furthermore, even if the set-up of the units was appreciated, the materials still were not completed and in some cases looked somewhat provisional, which is not a surprise given the stage of the design process when the pre-questionnaires were send out. In the eyes of some of the educators, the learning units might have been more exciting and engaging.

Before the actual field-test, the educators described their goals to do so as to improve the mathematical and didactical content of their course, but also to bring in new dynamics, inspiration and examples that would be applicable in teaching practice. Beforehand, some educators expected to just use the learning units directly in the Wikiwijs platform, whereas others considered inclusion in their institute's WLO. In short, the pre-questionnaires show that the responding educators were very open to the ideas of the project and to using (parts of) the learning units in their didactics courses.

The post-field test questionnaire shows the actual use of the learning units in the educators' courses (see Table 1). Some educators used (parts of) two learning units. Again, Table 1 shows a dominance of mathematics didactics units, compared to the science didactics materials. Most of the units have been used in upper-secondary teacher education. This may be because educators found them more suitable for that than for use in lower secondary education. Our conjecture, however, is that this is mainly caused because of an over-representation of upper-secondary educators in the sample.

The educators' opinions after use were not very different from their impressions beforehand, and overall were positive. Even if improvements on a detailed level were possible, and suggestions for that were provided, and the comments depended on the different units, the educators found them useful for their teacher training practice. Layout, global approach, and accessibility were the suggestions that were most frequent. The learning units could be studied by the students independently. This being said, the educators did struggle with finding ways to embed the online learning units in their courses for different reasons: face-to-face teaching time was limited and it was not easy to decide what to do in the meetings and what to leave over to the online activities. Also, there were existing course materials, and the fine-

Table 1 Number of field tests per learning unit

Learning unit	Number of courses
Mathematical thinking	4
Statistics didactics	4
Micro-meso-macro thinking	2
Warmth didactics	1

tuning between different resources was not always straightforward. Therefore, the actual way to use the learning units in most cases concerned using (part of) it to in the course meetings and leave other parts as online take-home tasks, the results of which for example needed to be uploaded in the students' portfolios.

Most educators were happy with achieving their initial learning goals. This satisfaction not only concerns the learning units, but also the way in which they were used in the frame of the courses, and the suitability for the target group of students. Some of the educators also asked their students to react to the learning units and the results were positive, in particular with respect to the online video resources and the options for variation in activities that the online units allowed for. Students appreciated the freedom to explore the content of the units. Concerning the technical aspect of the integration, most educators provided their students with hyperlinks to the units in the Wikiwijs platform and didn't feel the need to include them in their institute's WLO, even if some educators chose the latter options without any technical problems. Some educators also visited the units in whole-class sessions, for example on the interactive white board.

In short, the educators' responses to the questionnaires and the input by their students suggest that the experiences in using the online units in the institute courses are positive. Probably the most important success factor is the availability of new types of resources and activities that are suitable for students to work on online as part of self-study or homework.

5 Conclusion and Reflection

To address the issue of the co-design of online learning units for mathematics and science teacher education, three research questions were phrased, which we will now revisit. After that, we will reflect on the findings and on possible future steps.

The first research question concerns the features of the online learning units on mathematics and science didactics produced for teacher education. An important finding is that the online units cannot and should not consist of ready-to-use materials, but rather can only contain building blocks for courses that will be further tailored to the educator's ideas. Indeed, teacher educators are used to design their courses in relative autonomy, and want to be able to fine-tune their courses to the target group at stake. Furthermore, some general design heuristics are identified. One is to use the power of video recordings of students working on tasks, and to use them to make teacher-students reflect on possible didactical interventions. A second heuristic is to consider the subject knowledge that is a prerequisite for didactical analysis and intertwine content knowledge and didactical knowledge in the learning units, as to avoid the hindrance of content knowledge deficiencies. Third, it was important to keep in mind the two different target groups: the student teachers and the teacher educators, and to produce learning units that fit both. To summarize, the building block approach was fruitful, the presence of students was an important feature, and the different target groups deserved attention.

The second research question was how a process of co-design, in which teacher educators collaboratively design such online learning units, can be organized. The blended approach of on the one hand intensive joint design meetings, the so-called boot camp days, and on the other hand the distant co-design, made possible by the digital platform, has shown to be a fruitful one. Scheduling design sessions during which teams can collaborate for several hours with full focus on producing materials made it feasible to construct digital blended learning units in a short time span. Readily available technical assistance during these sessions lowered the barrier for producing film clips. It resulted in both rich learning units and processes of professional development within the design teams. The composition of these teams, including different levels of expertise, worked out well. The technical facilities, both for distant collaboration and for the production of video resources, facilitated the co-design process. A drawback of using mixed teams is that people need time to getting to know each other and to form a joint vision on the subject at hand. Although this is important for a fruitful collaboration, care must be taken that teams dwell too long in this phase. To summarize, small design teams of experienced teacher educators from different institutes leads to boundary crossing between institutes, resulting in (i) rich material and (ii) professional development of the educators themselves, although a pitfall is that (iii) too much time may be spent on discussion rather than on the actual design.

The third research question was how educators and students experience the use of the online units that result from the design process. The pilot field tests in the different teacher education institutions have shown that both educators and students appreciated the online learning units that resulted from the co-design as interesting and useful. Even if the units have clear limitations, which are no surprise in the light of the design conditions, they overall were perceived as inspiring. Educators noticed that, as a result from the design heuristic to design building blocks rather than ready-to-use courseware, the actual use of the materials in their courses required considerable time and effort, and that the overall study load of the units for students was high. To summarize the findings on this question, we conclude that the experiences are encouraging, but that more time might be needed for designers to finalize the design and for educators to prepare their incorporation in their courses.

Of course, these conclusions need to be considered in the light of the limitations of this small-scale and short-term project, which covered a period of 14 months. In spite of these limitations, we can extract some suggestions for future work. A first step is to further disseminate the results and to take care of their sustainability, for example, through the website of the mathematics and science educators community represented in ELWIeR/Ecent, and by setting up an editorial board to deal with new submissions. Furthermore, a next step might be to further investigate how teacher educators can continue to engage in the co-design of teaching materials, based on these and newly developed resources. In this way, they can develop professional expertise in the field of online learning and contribute to the community.

Appendix: Pre- and Post-field Test Questionnaires

Pre-field Test Questionnaire

1. Which learning unit do you intend to use in a course mathematics didactics?
2. Do you already have an impression of this learning unit and if so, could you describe it? Relevance, consistency, usability? Content, design, appearance?
3. In which subject and for which target group will you use the learning unit? Size in ECTS[6]? In what period?
4. What are the goals you hope to realize with the deployment of the learning unit? What expectations do you have? In what need the learning unit can hopefully provide?
5. How are you going to tackle this?
    a. Technically: refer to the online learning unit, or import parts in your own web-based learning environment?
    b. Practical: replace parts of the existing course, as additional material, as part of homework, as part of assessment? In what way do the students will work with the learning unit?
    c. Content: which content parts of the learning unit do you intend to use?

Post-Field Test Questionnaire

1. Which of the learning units did you use in your course didactics of mathematics?
2. What is, looking back, your opinion about this learning unit? Relevance, consistency, usability? Content, design, appearance?
3. To what extent have the goals you hoped to achieve with the deployment of the learning unit actually been achieved?
4. How did you use the learning unit:
    a. Technically: refer to the online learning unit, or import parts in your own web-based learning environment?
    b. Practical: replace parts of the existing course, as additional material, as part of homework, as part of assessment? In what way do the students will work with the learning unit?
    c. Content: which content parts of the learning unit do you intend to use?
5. How did the learning unit please the students? Were there any positive or negative reactions?

[6]European Credits Transfer System "is a credit system designed to make it easier for students to move between different countries". See https://ec.europa.eu/education/resources-and-tools/european-credit-transfer-and-accumulation-system-ects_en.

6. Do you have assignments to share with us that were given to students regarding the learning unit? Do you have students' work with respect to these assignments to share with us?

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