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Math MOOC UniTo & MathCityMap - Exploring the potentials of a review system in a MOOC environment

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During CERME10 in Dublin, a collaboration between the University of Turin and the University of Frankfurt has been initiated. The outcome was a module of a Massive Open Online Course (MOOC) for in-service teachers to improve mathematics teaching by creating outdoor math trail tasks for their students with the help of MathCityMap (MCM). MCM is a digital tool to create, manage and run math trails with mobile devices. Teachers had to create math trail tasks that were in line with previously defined task design guidelines to complete the MOOC module. An expert review system was used to improve and ensure material quality. The involvement of the teachers, the efforts of the reviewers and, in general, this collaboration have given satisfactory results that will be presented in this paper.

Keywords: MOOC, MathCityMap, teacher education, expert review system, material quality.

Introduction

Since October 2015, the Department of Mathematics “G. Peano” at University of Turin, Italy, has been engaged in an innovative initiative: the *Math MOOC UniTo* project (cf. Taranto et al., 2017). The project provides MOOCs (Massive Open Online Courses) for Italian in-service mathematics teacher education, with the use of the platform DI.FI.MA. (<http://difima.i-learn.unito.it>), a Moodle platform, managed by the mentioned department, where more than 2,500 Italian teachers of all school types are enrolled. The aims of these online courses are to cover the main topics in the official Italian programs for secondary school (Arithmetic and Algebra, Geometry, Relations and Functions, Uncertainty and Data) from a mathematical, didactical, and methodological point of view, and to give teachers an opportunity for professional development at the national level. So far, three MOOCs have been delivered: *MOOC Geometria* (based on geometry contents, from October 2015 to January 2016); *MOOC Numeri* (based on arithmetic and algebra contents, from November 2016 to February 2017) and *MOOC Relazioni e Funzioni* (based on relations and functions contents, from January 2018 to April 2018). In the following, we concentrate on the last one, which we will indicate as *MOOC Rel&Fun* in the following.

During CERME10 in Dublin, some team members of the MOOC Rel&Fun became acquainted with the *MathCityMap* project (MCM). This project has been developed by the Goethe University of Frankfurt, Germany, and enables teachers to implement smartphone supported mathematical trails in mathematics classes. One key feature is the MCM web portal. It allows teachers to easily create tasks in their local surroundings and therefore fits well into a MOOC for teacher education, since the MOOC-teachers learn necessary skills online and can directly apply them by creating tasks in their environment. A collaboration between these two projects was established with the intention to

provide an innovative approach to teach the mathematical contents of relations and functions in the real world with the support of technology on the one hand. On the other hand, the MCM project (including the math trail idea) is an expanding project and it was worth introducing and disseminating it in Italy. This paper aims to report outcomes and examples of mathematical tasks created by MOOC-teachers according to MCM task design guidelines, as well as to explore potentials of an expert review system as one way to ensure task quality in a MOOC environment.

Theoretical framework

Mathematics trails

Blane and Clarke (1984) were among the first ones to present the mathematics trail idea to a broader scientific audience. According to Shoaf, Pollak and Schneider (2004, p. 11), math trails are accompanied by a trail guide booklet showing mathematically interesting places and tasks, usually including a map, for the user to follow. A meta-analysis on outdoor learning indicates that students do not only remember fieldwork and outdoor visits for many years, but also the experience of outdoor learning is considered “more effective for developing cognitive skills than classroom-based learning” (Dillon et al., 2006, p. 107). Students need to understand the problem, find an appropriate mathematical model, collect data, work mathematically and validate and discuss their answer. These activities come close to the modelling cycle as described by Blum and Leiß (2005) and help to promote modelling.

The mathematical contents depend on the tasks that a math trail offers. Problems in the field of geometry and measurement are obvious, since many geometrical forms shape our environment. Nevertheless, it is possible to find many tasks in the other content fields of mathematics. In contrast to original trails, math trails at school are not voluntary; they are mostly prepared by teachers for their students with a focus on a certain topic and are subject to organizational obstacles. Since the available time is usually set by lessons of a certain period (e.g., 45 or 90 minutes) and the learning group consists of about 20 to 30 individuals, it is necessary for the teacher to structure the math trail activity well to be a success. There are many aspects a trailblazer has to consider while creating a math trail. For this reason, task design guidelines, which are presented in a following paragraph, have been formulated to help authors generate material with high quality.

The MathCityMap project

The MathCityMap project combines the idea of math trails with the possibilities of web technologies and mobile devices (cf. Gurjanow, Ludwig & Zender, 2017). With the help of the MCM web portal (<https://mathcitymap.eu>), teachers can digitally create and manage tasks and trails. Furthermore, the web portal offers task templates, many public tasks, and the possibility to automatically generate a PDF math trail guide. The purpose of the MCM web portal is to make the challenge of creating a math trail more convenient. It is available in eleven languages (Italian included, thanks to the collaboration born with Math MOOC UniTo). The MCM application for smartphones is a digital math trail booklet that uses GPS to display the tasks position on map and presents the task to the users. Additionally, users benefit from a stepped aid system, in case they get stuck and an automatic feedback system that evaluates entered answers. The app is meant for persons (e.g., students) who would like to walk a math trail.

MCM content quality assurance

“Carefully designed classroom tasks can be a powerful tool for enhancing the quality of math and science teaching, influencing the classroom culture and fostering students’ learning” (Maaß et al., 2014, p. 8). This is also the case for math trail tasks, since they constitute the core of the math trail activity. Web communities (e.g., Wikipedia or GeoGebraTube) that allow users to create content in general face the issue of maintaining quality standards. Peer or expert reviews are a common way to ensure quality in academic papers and material produced by different authors (Price & Flach, 2017). MathCityMap implements an expert review system to maintain a high quality of published tasks and trails. Experts are selected for each participating country. They are often experienced teachers or academics from the field of mathematics education who are well informed about specific circumstances of mathematics teaching in their respective country. The experts may decide if the task or trail meets the quality criteria and accept the publication or, if revision is needed, they decline the publication with a message, indicating necessary changes (cf. Jablonski, Ludwig & Zender, 2018). Published content can be viewed and accessed by all visitors or app users.

Task design guidelines have been formulated to help new authors and to ensure a good user experience. These guidelines are the basis of the MCM review system. The first set of aspects is derived from popular published math trails like “A mathematics trail around the city of Melbourne” (Blane & Clarke, 1984), “Maths Trailing in Dorset” (Ashworth, Cobden & Johns, 1991, p. 7) and from a more general description on how to create math trails by Shoaf et al. (2004, p. 10) and the British Association of Teachers of Mathematics (1991). The first collection of task design guidelines that come from the intersection of all of these sources, deals with the challenge of creating outdoor tasks.

1. Uniqueness. Every task should provide a picture that helps to precisely identify the situation, the object of the task and what the task is mainly about.
2. Attendance. To solve a task, the user should have to be present, therefore the task data can only be obtained locally. This also means that a picture and description of a task should never be enough to expose the solution.
3. Activity. The one who solves the task must be active in some way (e.g., measure, count or sketch).
4. Multiple solutions. The task should be solvable in various ways.
5. Reference to reality. “Problems that arise naturally from the situation are best” (Shoaf et al., 2004). The task should not appear too artificially.
6. Tools. The tools that are required to solve the task should be noted on the trail guide. In general, you should not expect people to bring extraordinary tools.

The second set of aspects deals with challenges of mathematics trails as a teaching method. After preparing the math trail the teacher steps back in a passive role, while students actively discover the trail in small groups. To support the groups in case they cannot find an approach to solve the problem, the MCM app provides a stepped hint system.

7. Stepped hints. Every task should provide at least two hints.
8. Sample solution. Authors should provide an elaborated sample solution including measured data.

Research Question

In the MOOC Rel&Fun, as regard the use of MCM, MOOC-teachers were invited to generate math trail tasks connected to the topic of relations and functions. In order to improve material quality, Maaß et al. (2014) recommend that teachers should experience and reflect new tasks themselves prior to develop own material. However, for their nature, the math trails are bound to particular surroundings. It leads to the fact that MOOC-teachers were not able to experience MCM math trail tasks before designing their one, since the existing Italian tasks were - at that time - few and only located in Turin (where the MOOC team worked). Nevertheless, it was a main concern of the module to produce tasks that are in line with the task guidelines. This leads us to our research question: *What are advantages and disadvantages of an expert review system to ensure material quality?*

Methodology

MOOC Rel&Fun, like those who preceded it, is open, free, and available online for teachers on the DI.FI.MA platform. It consists of modules with a duration ranging from one to two weeks. Each module requires the performance of a task. Once the task is executed, the platform releases a badge¹. The users have time to perform the task from the beginning of the module in which it is inserted, until the closing date of the MOOC. The MCM module started in the fourth week of the MOOC Rel&Fun and lasted 2 weeks (since MOOC Rel&Fun lasted 11 week in total, the MOOC-teachers had 7 weeks to be able to accomplish the task provided by the module). As already mentioned above, the aim of the module was to learn how to use a new technology (MCM web portal and app) to create a math trail task on the subject of relations and functions. In the following, we explain in detail the integration of MCM into the MOOC Rel&Fun. In particular, we refer to *German team* meaning the MCM members, while with *Italian team* we mean the MOOC Rel&Fun members.

The MCM module begins by sharing the theoretical and technical aspects of MCM with the participants. The German team made a video in which they illustrated the spirit of the MCM project to the MOOC-teachers. The voice output was in English. The Italian team added Italian subtitles. Subsequently, it was necessary to make the MOOC-teachers autonomous to work with MCM, namely, allow them (i) creating new tasks; (ii) compiling a new trail; (iii) using the MCM app to walk a trail. Therefore, for each of these points a video tutorial was necessary. Both the teams agreed that for these videos the voice should be in Italian. So, the German team prepared English transcriptions and the Italian team added the voice to the mute tutorial videos made by the German team. Having clarified the technical details, it was time to show some examples to the MOOC-

¹ Digital badges are a validated indicator of accomplishment, skill, quality or interest that can be earned in various learning environments (Carey, 2012). In the case of our MOOC, they are created by a course administrator and then they can be issued automatically by the platform each time the user accomplish the tasks required within the module.

teachers. In the web portal, there were already some tasks, but they were mostly in German or English. A few months before the start of the MOOC, in October 2017, the German team visited Turin to explore the city with the Italian team. They together created and implemented some Italian tasks in the web portal. Subsequently, the Italian team prepared some Sways², where the methodological and mathematical details of each task were explained. In addition, a card with the criteria for designing a good task (task design guidelines), formulated by the German team, has been loaded onto the platform available to the participants. In this way, the teachers had high quality examples to take inspiration from and all the information needed to perform the module task. This one consisted of (i) creating a math trail task on the web portal on the topic of relations and functions; (ii) requesting publication of the task through the review process; (iii) sharing the link of their public task on a specific repository created in the MOOC module. Only three members of the Italian team were responsible for reviewing the MOOC-teachers' math trail tasks. They could directly approve the task for publication if it complied with the task design guidelines. Otherwise, they declined the publication by sending an e-mail to the MOOC-teacher through the MCM review system explaining the reasons for the refusal. The data on the review effort was gathered from the MCM review database. It stores each review that was performed by each Italian reviewer and links it to a particular task. The module ends with a questionnaire that intends to investigate the MOOC-teachers' satisfaction level on MCM and their intention to use it again with their students.

Data analysis

There were 358 enrolled teachers in MOOC Rel&Fun. As far as the MCM module is concerned, 287 tasks were created by the MOOC-teachers. 257 of them were added to the review system. Among these, at the closing of the MOOC, 231 tasks (90%) were considered to meet the task design guidelines and therefore got published. The Italian team performed 396 review processes (multiple reviews until publication of a task are possible) to ensure content quality. The MCM review database shows that among the 257 tasks that were submitted to get published, 119 (46%) tasks matched the MCM task design guidelines on their first review, 138 (54%) tasks did not. The MOOC-teachers revised 112 out of the 138 (81%) declined tasks according to reviewers' feedback and were later on published. In reality, the situation has been a little more complex. The tasks that were directly accepted were not always in line with the design criteria, so there were less than 119 tasks that matched task design guidelines on the first review. The Italian team has indeed noticed this: when they immediately declined the tasks, the MOOC-teachers not always revised and submitted their tasks again for review. Instead, when reviewers sent feedback with a request of revision without declining the task³, the MOOC-teachers made the changes and the reviewers could approve their task like if these revised tasks were their first submission. However, unfortunately, we are not able to exactly quantify this data.

In the following, we indicate the common errors identified by the Italian team for declining the MOOC-teachers' tasks.

² Sway (<https://sway.office.com/>): Microsoft tool that allows users to combine text and media to sustain the showing of online content.

³ Sending personal emails, like the MOOC team used to do for other commitments in the MOOC (i.e. soliciting the MOOC-teachers to get the badge of the modules, ...).

| <i>Most common errors</i> | <i>Less frequent errors</i> |
|--|---|
| Instruction of the task unclear or ambiguous, namely in the same task there was more than one question | picture related to the task unclear and not always shared according to the indications |
| No indication of the unit of measure in the task instruction | incorrect geolocation ⁴ |
| Solution provided without the data collected or without the calculations made ⁵ | inserting the entire solution in the hints |
| If the solution was expressed by a range of possible values, this range was not always indicated in a plausible manner | inserting more than one hints in the space that is generally dedicated to a single hint |
| Solution difficult to read because the text editor was not used ⁶ | create the task inside the school premises ⁷ |

Table 1: MOOC-teachers' common errors designing a math trail task with MCM

We now show an example of activity that has been published. The task in Figure 1 was created by a teacher from Lecco (a city in Northern Italy) for students of grade 11.



Figure 1: Pendulum equation as a function of time

- $s(t) = 0,94 \cdot \sin(360^\circ t / 2,33)$
- $s(t) = 1,88 \cdot \sin(360^\circ t / 2,33)$
- $s(t) = 0,94 \cdot \cos(360^\circ t / 2,33)$
- $s(t) = 1,88 \cdot \cos(360^\circ t / 2,33)$

Figure 2: Solution as a multiple choice

This is her delivery: “Starting from a position that forms an angle of about 44 degrees with the vertical, determine the equation that describes the displacement by the swing, as a function of time, while it oscillates. The units of measurement to be used are the meters and the seconds”. The teacher chose to represent the solution as a multiple choice (Figure 2) and inserted three hints: (i) a YouTube video (<https://goo.gl/dqJuMH>); (ii) an image (Figure 3); (iii) a sentence: “Calculate the amplitude of the movement (maximum displacement) and the time of complete oscillation”. She indicates that the tools needed to solve this task are the folding ruler and the calculator. She also clearly describes the procedure she followed for the resolution.

⁴ someone had put the Mole, a typical monument of Turin, in Switzerland

⁵ someone was looking for the monuments data on the internet, so he did not actually go there in person to find the data

⁶ i.e. m2 instead of m² to indicate the square meters

⁷ if on the one hand this was done for security reasons related to the responsibilities that teachers have on their students when they propose activities outside of the school; on the other hand, in this way, the possibility of making the task accessible and usable by anyone is lost.

“I moved the swing to form an angle of about 44 degrees with the vertical (Figure 4). I measured the length of the wire and I got 1.36 m. Taking advantage of the stopwatch of the phone I measured the time it took the swing to make one full oscillation. I repeated the same operation three times and I calculated the average time. So, I got that to make a complete oscillation it takes 2.33 sec. I calculated the maximum displacement $A = 1.36 \cdot \sin(44^\circ) = 0.94$. Finally, I wrote the pendulum equation as a function of time: $s(t) = 0.94 \cdot \cos(360^\circ \cdot t / 2.33)$ with t in seconds”.

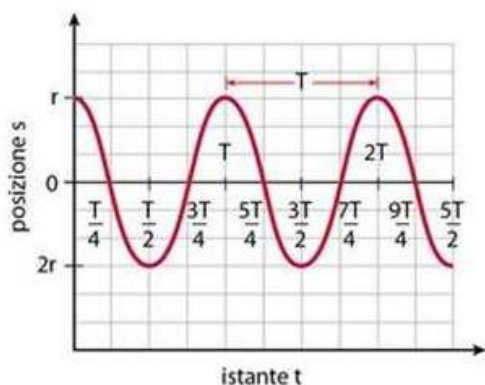


Figure 3: Second hint



Figure 4: Explanation of the solution

Discussion and Conclusion

The collaboration between Math MOOC UniTo and MathCityMap was a success. MOOC-teachers were very engaged and created almost 300 math trail tasks all over Italy. 142 MOOC-teachers completed the questionnaire inserted in the MCM module and the 76% of them were satisfied with the module contents and would recommend MCM to colleagues. Although the MCM module provided tutorial videos, as well as best practice examples and explicitly formulated task design guidelines, not all and not immediately were able to meet the task of the module. The review phase was indeed challenging and demanding. In fact, if we consider the data of the MCM review database, only 46% of the created tasks met the task design criteria. The expert review system helped to improve a total of (at least) 112 tasks (44%). At the end of the module, 90% of the tasks were considered good quality and allowed their respective authors to obtain the desired module badge. The quota of revised tasks (112 out of 138, 81%) is remarkably high and shows that teachers accepted and appreciated the expert feedback. In general, teacher education that aims to improve mathematics classes through high quality material, especially those that want their participants to create own material adapted for their students, need to take care of material quality (Maaß et al., 2014). In the case of a MOOC for teacher education, the expert review system turned out to be a suitable method to achieve this goal. In total 396 review processes were necessary to implement the review system during the MOOC MCM module. On the one hand, we recognize that a disadvantage of the review system is that of having to manually write reviews. This implies that reviewers must be highly motivated to accomplish this task and to assure high-quality materials. On the other hand, the possibility of giving highly adapted feedback that considers not only the mathematics but also the cultural background and the educational landscape of mathematics classes in Italy, could be

identified as a major advantage of the review system. However, the success of the review system relies on the willingness of the participating teachers to accept the review and to revise the task. Since we did not explicitly examine factors that lead to a revision of a task, the willingness can be traced back to a mixture of a high-quality feedback combined with the desire to obtain the module badge and the satisfaction with the module contents. Finally, we can certainly state that the engagement of MOOC-teachers in creating the math trail tasks and the efforts made by the reviewers have constituted a heritage, not only for the MOOC community but also for all MCM users.

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