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Integrated STEAM Approach in Outdoor Trails with Elementary School Pre-service Teachers

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ABSTRACT: Due to the COVID-19 pandemic it was impossible to carry out on-campus teaching and examinations as planned for the first-year elementary school Bachelor's degree teacher training courses during the summer term of 2019/2020. Therefore, we moved our on-campus STEAM (Science, Technology, Engineering, Arts and Mathematics) related courses to schooling at home. For their course examination, students designed outdoor trails in groups with the educational technology MathCityMap based on an integrated STEAM approach. Hence, they combined STEAM with real-world situations (e.g., monuments, marketplaces, playgrounds). The tasks within the trails required the use of technologies such as augmented reality (AR), digital modelling (e.g., GeoGebra 3D Graphing Calculator), and GPS. Analogue measuring tools (e.g., triangle ruler) were also used in the task designs. We collected data from 21 trails with 259 tasks from 49 pre-service teachers to analyse the effects on professional growth in STEAM education. Through hierarchical cluster analysis we identified three different clusters with patterns regarding STEAM in outdoor trails. This paper will describe a pedagogical framework for the integrated STEAM approach to designing and evaluating outdoor trails. Furthermore, we will explain patterns pre-service teachers developed during this professional development.

Keywords: STEAM, Outdoor trails, Professional development, Pre-service teachers, Higher education

1. Introduction

Digital technology (e.g., smartphones) and the digitalisation of processes (e.g., online purchases) are an important element of student lives. As a result, policymakers aim to develop skills in STEAM (Science, Technologies, Engineering, Arts and Mathematics) early, even in elementary schools, so students can understand and engage actively with their environments. A particular focus is on fostering STEAM-related process skills (NCTM, 1999; Selter & Zannetin, 2019). Therefore, teaching in elementary school needs to develop hands-on activities related to real-world problems (Blum & Leiß, 2007) in students' living environments (Lavicza, Haas, & Kreis, 2020). However, this teaching represents significant challenges for school communities. The integration of STEAM skills, where arts (e.g., architecture, monuments, paintings) extends STEM, is relatively new to teachers. Teachers tend to teach content skills in an isolated manner. According to Radloff and Guzey (2016), teachers understand only basic concepts in STEAM and thus feel uncomfortable teaching it. This led us to reconsider our higher education teaching in the first year's elementary school teacher training.

Our courses are built on hands-on activities, related to technology (e.g., dynamic mathematics software) and to the environment of elementary school students. During the last on-campus courses, we thought about teaching approaches to connect mathematics to architecture, cultural constructions or paintings and how mathematics within STEAM could be connected to real-world examples. However, we observed, that our pre-service teachers tended, based on their internship experience, to teach mainly on written tasks in-class and integrated only few tasks outside students' school environment. Moreover, we observed, most pre-service teachers, conceived their lesson plans in an isolated skills approach (e.g., teaching geometry, without technology and without connection to real-world), rather than using an integrated STEAM approach. Thus, in an integrated STEAM approach (Psycharis, 2018), methods and contents from the different STEAM domains are connected through transdisciplinarity (Kim & Bastani, 2017), similar to real-world situations, objects or problems (e.g., architecture needs mathematics, engineering, art, science and technology). It seemed more meaningful to teach through an integrated STEAM approach instead of creating learning and teaching settings for each domain separately.

As did Cooke and Walker (2015), we concluded that pre-service teachers should experience real-world problems within an integrated STEAM approach to improve STEAM teaching. According to Singer, Ellerton, and Cai (2013), connecting process skills to real-life situations could create new understandings of education, particularly the integrated STEAM approach. Therefore, we aimed to make this next step and work with pre-service teachers on outdoor STEAM trails related to places or objects within the real-world (Cahyono & Ludwig, 2019). With MathCityMap (Ludwig & Jesberg, 2015) pre-service teachers created in a collaborative approach, outdoor trails using GPS technology outside the classroom, with guidance and scaffoldings.

The designed tasks and trails relied on the integrated STEAM teaching approach, mathematical processes and content skills (e.g., areas, volumes, number theory) of the national curriculum (MENFP, 2011). During the trail creations, we performed a close monitoring through a series of tutorials. Finally, students performed a self-evaluation and three peer-reviews of the submitted outdoor trails.

Considering that we undertook an experimental investigation on teachings, we focused on identifying teaching patterns with this new approach, among pre-service teachers. Furthermore, we wanted to understand which possible support or scaffoldings would be needed in their future professional developments.

We carried out a quantitative investigation by addressing the following two research questions:

- Which integrated STEAM teaching patterns are pre-service teachers likely to develop during the creation of outdoor trails?
- What can we learn of this first integrated STEAM approach through outdoor trails for future professional developments in pre-service teacher courses?

Due to the complexity of measuring teaching patterns, we used a mixed-methods triangulation design by combining quantitative and qualitative instruments (Creswell & Clark, 2011). Thus, we collected data for 21 trails with 259 tasks from 49 students. Based on hierarchical cluster analysis (Antonenko, Toy, & Niederhauser, 2012), we identified the task design patterns. Besides, we analysed field observations from tutorials (e.g., questions and remarks during online meetings) and students' interactions during our courses (e.g., interactions or requests on Moodle™). This qualitative data was coded in a similar approach as grounded theory (Corbin & Strauss, 2014) and used further to describe upcoming needs in the elaborated learning settings. We will present in this paper a pedagogical framework, our findings on patterns in task design in outdoor trails and describe future improvements we learned through our initial experiences.

Amidst the COVID-19 pandemic in 2020, on-campus learning and teaching at the university was suspended and changed to schooling at home (Kreis, Haas, Reuter, Meyers, & Busana, 2020). Therefore, the professional development we present in this article was done exclusively in remote teaching.

2. Literature review

To prepare a STEAM integrated approach in outdoor trails, we performed a literature review of topics related to the professional development we wanted to experiment. Thus, we investigated frameworks and experiences with STEM integrated approach (Breiner, Harkness, Johnson, & Koehler, 2012; Kelley & Knowles, 2016; Lavicza et al., 2018; Madden et al., 2013). The frameworks described strong interactions between STEM disciplines (e.g., didactical approaches, problem solving, contents) and how important the transdisciplinary approach is. Findings from the studies indicated the need to connect STEM to real-world or as we wrote earlier, to students' living environments. However, there are various recommended teaching approaches and experiences for implementing STEM integrated teachings.

We consulted the literature on STEM in- and pre-service teachers training (Brown & Bogiages, 2019; Cooke & Walker, 2015; Madden, Beyers, & O'Brien, 2016; Michaluk, Stoiko, Stewart, & Stewart, 2018). Pre-service teacher training in STEM from the consulted literature highlighted the importance of hands-on activities and practical approaches in STEM teachings. Throughout the first reviews, we identified possible added values (e.g., creativity, presence of arts in myriad outdoor objects) to add Arts in the STEM. Hence, in completion, we investigated the extension to STEAM (Conradty & Bogner, 2018; Kim & Bastani, 2017; Land, 2013). Furthermore, students learn their first skills in the design process in arts, similar to engineering through problem-based learning with real design projects (Cook et al., 2017). According to Quigley, Herro, and Jamil (2017), arts support students to connect the other STEM disciplines to real-world problems. We decided therefore to work on a STEAM rather than a STEM integrated approach for our initial experience.

The connection to real-world in outdoor trails, led us to identify possible models used within literature and documented teachings. Out of the reviews on STEAM integrated approach, we identified the importance of mathematics in connection to the different domains of STEAM and referred to frameworks, which are usually used in mathematics education in our elementary schools to connect to real-world. Different mathematical modelling process approaches with real-world information (Blum, 2013; Blum & Leiß, 2007; Cahyono et al., 2020; Schukajlow et al., 2012; Selter & Zannetin, 2019) described how to apply mathematics and/or scientific solving approaches during task solving processes. These approaches allowed to structure the outdoor tasks by indicating important steps in solving (e.g., creating a situation model, modelling a situation model, modelling mathematical concepts, and interacting with real-world situations).

We used educational technology to apply an integrated STEAM approach through outdoor trails; thus, we consulted several research approaches on technology (e.g., MathCityMap) and outdoor trails involving real-world data (Cahyono & Ludwig, 2019). In these studies, most tasks focused on mathematics alone, however they described numerous interactions with real-word objects or places. Due to the technology, students used digital instruments, in addition to more traditional analogue measuring instruments. To understand how users get involved with educational technology, we referred to the theory of instrumental genesis (Lieban & Lavicza, 2019; Trouche, 2004) and the TPACK (Technological Pedagogical Content Knowledge) framework (Tondeur, Scherer, Siddiq, & Baran, 2020), which focus on the interconnections in teaching between pedagogy, content and technology knowledge. Teachers use educational technologies differently and show different manipulations of the same technology in their teachings. However, considering the different appropriations of technology by pre-service teachers, scaffoldings could help them develop skills to advance their use of technology (Tondeur et al., 2020). Based on the reviewed literature, we were able to identify, how pre-service teachers could use different technologies in the task design (e.g., augmented reality or GPS based measuring).

Pre-service teachers gained experience through working with frameworks for task designs, since they used the TPACK framework during their remote internships (during the pandemic) to create online teaching settings and contents for elementary school students. We observed a quality gain in the pre-service teachers created content and new teaching patterns, while using pedagogical frameworks. Therefore, we elaborated a pedagogical framework for our professional development course.

3. Pedagogical framework

Based on the literature review and the theoretical references, we designed a pedagogical framework (Figure 1) for outdoor task design with two major components (i.e., outdoor trails, STEAM integrated approach) and two subcomponents (i.e., process and content skills). This pedagogical framework, served, on one hand, to guide pre-service teachers' professional development in applying STEAM in their trail and tasks design and on the other hand to identify possible teaching patterns (e.g., tasks in the trails, use of technologies, connections to real-world).

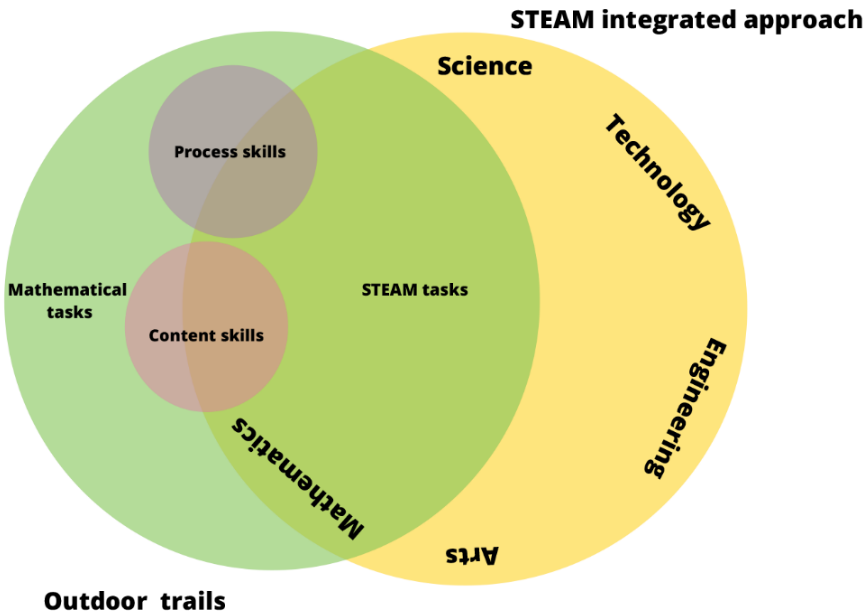

Figure 1. Pedagogical framework

3.1. Outdoor trails

Any structured learning activity outside the classroom can be qualified as learning STEAM outdoors (Kendall, Murfield, Dillon, & Wilkin, 2006). Moreover, such learning activities provide direct experiences with the real world (Moffett, 2012). Such structured learning activities support the interaction between STEAM and the environment in which students live, with real-world problems (Blum, 2013) by reinvesting skills learned in school. However, as written by Beard and Wilson (2006), being outside is not stimulating mathematics and in this case, STEAM skills alone. The tasks should be structured and conceived, according to the findings of Vos (2015) by subject matter experts (SMEs) in STEAM didactics.

To support these structured outdoor learning activities in STEAM, since pre-service teachers are not yet SMEs in STEAM didactics, we referred to MathCityMap, which allows creating outdoor trails with tasks related to mathematics and STEAM (Jablonski & Ludwig, 2020) in an organised guided approach. Pre-service teachers are guided in MathCityMap (https://mathcitymap.eu; Figure 2) by responding to a set of predefined elements (e.g., visual identification of the chosen GPS coordinate, task description or hints) and respecting criteria and effects on trail designs (e.g., uniqueness, attendance, activity, various ways of solution).

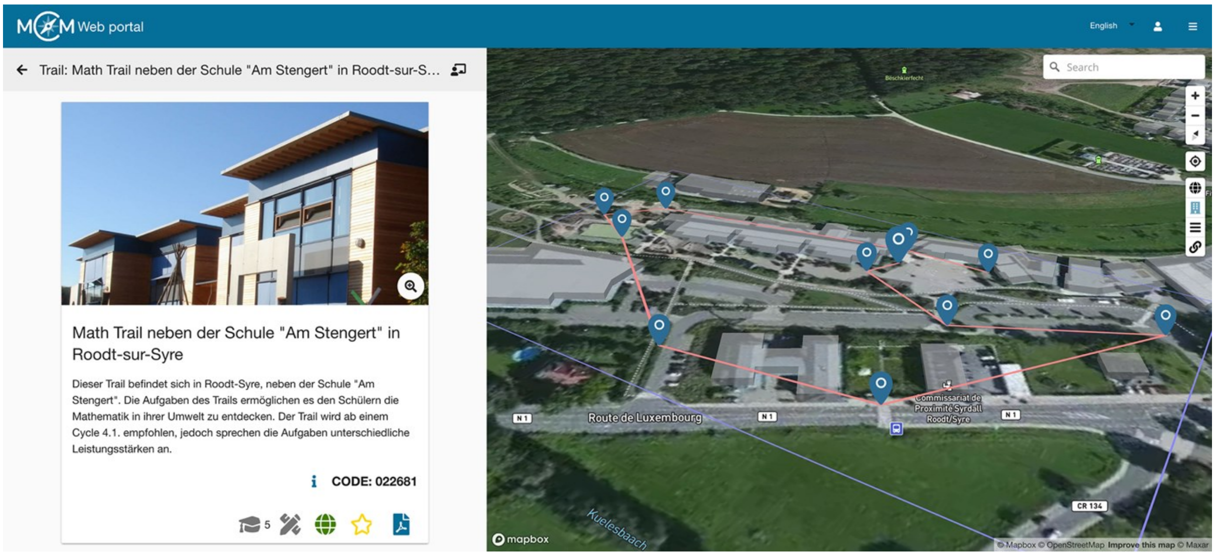

Figure 2. Users view of the MathCityMap web portal showing a trail with tasks bound to GPS coordinates

In MathCityMap, students navigate through trails and get descriptions and potential hints of tasks (Figure 6) as well as a sample solution (Figure 4). Pre-service teachers' outdoor trails are connected to places in environments which are of interest to learning activities (e.g., architecture, market square). These places or objects of interest in the real world are at the beginning of an outdoor trail design process and determine a development direction (e.g., STEAM disciplines) of the design process. According to Brown and Bogiages (2019), for an integrated STEAM approach, at least two disciplines and practices (e.g., mathematics and science) are needed. However, real-world places or objects can promote inequities among the use of the different STEAM disciplines. Moreover, as pointed out by English (2016), some of the STEAM disciplines tend to be more represented than others in education. Thus, we clarified for pre-service teachers, the integrated STEAM approach in outdoor trails, to ensure a higher variety of the STEAM disciplines in the trails.

3.2. Integrated STEAM approach

We used an integrated STEAM rather than a STEM approach which is described as "an instructional approach, which integrates the teaching of science and mathematics disciplines through the infusion of the practices of scientific inquiry, technological and engineering design, mathematical analysis, and 21st-century interdisciplinary themes and skills" (Johnson, 2013, p. 367). Kelley and Knowles (2016), argued similarly in their conceptual framework for integrated STEM and highlighted the importance of connecting real-world problems to the different subjects. Hence, in the outdoor trails, elementary school students interact with real-world problems in outdoor places. Besides, depending on the places, students need to apply creative thinking to identify and connect real-world information to in-class learnings. In this creative thinking process, students "decompose a complex problem using convergent thinking and then apply the corresponding solution to the real world" (Land, 2013, p. 552). Arts within STEAM, as reported in research (Conradty & Bogner, 2018), cultivates creative thinking process and further supports students with new accessibilities to STEM. During the outdoor trail design process, pre-service teachers needed to consider different contents and skills from STEAM disciplines out of the curriculum for elementary schools and seek interconnections. This was a rather new approach in their teachings, as they regularly reflected only one discipline as mentioned earlier. However, using MathCityMap and after the preparation tutorials, connections between disciplines can become more visible to pre-service teachers. Figure 3 shows an example of an outdoor task related to arts, technology, engineering and mathematics. In this task, you have to use AR (technology) to find out which geometric shape (mathematics) fits the architecture (arts) and model it accordingly (engineering). The chosen GPS spot in MathCityMap, in this case an architecture construction, is guiding how disciplines in STEAM could be connected or used in the task.

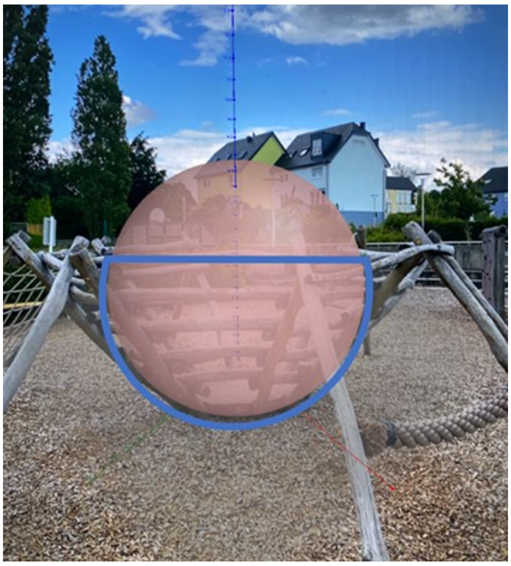

Figure 3. Task involving STEAM

The use of technology in MathCityMap within a STEAM approach is possible through AR (e.g., GeoGebra 3D Graphing Calculator), GPS tasks and digital measurement tools (e.g., protractor application). These technologies engage in a modelling process of real-world problems (Cahyono et al., 2020). Further, using AR to represent shapes in real-world has proven to support students' learning in solid geometry (Liu, Li, Cai, & Li, 2019). However, many created outdoor tasks refer to the use of analogue measuring instruments (e.g., triangle ruler, measuring tape). Some outdoor tasks even relate to more uncommon scholar engineering, like measuring the height of a tree (Figure 4) with an isosceles right-angle triangle (ruler) (Gellert, Gottwald, Hellwich, Kästner, & Küstner, 1990, p. 243).

Figure 4. Measure the height of the tree with a triangle ruler

As shown in the pedagogical framework, there are mathematical tasks and STEAM tasks. However, both typologies of tasks are built upon mathematical skills. They referred to process skills (e.g., problem solving) due to their relations to real-world problems and content skills (e.g., distance of a segment), depending on the nature of the task.

3.3. Tasks in outdoor trails

Blum and Leiß (2007) stated in their model on real-world problems that students modulate information with process skills and connect real-world to mathematical models. With the use of educational technology, in this case MathCityMap, process skills are widely supported and developed (Liljedahl, Santos-Trigo, Malaspina, & Bruder, 2016). Process skills have been described by various researchers and organisations. Thus, we wanted to establish a common understanding between international references (NCTM, 1999), mathematics didactics references (Selter & Zannetin, 2019) used in elementary schools and the national curriculum (MENFP, 2011). We categorised the process skills from the different references and created connections between the definitions. We were able to identify four major skills based on our analysis of references (Table 1).

Table 1. Process skills

Skills	Description
Problem Solving	Engage in a task where the resolution method is not known in advance. Transfer skills and knowledge in this task to find a solving path.
Reasoning and Proof	Argue, communicate, analyse and justify the conjectures made in the task.
Representation	Represent conventional or unconventional models to solve the task.
Modelling	Modulate, connect and communicate mathematical concepts to solve the task.

According to Schukajlow et al. (2012), the process of modelling real-world problems with mathematics, is not a linear but an iterative process. Thus, elementary school students try out, discuss, draw schemes, and reason their solving process iteratively during the tasks in the outdoor trails. To illustrate process skills in these tasks and to evaluate our classification, we undertook testing with a class. 16 elementary school students (age 10 to 12) completed some outdoor trails and were observed actively using process skills while solving tasks (Figure 5).

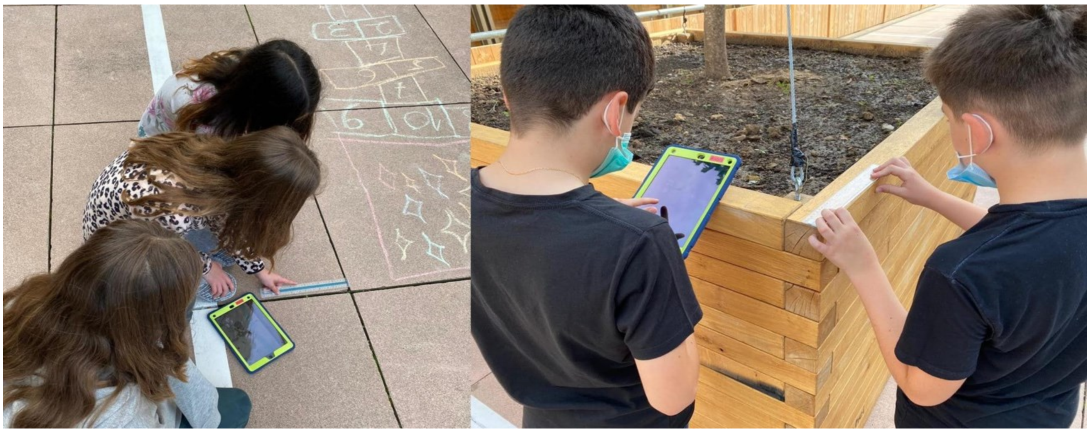

Figure 5. Elementary school students solving outdoor tasks on measuring segments and calculating volumes

Figure 6. Calculate the volume (in m^2) of the raised garden bed

In addition to process skills, the tasks refer to content skills from the national curriculum (e.g., recognise shapes or solids). In Figure 6, for example, the task requires geometric and measurement content skills. Besides the recognition of the correct solid, students need to remember and apply the formula of the volume of the rectangular cuboid and transform the result into the requested unit of measurement. Within an integrated STEAM approach connected to real-world problems and situations in the outdoor trails, students were able to solve these complex tasks with several content and process skills.

4. Data analysis

In the pedagogical framework, we described the integrated STEAM approach and process and content skills used in the outdoor trail creation process. There were many different possibilities in connections of STEAM disciplines, outdoor places and objects. In the professional development on integrated STEAM approach with pre-service teachers, we set up a teaching methodology and tested this framework. During our research, we wanted to identify how these outdoor trails with educational technology (e.g., MathCityMap) are likely to develop teaching patterns in STEAM and wherever our methodology would need improvements for further courses.

4.1. Sample description

Our sample consisted of 35 female and 14 male first-year pre-service teachers enrolled in the Bachelor's degree at the University. The pre-service teachers were in their second term and taught basic mathematics educational principles regarding numbers and operations, geometry and technology usage.

4.2. Process description

The study started in the second half of the semester, after the schooling at home (Kreis et al., 2020) started and was thus entirely conducted remotely. The findings on fully online courses on pre-service teachers' technological and pedagogical skills development (Corry & Stella, 2018) suggested potentially positive outcomes. Furthermore, we included the cooperation, role models, tutorials, feedback on pre-service teachers' support, and theory and praxis alignments to ensure the pre-service teachers' support. Thus, the pre-service teachers created groups with two or three members. They created overall 21 outdoor trails with 10 to 18 tasks per trail (259 in total) and received remote guidance from the lectures. The creation process of the outdoor trails was organised into three different phases (Figure 7).

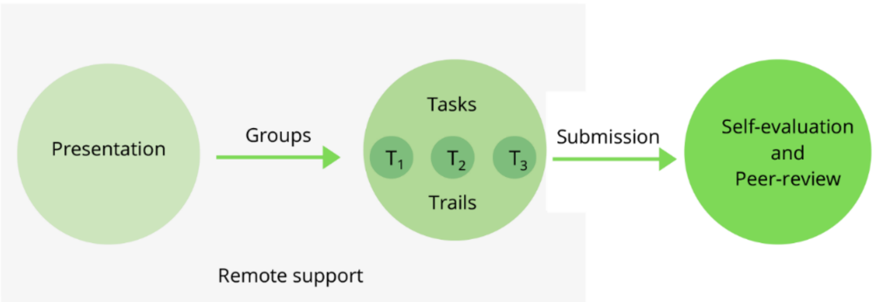

Figure 7. Outdoor trail creation process

In the first phase, pre-service teachers received an introduction into MathCityMap and outdoor trail examples, fulfilling all evaluation criteria. Alongside this, the lectures indicated several possibilities to create tasks with digital or analogue measurement tools. The duration of this online session was 90 minutes including pre-service teachers' questions. Resources on technology and trail and task examples remained available and the pre-service teachers were allowed to send in further questions during the whole process. Before the second phase, pre-service teachers formed their groups with two or three members on the University Moodle™ platform. Proximity of residence was an advantage for the intended collaboration. This choice was made to support peer learning throughout our teaching in the Bachelor's degree, and we aimed to prepare the pre-service teachers working in teams rather than as individuals for their future teaching career. Furthermore, according to findings of Guskey (2003), working together and sharing ideas is important to become a reflective practitioner.

In the second phase, the pre-service teachers were developing the tasks and the trail. Several groups responded to the offer of up to three tutorials of approximately 10 minutes to receive additional guidance and explanations. Most questions were about technical issues (i.e., PDF creation of the trail) and tasks' presentation (i.e., cropping of the pictures, wordings). Some groups asked for guidance regarding AR in their tasks and received a brief introduction in the 3D creation process using GeoGebra. Overall, in each tutorial, we adapted our scaffoldings to fit the questions and needs for support. Moreover, we encouraged (with additional guidance) to experience new technologies (e.g., AR) or new points of views (e.g., connecting arts, mathematics and technologies).

In the third phase, the trails were self-evaluated and peer-reviewed based on five questions. We will report on the evaluation process in upcoming papers.

4.3. Instrument description

We adopted a mixed-methods triangulation (Creswell & Clark, 2011) with quantitative and qualitative instruments to identify teaching patterns through cluster analysis (quantitative) based on coded data (qualitative) for research question 1. Moreover, we used the coded data to describe upcoming needs from this first experience for research question 2. We originated our qualitative coding on the designed pedagogical framework to identify STEAM integrated teaching characteristics with a similar grounded theory approach (Corbin & Strauss, 2014). Thus, out of the data, we identified codes that would most likely describe STEAM integrated teaching in outdoor trails (e.g., characteristics of sciences in the tasks, mathematical skills or technology use). We identified codes for the cluster analysis throughout iterative coding (open, axial and selective) and further obtained findings on necessary improvements in our teaching setting (e.g., needed scaffoldings in sciences didactics or peer interactions) during the coding process. Furthermore, each task was tagged by the dominant content skill (e.g., segment measurement). The final coding for cluster analysis (Table 2) was binary (0 = not present; 1 = present).

Table 2. Final codes

Code	Description
S	Science
T	Technology
E	Engineering
A	Arts
M	Mathematics
MPS1	Problem solving
MPS2	Reasoning and Proof
MPS3	Representation
MPS4	Modelling
MCS1	Numbers and Operations
MCS2	Geometry
MCS3	Measurement
MCS4	Data Analysis and Probability
AR	Augmented Reality
GPS	Global Positioning System
C	Calculator
DMI	Digital Measuring Instruments
AMI	Analog Measuring Instruments

Following findings of Antonenko, Toy, and Niederhauser (2012), we chose cluster analysis (CA) with variables from the different outdoor trails to identify groups in teaching patterns. Thus, this data mining allowed us to identify clusters (e.g., groups of teaching patterns), without recordings screens, analysing log files or interpreting the pre-service teachers' self-reports in times of confinement and social distancing. Further, we decided to use CA to develop a differentiated, tailored support for each cluster in the upcoming courses. Among the different methods in CA, we used a hierarchical cluster analysis (HCA) based only on the integration of the fields Science, Technology, Engineering, Arts, and Mathematics (STEAM) in the tasks of the outdoor trails. The other codes, like the use of different technologies (e.g., AR, GPS, C or DMI) or contents and process skills, which added valuable details, were used during the description of the identified clusters, along with the collected field observations (e.g., tutorials and course interactions).

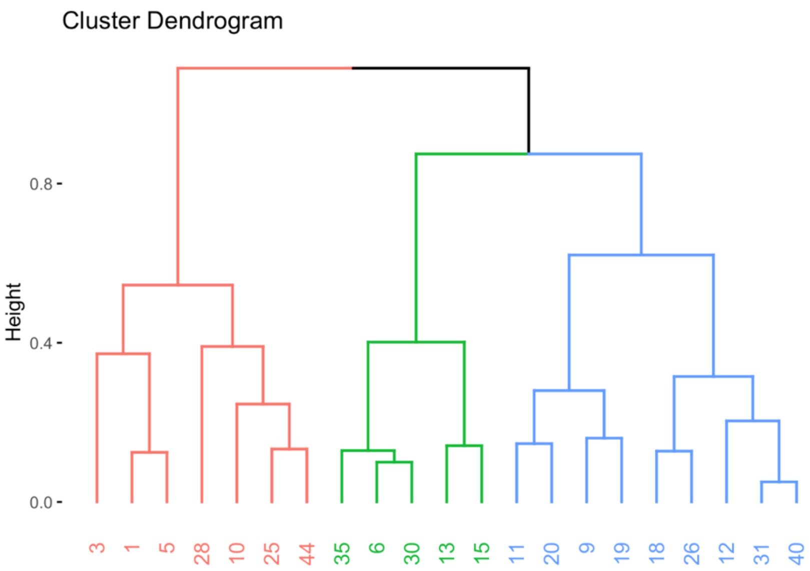

Figure 8. Cluster Dendrogram of the trails based on the integration of STEAM fields

Before starting the cluster analysis, we converted the five field variables to percentages, to get comparable continuous data. The following statistical analysis was done using R (R Core Team, 2020). The HCA for our concept of a cluster in this project used Ward's agglomeration method (i.e., minimal increase of sum-of-squares) and the euclidean metric for calculating dissimilarities. The corresponding dendrogram suggested a cut into three clusters (Figure 8) represented by three colours. The horizontal axis of the dendrogram represents the trails, labelled by a given number for each trail. The vertical axis of the dendrogram indicates the height where similar clusters are combined into a bigger cluster starting with single-element clusters. These calculations relied on the package factoextra (Kassambara & Mundt, 2020). This number of clusters was verified using the package NbClust (Charrad, Ghazzali, Boiteau, & Niknafs, 2014), which provided 30 indices for determining the number of clusters. The number of outdoor trails per cluster varied from 5 (cluster 2) to 9 (cluster 3).

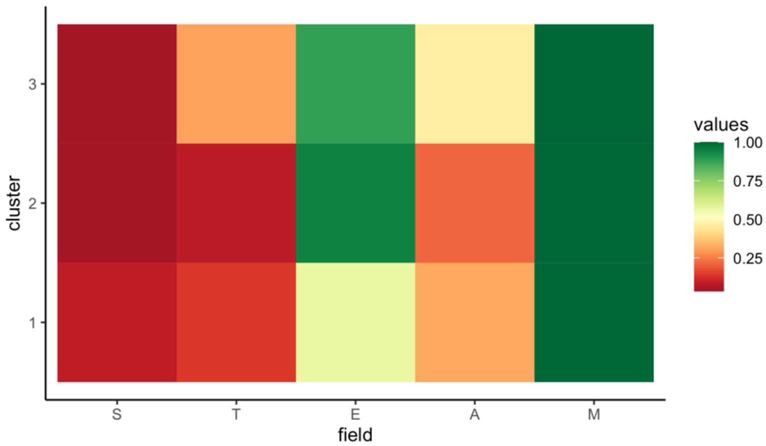

Figure 9. Cluster Heatmap of the trails based on the integration of STEAM fields

The mean percentages per cluster of the integration of STEAM fields (Figure 9) range from 100% (Mathematics) to 3.3% (Science in cluster 2). One could argue that both mathematics and sciences are cornerstones of STEAM. Thus, a course orientation in one or the other direction results in higher mathematics or sciences in the outdoor trails.

5. Results and discussion

5.1. Research question 1: Teaching patterns

In every cluster on teaching patters, the outdoor trails' tasks were based on the previously defined processes and content skills. Only the representation skill (11.1 %) was present less often in the trails for the process skills.

Those tasks required the use of technology for representation or reconstruction of shapes and forms. There have been fewer tasks on data analysis (5.9 %), which could partly indicate the missing science in the outdoor trails. However, the nature of the educational technology, which was initially conceived only for mathematics education, could possibly as well support this tendency. Most of the outdoor tasks were based on topics in geometry (58 %) and requested measurements. The cluster analysis and its interpretation revealed three major patterns in the creation of outdoor trails within an integrated STEAM approach. In general, pre-service teachers used mathematics in each task and almost no science.

5.1.1. Cluster 1: Trails with mainly mathematics tasks

In cluster 1 were 7 (33.3 %) outdoor trails with 82 (31.6 %) tasks created by 14 female and 2 male pre-service teachers. In this cluster, the tasks were less marked by an integrated STEAM approach. Nevertheless, all tasks related to mathematical content and process skills, but the other fields of STEAM were almost all under 50% for the different trails. The cornerstone of mathematics strongly guided the groups within this cluster. According to Shaughnessy (2013), mathematics must be made explicit and transparent in the integrated STEAM approach to connect to the other STEAM disciplines. Not every pre-service teacher recognised all possibilities in mathematics and connections to STEAM. This aligns with the observations during the courses in winter term, where we observed that pre-service teachers need further teaching and learning on mathematical language, models and didactics.

Engineering (56.9 %) was present in every second task, but without being connected most of the time to technology. In these trails, the groups of pre-service teachers created mostly tasks using analogue measuring tools (e.g., triangle ruler) to perform tasks in the content area of measurement. Thus, the use of technology (13.9 %) was rather low and only a few tasks related to technologies in the trails. 31.4 % of the tasks targeted arts mainly by counting or measuring elements from architecture or monuments (e.g., counting the number of windows). The implementation of science (8.3 %) within the outdoor trails and tasks was low, only some tasks included science (e.g., earth science with the cardinal directions).

In this cluster, pre-service teachers employed a traditional approach, close to the tasks described in the textbooks in mathematics course, with low interactions between STEAM disciplines. Similar to the findings of Adalberon, Hauge, and Säliø (2019), this could be due to the new situation or as mentioned earlier to low mastery in mathematics. Furthermore, the lack of analysing teaching and learning situations within the use of new educational technologies (Blomberg, Sherin, Renkl, Glogger, & Seidel, 2014) could lead to use of self-experienced learning situations rather than new innovative teaching.

In some tutorials, we were able to identify uncertainties regarding technologies and connections to places or objects in real-world. Pre-service teachers were not confident in identifying all possible connections in the different selected GPS spots and choose tasks close to the ones in textbooks. With these groups of pre-service teachers, an analysis of their outdoor trails and tasks should be done to evaluate each in its possibility to integrate science, technology, and arts to crossover STEAM.

5.1.2. Cluster 2: Trails with combined mathematics and engineering tasks

In cluster 2 were 5 (23.8 %) outdoor trails with 60 (23.2 %) tasks created by 6 female and 6 male pre-service elementary school teachers. In this cluster, the outdoor trails were dominated by mathematics (100 %) and engineering (94.7 %). Many outdoor tasks combined engineering with analogue measuring tools (e.g., measuring tape). Yet, tasks based on engineering are close to design-based learning settings (e.g., designing household artefacts in school) and have often been experienced by the pre-service teachers in their own learning. Moreover, similar to the National Research Council (2011), engineering could have been used in the tasks to make these more relevant for students, as engineering is widely present in real-world situations and problems.

The use of technology (8 %) was again very low for this cluster, although it could have been used in several engineering tasks. The pre-service teachers did not really integrate technologies in the tasks, apart from some uses of an application to measure a segment with GPS, which is per se integrated in MathCityMap. The low integration of technologies could be related to insufficient time pre-service teachers had (Chittleborough, 2014) and more probably low perceived skills in technologies (Lemon & Garvis, 2016).

21.3 % of the tasks touched art (e.g., completing the missing numbers of grapes of an artistic representation). Even though art was present, foremost combined with engineering, it could have been more. During the tutorials, some groups showed high motivation while presenting tasks related to arts. This was similar to Myunghee et al. (2013) ‘s findings, who reported that arts increased motivation and facilitated connections to other STEM disciplines. However, the interconnections of arts, mathematics and engineering were few in the task designs.

Like cluster 1, science (3.3 %) was very lowly represented in the outdoor trails for cluster 2. Only a few tasks connected to the discipline or practices of sciences. Although Bossé, Lee, Swinson, and Faulconer (2010) identified large interconnections between process skills in mathematics (i.e., NCTM process standards) and sciences skills, this alone does not ensure that pre-service teachers would identify these connections (L. Madden et al., 2016). The disciplines have been thought separately in schools, and therefore, it may be difficult for them to connect both science and mathematics in the same tasks.

5.1.3. Cluster 3: Trails with (S)TEAM tasks

In cluster 3 were 9 (42.9 %) outdoor trails with 117 (45.2 %) tasks created by 15 female and 6 male pre-service elementary school teachers. In this cluster, the outdoor trail tasks were marked by an integrated STEAM approach with again mathematics (100 %) and engineering (88.3 %) dominating the tasks. Far more tasks (30.7 %) than in clusters 1 and 2 relied on the use of technologies (e.g., AR to identify solids). Further, pre-service teachers employed a variety of measuring apps, from distances to angles. Some trails were essentially technology guided, and the groups experimented with different applications. This pattern in the integrated STEAM approach could be similar to the findings of Tondeur et al. (2020), related to technological and pedagogical knowledge of the individual pre-service teachers, which influenced the groups.

Arts (46.5 %) were often present in the tasks. Combined with technologies and engineering, architectures, monuments and outdoor paintings were used in these cluster’s trails to work on different content skills. Examples of the (S)TEAM integrated approach were the reconstruction of missing shapes with AR, measuring the diameter on building entrances and analysing patterns in painted floor art. In the tutorials, the pre-service teachers presented tasks that were close to the ones we demonstrated in the introduction session and tasks where they clearly experimented with technology, engineering and arts.

Based on these correlations, we could observe dynamic teaching interactions, which were reproduced in their trails. In the upcoming courses, we need to encourage these pre-service teachers to share their experiences and support their peers as peer-coaches. According to Britton and Anderson (2010), peer-coaching can significantly support emerging teachers to develop the requested skills. Thus, we will need to develop training sessions for those peer-coaches to support our professional development courses. However, as for the other clusters, the number of tasks, including science (3.4 %) was low. As mentioned earlier, pre-service teachers may not connect science and mathematics in outdoor trails.

5.2. Research question 2: Possibilities and hinderances

In the second research question we investigated possibilities and hinderances on this professional development experience using integrated STEAM approach and technology through outdoor trails. Based on perceptions from the lecturers, coded data and field observations, the important turnovers in this experience were (a) acceptance to teach STEAM, (b) the pedagogical framework, (c) supportive teaching environment and (d) peer interactions.

During and after this experience, we were able to identify high acceptance (higher than regular course teachings) and examination results were better than in previous years. Most of the pre-service teachers seemed to engage more positively with STEAM disciplines than they normally would when taught separately. However, similar to the findings of Michaluk, Stoiko, and Stewart (2018), the support of attitude and beliefs through a structured course on integrated STEAM should reinforce teaching skills and allow the development of patterns in order to fully integrate STEAM.

The pedagogical framework guided the design process and allowed pre-service teachers to learn skills in integrated STEAM approach with outdoor trails. However, pre-service teachers should work over a longer period with the pedagogical framework, to develop skills and deeper understandings for outdoor trails, similar to frameworks like TPACK (Tondeur et al., 2020). According to findings of Philipp et al. (2016) a closer guidance in the process with clearer instructions on the tasks (i.e., indicate the topics and methods to employ) could lead to a more diverse task outcome, including science. This course experience, however, endured only one semester.

We saw many opportunities in integrating technology, which was present in nearly half of the trails at the end of the analysis. Pre-service were supported during the tutorials to try out new technologies and approaches. AR was shown to be very useful to combine all process skills in mathematics and connect the different STEAM topics (Sırakaya & Alsancak Sırakaya, 2020). However, since we connected not all pre-service teachers in the same amount of time and intensity, an online tutoring system, similar to a previous research (Haas, Kreis, & Lavicza, 2020), to develop skills in the use of technology in outdoor trails, could be an added support. Pre-service elementary school teachers could by then receive a guided approach on the use of AR for the tasks in the outdoor trails.

Pre-service teachers worked in groups to create outdoor trails within an integrated STEAM approach. Overall, this was experienced positively and should be a good preparation for upcoming teaching in the Bachelor's studies. Nonetheless, we need to identify how the peers worked together, which roles they attributed to themselves and how they managed the STEAM approach jointly. However, we estimate that, similar to Buchanan and Stern (2012), peer interaction supports the pre-service teacher in professional growth.

6. Conclusion and way forward

This first professional development with pre-service teachers on STEAM integrated approach with outdoor trails was very rich in its outcomes. Although held in fully remote teaching, we observed innovative teaching approaches while working with hands-on activities in real-world, supported by educational technology. Furthermore, pre-service teachers experienced STEAM, through collaboration, in a very positive and motivating way.

In general, we estimate that this kind of professional development could be significant for upcoming or even in-service teachers. Hence, teachers interconnect STEAM disciplines in an outdoor trail through the educational technology MathCityMap's guidance in an efficient approach. However, a pedagogical framework should be made available for teachers over a more extended period and of course, adapted to further investigations. In upcoming professional development sessions, we will closely monitor how pre-service teachers collaborated and made pedagogical choices in their task designs.

Overall, the use of technology was significant in this experience and was a valuable tool for learning STEAM didactics. Pre-service teachers received a supportive structure in their task and trail designs, and as lecturers, we were able to observe how a professional growth in their teachings. The promotion of this approach could, lead to a change in STEAM perception in school communities.

7. Limitations of the study

This study had time constraints and several restrictions due to restrictions imposed by the pandemic. Further, there is still a limited number of research on outdoor trails with STEAM integrated approaches in higher education and in elementary school teaching.

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