Pre-Service Mathematics Teachers' Lesson Plans as a Source of Information About Their Readiness to Teach Online

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Abstract: This paper presents a study of lesson plans created by pre-service mathematics teachers (PMTs) from two universities (Faculty of Education, Charles University in Prague, and Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava) in the course Didactics of Mathematics. The collaboration of the two research teams brought new perspectives on several questions that were come across in one or the other group of PMTs. The focus of the study was on lesson plans since the lesson plan is one of the significant parts of mathematics teacher education. The studied issues were the PMTs' willingness to implement digital technologies (DT) in their lesson plans and the changes in their lesson plans that could be linked to the COVID-19 pandemic. For data processing, a mixed research design was used. In the qualitative part of the research, the thematic analysis resulted in identification of several codes related to the hybrid mode of teaching. In the quantitative part, Statistical Implicative Analysis (C.H.I.C) was applied. Relations inside the groups of PMTs and among them are presented and discussed in the paper by interpreting the results from the implicative trees and graphs. We concluded that (i) PMTs from our sample are, to a limited extent, prepared for using DT in their teaching, (ii) PMTs used DT in their teaching mainly for testing and feedback collection, (iii) PMTs in our sample focused on the content and the choice of software (or application, applet, etc.) when preparing a lesson plan. Besides that, we found (by using C.H.I.C.) that not all codes identified in thematic analysis were connected to the others. The findings are of interest to teacher educators in general, researchers interested in teachers' lesson planning, and in-service teachers in general. In this paper we focus on PMTs' lesson plans. We plan to do a similar analysis of in-service teachers' lesson plans in order to gain a deeper insight into the role of experience in the studied domain.

Keywords: teaching in online environment, use of digital tools by preservice teachers, lesson plans, teacher training

1. Introduction

The paper focuses on one part of a long-term collaboration of two groups of researchers/teacher educators at two faculties, the Faculty of Mathematics, Physics, and Informatics of Comenius University in Bratislava (Slovakia) and the Faculty of Education of Charles University in Prague (Czech Republic). One currently discussed education topic is the hybrid organization of teaching mathematics at the lower and upper secondary levels. Several problems in online education were identified in both countries; not all were just poor connectivity and technical parameters of computers used by teachers and pupils. Many in-service teachers were unfamiliar with the digital environment, could not use the software properly, did not know how to engage pupils in the learning process, etc. One of the findings from our previous research (Slavíčková and Novotná, 2022a) was that development of digital literacy only in one subject (computing) is not sufficient, and closer cooperation among PMTs' educators in the field of mathematics, technology, and pedagogy is needed.

Experience from schools shows that the pace of integration of DT into teaching is languid compared to the speed of evolution of technology. One important retarder of the successful use of DT in teaching is a lack of teachers' insight into the roles of DT in education. If this information is to improve, information on the potential, advantages, and dangers of activities using DT in teaching is crucial (e.g., Aktumen and Kacar, 2008). Despite the considerable potential of DT in education (e.g., Jančařík and Novotná, 2011), examples from practice show that in many cases, "for show" use of technology contributes very little to the development of mathematical knowledge and may even be counterproductive.

The collaboration of the two research teams opened new perspectives on how to address some questions that both groups worked on. In this paper, we focus on our pre-service mathematics teachers' (PMTs) ability to develop lesson plans on a given topic, considering the use of different digital tools (DTs). We identified this topic as necessary not only because of the COVID-19 situation and sudden shift of teaching into online space but also because of current societal developments and the changes in using DT in everyday life. Since PMTs in our sample

were taught in a hybrid form or fully online, we hypothesized that they could find inspiration in our use of DT for their own teaching.

Learning how to develop a lesson plan is one of the significant parts of mathematics teacher education. The fact that PMTs' learn to develop lesson plans for teaching in a regular lesson does not guarantee they will be able to adapt this plan or establish a new one for online education. It became apparent in the pandemic that not all in-service teachers were prepared to teach in the digital environment. If teachers do not get experience with adequate use of DT in their lessons during their teacher education, we cannot expect them to learn it on their own in their teaching practice.

The COVID-19 pandemic caused teachers to "jump in at the deep end" without resources, knowledge, or support (e.g., Engelbrecht et al., 2020); some results confirm that the "quick transition to the online form of education went successful and gained experience can be used in the future" (Basilava and Kvavadze, 2020, p. 1). Therefore, this issue (remote teaching, digital resources, etc.) should be addressed in teacher training.

The research study was designed to target in-service teachers' issues that were not related to the development of digital skills and literacy but to the use of DT in mathematics (or another subject). That is why the focus of the study was on using DT when preparing a lesson plan with the goal of mapping PMTs' preparedness for transitioning face-to-face environments into digital ones.

2. Theoretical framework

The use of IT in teaching and learning mathematics is not a new topic in mathematics education. It has been broadly discussed from several perspectives in a number of publications. For example, in (Clements et al., 2013), eight chapters are included in Section C: Technology in the Mathematics Education (pp. 517-790). Theoretical as well as practical developments related to the rapid growth of implementing IT in mathematics teaching and learning are discussed. The topics presented are technology in mathematics curriculum (Roberts, Leung and Lins, pp. 525-547), modelling with mathematics and technologies (Williams and Goos, pp. 549-569), role of technology in proving (Sinclair and Robutti, pp.571-596), consequences of the use of CAS for school curriculum (Heid, Thoms and Ziek, pp. 597-641), role of technology in enhancing statistical reasoning (Biehler, Ben-Zvi, Bakker and Makar, pp. 643-689), learning with the use of Internet (Borba, Clarkson and Gaganidis, pp. 691-720), influence of technology on assessment in mathematics (Stacey and William, pp. 721-751) and technology-driven developments and policy implications (Trouche, Drijvers, Gueudet and Sacristán, pp. 753-789). Since it is broadly accepted that teachers have an important role in mathematics education, especially in the fruitful implementation of new ideas and approaches to teaching procedures, all of mentioned topics should be discussed with PMTs to provide them an overview of where, how and why to use, or not use DTs. For example, Kieran, Krainer and Shaugnessy (2013) regard teachers as the key persons making the link between research and practice.

"Teachers of mathematics should master solving mathematical problems, selecting the most suitable problems and procedures for their pupils. Moreover, they should plan and present the lessons so that the activities stimulate pupils' cognitive processes." (as documented in Slavíčková and Novotná, 2022b). To fulfil this important role, they should be equipped with appropriate knowledge and skills already during their teacher education. To get insight into teacher's (or PMT's) thinking about the lesson (e.g., what resources to use, how to organize the lesson, what is the role of teachers, pupils, etc.) we collected their lesson plans. Collected lesson plans were analysed from the perspective of using DT in different ways (from visualization through observation, manipulation to modelling) and related task redesign. Since, as we mentioned sooner, PMTs were trained during the pandemic hybrid form of teaching, we were expecting using their experiences and reflecting them in their lesson plans. Therefore, we stated our research questions as follows:

- RQ1: To what extent are PMTs (for lower and upper secondary school) prepared on shift to a hybrid or fully online environment?

- RQ2: Which components of hybrid/online teaching do PMTs focus on, and which do they accentuate when developing a lesson plan?

3. Methodology

Our research sample consisted of two groups of PMTs in their 1st year of master studies (19 PMTs from Slovakia and 21 PMTs from the Czech Republic). The unifying factors for the groups were: 2 years of online education at the university, studying mathematics on bachelor's degree, similar educational systems (Slovakia and the Czech Republic are the two countries of former Czechoslovakia with similar educational systems). In both universities, the scenario was the same (see Figure 1). Each group was taught how to integrate DT into their teaching. Then PMTs were asked to prepare their own lesson plan (on different topics in each of the countries) and discuss it with their peers and the teacher educator.
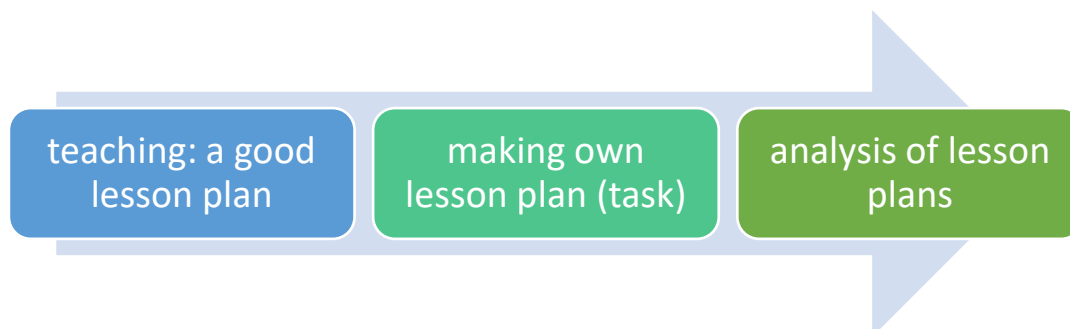

| teaching: a good lesson plan | making own lesson plan (task) | analysis of lesson plans |

Figure 1: Process of collecting data

The developed lessons plans were analysed using the mixed research approach of Concurrent Embedded Strategy (Creswell, 2009). According to Creswell (2009, p. 228) the Concurrent Embedded Design consists of a primary method that guides the project and a secondary method that provides a supporting role in the procedures. In our case, the primary method was qualitative analysis of the gained data (using thematic analysis as defined in (Braun and Clarke, 2006)), the secondary was quantitative procedure using the Implicative Statistic method.

In the qualitative part, we analysed lesson plans developed by the participating PMTs in both groups. We used thematic analysis (see e.g., Braun and Clark, 2006) to identify codes related to the hybrid mode of teaching (see Table 1). For the quantitative part of our research, we applied the Statistical Implicative Analysis of PMTs' solutions using the software C.H.I.C. The goal of this method was to define the way that would allow to answer the question: "If an object has a property, does it also have another one?" (Courtier, 2008). Based on the implication and similarity intensity, C.H.I.C. allows the building of two trees and one graph. It enables the user to handle binary variables, frequency variables, variables over intervals, and interval variables. In the implication graph, we can see the rules with greater intensity than a given threshold. Four thresholds settable by the user are available, and C.H.I.C. uses different colors to show which rules are the most important. The used variables for the implicative analysis were the identified codes presented in Table 1 (the 2nd column – used name of codes).

Table 1: Identified codes related to the hybrid mode of teaching

No.	Used name of codes	Description
1	real_context	The mathematical concept is linked with a real-life situation.
2	key_moments	Key moments in the lesson, moments when discussion could arise, etc. were identified.
3	DT_vizualization	Using DT only as a tool for visualizing the concept by the teacher
4	DT_manipulation	Using DT by pupils as virtual manipulation
5	DT_exploration	Using pre-prepared situations where students work with DT to explore a mathematical phenomenon (e.g. microworlds, applets for specific characteristics).
6	DT_online_ environment	Using DT by pupils to work with and construct new knowledge (e.g. GeoGebra)
7	DT_online_testing	Using an online environment to test the students or exit tickets[1]
8	task_redesign	Changes of the selected tasks proposed
9	own_material	Own material created or a material from a resource modified
10	tasks_no_changes	Material from resources used without any modification

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[1] Exit tickets are a formative assessment tool that give teachers a way to assess how well students understand the material they are learning in class. (Adapted from: https://www.edutopia.org/practice/exit-tickets-checking-understanding.)

No.	Used name of codes	Description
11	*pupils_special_needs*	Special activities for pupils with special needs and/or gifted pupils were proposed.
12	*pupils_engaging_environment*	Inclusive and cooperation supporting activities, creating safe environment for learning and discussion etc. proposed.
13	*changes_to_online*	proposals what to do with the lesson plan in case of online teaching/learning process.

Before implicative analysis, a table with occurrences of the codes in each lesson plan was created. The value assigned to a particular code was chosen from the interval $\langle 0, 1 \rangle$ as a value from a six-value scale, where 0 represents no occurrence and 1 means that the code was identified and the supporting activity was described in detail by the author of the lesson plan (one of the PMTs). E.g., if PMT just stated in lesson plan "I'd like to prepare engaging environment for pupils to …" but it was not present in the lesson plan, we assign value 0 to this variable. If PMT's trial with engaging environment was present but not engaging, we assigned one of the values 0.2, 0.4, 0.6, 0.8 according to the reached level.

4. Results

We present results based on the outputs of the C.H.I.C. For easier orientation in the graphs produced by C.H.I.C., we re-draw them.

At first, we looked on our data as a whole. As shown in Figure 2, there are two connected components of the graph.
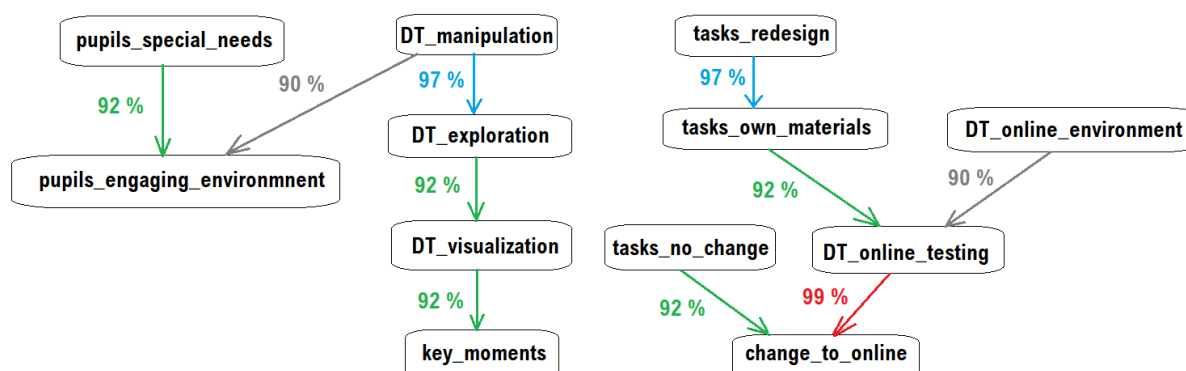

Figure 2: Implicative graph - all codes (re-draw based on C.H.I.C. output)

The first connected component has two main subgraphs:

- The first subgraph starts in the vertex[2] *<pupils_special_need>*: 92% of PMTs who considered pupils with special needs (minority of the PMTs), wanted to prepare an engaging environment for their pupils to eliminate obstacles when learning a new topic. In these cases, mostly GeoGebra or special devices were suggested (e.g. for visually impaired pupils)

- The second subgraph starts in the vertex *<DT_manipulation>*: PMTs who considered using DT as a tool for manipulation in 97% also included DT as a tool for exploration of a phenomenon, and 90% suggested development of an engaging environment for their (hypothetical) pupils. Furthermore, in case of PMTs who would use DT as a tool for exploration, 92% would use it as visualization tool and 92% identified the key moments of the teaching/learning process.

The second connected component consisted of three subgrahps:

- The first subgrahp starts in the vertex *<task_redesign>*, it works with the PMTs who redesigned several tasks from different sources (e.g. textbooks, workbooks, internet, etc)

- The second subgraph starts in the vertex labelled *<DT_online_environment>* works with the PMTs who were designing their lesson plan for on-site and on-line teaching parallelly.

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[2] Vertex (or node), see e.g. https://www.maths.ed.ac.uk/~v1ranick/papers/wilsongraph.pdf, p. 2, definition of concepts

- The third subgraph starts in the vertex *<task_no_changes>* and works with the PMTs who used their lesson plans tasks from different sources that were cited in their lesson plans.

The PMTs who redesigned existing tasks in 97% also included their own tasks and thought about using DT for online testing of their (hypothetical) pupils. 92% of them would use an online test (majority of the PMTs) or exit tickets (minority of the PMTs), and 99 % of them considered also "plan B" for situations of online teaching. The code *<changes_to_online>* was present in 92% of lesson plans of PMTs who did not adapt tasks from some original source. Furthermore, 90% of the PMTs who considered working with pupils in an online environment would test the pupils also digitally.

Since we were interested especially in the use of DT, we focused on the codes 3-7 described in Table 1 separately. There are two groups of students identified (see Figure 3).
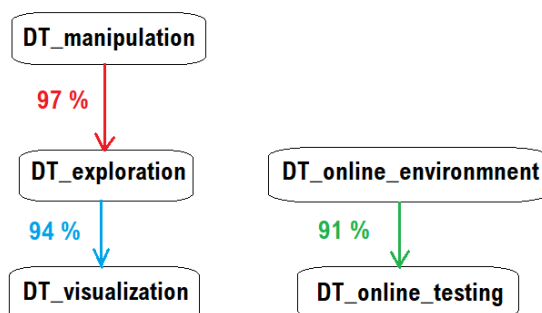

Figure 3: Planned different use of digital tool in PMTs lesson plans (re-draw based on C.H.I.C. output)

PMTs who considered using DT for manipulation in 97% considered also using DT as a tool for exploration and in 94% as a visualization tool. PMTs would prefer pupil's individual or pair work with DT (computer or mobile devices depending on the topic) with software suitable for the pupils' age and the topic. Several PMTs also described applets in English to support pupils' understanding. Some of the applets were inappropriate (e.g. too difficult to understand the concept, new difficult terminology, not correctly prepared, etc.). PMTs who mentioned in their lesson plans visualization activities would do so only in the case when pupils would not have enough devices or if there were problems with internet connection. We found this important since this could lead to modelling in later stages of teaching/learning process.

Then we analysed the group of the PMTs who considered online environment in their lesson plans and in 91% they would like to test their (hypothetical) pupils using online tests (majority of PMTs) or asked for online exit ticket (minority of PMTs). In this group, 86% of PMTs would use DT as a visualization tool even when pupils were working in the online environment. The reason identified in the analysed lesson plans was "to save some time", which we do not consider as a well justified reason. Online environment in these lesson plans was only used as a space for attracting pupils' attention or for keeping them active. In some cases, we found those activities counterproductive (e.g., shooting on fractions as part of a game could disturb pupils).

As our data shows that the *<real_context>* was only one of the variables and is not present in the implicative graphs above. Therefore, we plotted another implicative tree to get better insight into the connections among the codes (Figure 4).
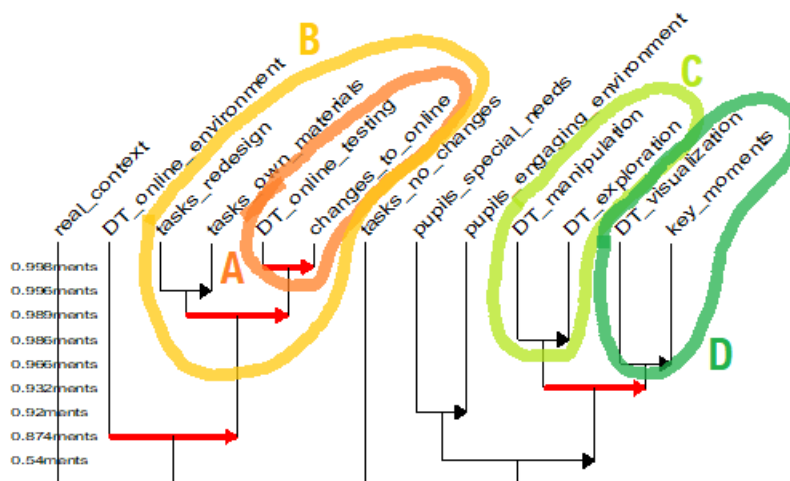
Figure 4: Implicative tree (original outcome from the C.H.I.C. software with added marks A, B, C, D for easier orientation and description in the text)

As can be seen in Figure 4, the *<real_context>* did not play an important role in PMTs lesson plans.

The Implicative tree shows there are 4 significant implications among the codes:

- **A**: Using <DT_online_testing> implies <changes_to_online_environment>

- **B**: Cluster {<task_redesign>, <task_own_materials>} implies **A**

- <DT_online_environment> implies **B**

- **C**={<DT_manipulation>, <DT_exploration>} implies **D**={<DT_vizualization>, <key_moments>}

The first three bullets have already been discussed in the subgraph of Implicative graph in Figure 2. However, all four bullet points were not identified in Figure 3 focusing on using (or mentioning) DT in the PMTs lesson plans. For example, the label *<key_moments>* is absent from Figure 2. Therefore, we looked on our data again using the Implicative tree to find out how identification of the key moments in the PMTs lesson plans is connected to the usage of DT (see Figure 5).
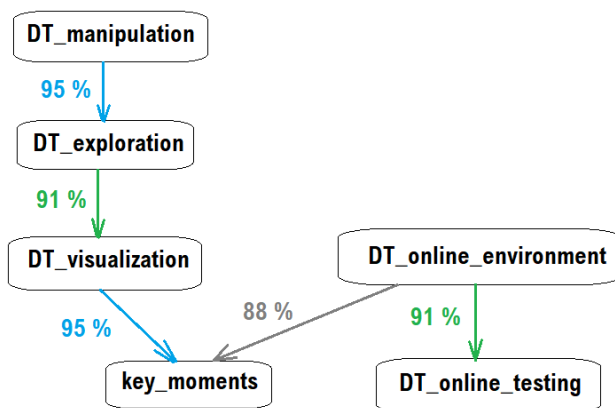

Figure 5: Implicative graph - using DT and identification of key moments (re-draw based on C.H.I.C. output)

Lowering the probabilities of occurrences of other variables, we identified two cases in which the PMTs identified the moments crucial for pupils' understanding of the phenomenon in their lesson plans:

- 95% of the PMTs who considered using DT for virtual manipulation in their lesson plans also considered DT as a tool for exploration, 91% of them would use DT as a visualization tool and 95% of them identified the key moments.

- 88% of the PMTs who prepared their lesson plan considering work online identified the key moments in their hypothetical classrooms.

Even though several PMTs tried to include tasks with real-life context, it had no impact on the use of DT or other variables/codes.

5. Discussion

When comparing our findings with (Clements et al., 2013), we confirm that PTMs focus on learning using the internet (Borba, Clarkson and Gaganidis, in Clemens et al, pp. 691-720). The studied groups of PMTs would use DT as a tool for assessment similarly to Stacey and William (in Clemens et al, pp. 721-751) or as a tool for virtual manipulation. In later stages, proper manipulation could lead to modelling using DT as mentioned in Williams and Goos (pp. 549-569). In PMTs' lesson plans there was a visible link between research and practice, as mentioned by Kieran, Krainer and Shaugnessy (2013). This link was observable in the lesson plans in which our PMTs included the most actual topics discussed in the lessons (e.g., inclusive teaching/learning environment supported by DT, "good questions", implementation of DT as a tool for manipulation and observation).

Answering the first research question RQ1: *To what extent are PMTs (for lower and upper secondary school) prepared on shift to a hybrid or fully online environment?* we conclude that PMTs from our sample are, as their lesson plans show, prepared for using of DT to a limited extent. The application of DT most used in their teaching was for testing and feedback collection. We do not find this sufficient. Therefore, more specific examples of pedagogically meaningful ways of using DTs in education for PMTs to gain the knowledge and confidence to use DT in education (Ertmer and Ottenbreit-Leftwich, 2010; Slavíčková and Novotná, 2022). We also suggest that a higher emphasis on using DT as a modelling tool is needed not only in courses of didactics of mathematics but also in mathematical courses in Bachelor and Master studies.

Answering the second research question RQ2 *Which components do they focus on and are stressed when developing a lesson plan?* we identified two most accentuated areas our PMTs' lesson plans:

- Content – what tasks we will work with in the lesson

- Chosen application – in many cases only name, or kind of the application was provided without the description of how to use the chosen app (e.g., we can use GeoGebra, Kahoot, learning apps, etc.)

These two areas the PMTs paid attention to, could be the result of several factors, e.g., how they were taught on secondary school, during their bachelor's degree or in another subject. We plan to focus more on these factors in our future research.

6. Conclusion

The here reported research study is a part of a larger project. In the next step of our research, we plan to focus on factors identified in the discussion, mainly how the PMTs in our research sample are prepared for mathematics lessons, what their background is, etc. (the so-called context and need analysis) and prepare a new intervention. Cooperation with in-service teachers could be useful in this step, as well as focus on in-service teachers' education (lifelong learning).

The presented study confirms that closer cooperation among teacher educators from different institutions in one country or from different countries is needed. It could be beneficial for all participants. It could result e.g., in deeper changes in the organization of pre- and in-service education of (not only) mathematics teachers.

In our study, 40 PMTs participated. The gained results cannot be generalized. However, they indicate some ways in which the training of PMTs for their future work could be improved.

Acknowledgements

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