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Higher Education Learning Methodologies and Technologies Online

4th International Conference, HELMeTO 2022
Palermo, Italy, September 21–23, 2022
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Preface

This volume of Communications in Computer and Information Science (CCIS) contains the post-proceedings of HELMeTO 2022, the fourth International Conference on Higher Education Learning Methodologies and Technologies Online, which took place during September 21–23, 2022 in Palermo, Italy.

The conference was organized by the Department of Mathematics and Computer Science at the University of Palermo and by the Institute of Educational Technology of the National Research Council of Italy. The 2022 edition of HELMeTO also marked the return of the event in presence, as the previous two editions had been held entirely online due to the Covid-19 emergency.

The growing interest in the topics of learning methodologies and technologies in higher education, and in particular in the interdisciplinary approach that characterizes this research field, suggested a change from a workshop format to a conference event, thus promoting a more international perspective. The success of this approach was highlighted by the 126 submissions received (almost double those received for the previous event) from more than 400 authors in 24 countries.

These numbers not only confirm the growth trend of an event that was born just four years ago (39 submissions in 2019, 59 in 2020, and 65 in 2021), but above all they consecrate HELMeTO as a key event for researchers and practitioners working in Higher Distance Education Institutions or studying Online Learning Methodologies to present and share their research in a multidisciplinary and international context.

The conference included two general tracks on Online pedagogy and learning methodologies and and on Learning technologies, data analytics and educational big data mining as well as their applications. Thanks to the growing attention that the conference has attracted over the years, this edition collected twelve special tracks, focusing on specific topics, previously proposed by their organizers and peer-reviewed by the Program Committee.

- Special Track 1 - Improving education via XR and AI
- Special Track 2 - Educational Approaches and Innovative Applications to Counteract Social Media Threats
- Special Track 3 - Hybrid Learning and Accessibility in higher education
- Special Track 4 - E-learning for providing "augmented" mathematics education at University level
- Special Track 5 - STEAM Education old and new challenges in distance teaching/learning approaches in Higher Education
- Special Track 6 - Online Faculty Development: Next Steps for Practice and Future Research
- Special Track 7 - Artificial Intelligence and Multimodal Technologies in Education (AI&MTEd '22)
- Special Track 8 - Experience-based training activities for online higher education
- Special Track 9 - Intelligent Analytics for Process-aware Higher Education

A Phenomenological Study About the Effect of Covid-19 Pandemic on the Use of Teaching Resources in Mathematics

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Abstract. In this contribution, we discuss phenomenological research related to a pilot study carried out by the Consortium of the MaTeK Horizon 2020 project during the 2020–21 academic year. The research aims to analyse the effects of the Covid-19 pandemic on the use of teaching resources in mathematics in five countries. A questionnaire made of seven questions was administered to a data sample made of teachers of all grades. The answers coming from the questionnaire were quantitatively and qualitatively analysed. Closed-ended questions were analysed by using a clustering methodology called k-means. Open-ended questions were qualitatively analysed. The results show that almost all the teachers are aware of the impact of the Covid-19 pandemic on education. However, their perception of how the pandemic situation changed the use of educational resources mostly appears linked to cultural factors, age, teaching experiences and school grades of the teachers.

Keywords: Phenomenological study · Teaching resources in mathematics · Covid-19 pandemic · Cluster analysis

1 Introduction

If we study the history of societies, we can find several pandemic events such as smallpox, cholera, plague, and, more recently SARS [1, 2]. Each one of these pandemic events affected human life in many aspects from health to the economic sphere [3]. Education is one of these aspects. In 2020–21, the SARS-CoV-2 pandemic (Covid-19) has had a massive impact on Education. Students from different countries have been affected by

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school and university closures. Italy was the first Western country to suffer a coronavirus emergency. On March 4, 2020, the Italian Prime Minister announced a strict lockdown and the immediate closure of all schools and universities to contain the spread of the virus.

This phenomenon then extended to other countries as well all over the world. In response to school closures, UNESCO recommended the use of distance learning programs and opened educational applications and platforms that schools and teachers can use to reach learners remotely and limit the disruption of Education. These proposed "solutions" involved all levels of Education [4, 5]. According to [6] Covid-19 has shown different everyday situations and different related emerging problems around the world. The problems with connectivity and stability of the internet connections were only minor parts of them. A new environment implied looking for using new pedagogical and didactical perspectives in revising competencies needed for the further life of the pupils (what, how and why the need to learn) and those who should be adopted by teachers [7, 8]).

In 2020 and 2021 several researchers investigated teaching practice and their response to the crisis [7, 8]. Steed and Leech [9], discussed the US teachers' difficulties in personal interactions with students and their inadequate resources. Hu et al. [10], painting the Hong Kong Covid-19 teaching scenario, provided evidence of barriers including difficulty engaging students in online activities and highlighted inadequate support from several parents for learning activities. Nikolopoulou [11] highlighted teachers' negative feelings in particular, at the beginning of online education in Greece. Brunetto et al. [12] proposed a new teaching model for describing and analysing a new teaching system in Covid-19 time. Several Researchers in [5, 11–13] put in evidence as the pandemic was for many teachers and students the opportunity to re-examine their teaching/learning also concerning the use of curricular resources.

The types of resources used by teachers fall into different categories. Pepin, Gueudet and Trouche [14] distinguish 1) curriculum resources, 2) social resources, and 3) cognitive resources. Curriculum resources are "developed and used by teachers and students in their interaction with mathematics in/for teaching and learning, inside and outside the classroom" [14, p. 172–73]. They are further categorized as a) text resources (e.g. textbooks, syllabi, websites), b) digital curriculum resources (e.g. e-textbooks, educational platforms), and other material resources (e.g. calculators, digital instructional technology) [14].

The study of resources and mathematics teachers' interaction/work with those resources has become a prominent field of research (e.g., [14]). Very few of these works deal with the effect of the Covid-19 pandemic on resources used by teachers.

That was one of the reasons we decided to focus on this phenomenon. This research is one thread of the different researches conducted under the Horizon 2020 MaTeK (Mathematics Teacher Knowledge) project (2021–2023) in which five universities from as many countries are involved: Comenius University in Bratislava, Slovakia; Charles University, Czech Republic; University in Palermo, Italy; NTNU, Norway, and METU, Turkey. Our consortium focuses on enhancing the design capacity of pre-service mathematics teachers. Preparation of future mathematics teachers is specialized and includes mathematical and pedagogical content knowledge as well as reflecting this knowledge in practice [15]. The process includes the use of resources, and the ability to judge and design own materials when making and enacting a lesson plan [16]. Teacher knowledge

is the prerequisite of the education enterprise, and student knowledge development is its objective. Therefore, it is essential to understand what kinds of knowledge mathematics teachers develop, and how they use their expertise in teaching to help students to develop deep knowledge of mathematics [16]. Since that pre-service teachers are often not adequately prepared to cultivate opportunities for students to engage with reasoning and proof [17, 18] we are focusing on reasoning and proving skills. These skills also form an important strand of mathematical proficiency [19, 20]. The main framework used to study this research subject is referred on Stacey and Vincent's theory [21].

In this contribution, we refer to the study that the Consortium did about this theme and in particular the work that was done about the study of the Covid-19 pandemic effects on the use of resources by all grade teachers. In the following paragraphs, we discuss the methodology used for this research (an open-ended questionnaire was designed ad hoc) and some remarks about the results obtained from a pilot study carried out at the end of the 2020–21 academic year.

2 Methodology

2.1 Design

A quantitative and qualitative research design was used to determine by an open-ended questionnaire the repercussions of the Covid-19 pandemic on the use of resources by teachers. This phenomenological research aims to describe how teachers from several different school institutions of all five MaTeK countries express and make sense of their shared experiences with the complex phenomenon/scenario that they are living in pre/during and post Covid-19 times. In this context, we focused on teachers' feedback about their experiences of meaningful activities, compatible with Covid-19 restrictions on the use of teaching resources [14, 22].

2.2 Participants and Questionnaire

The research involved 110 voluntary teachers from several different school institutions of all five MaTeK countries. The involved teachers – mainly females (83%) – had 3–25 years of work experience in teaching Mathematics, as main taught subjects. All participants were ensured anonymity.

The questionnaire was designed by a strong collaboration between all five MaTeK partners and was online administered. It is made up of twenty-three items aimed to focus on some key aspects in studying teachers use of resources in mathematics, in several topics such as refreshing or improving teachers' personal knowledge in mathematics, inspiration or ideas for teaching mathematics, preparing assessments, finding materials to be used with their students in class. Six more question were dedicated to particularly analyse teacher's conceptions about Reasoning, Proving and the related of teaching resources [23–25]. The last part of the questionnaire was dedicated to collect demographic data such as age, experience, etc.

In this contribution we only refer to a subset of questions in the questionnaire. In particular, we analysed the answers given to questions related to demographic data such

as age, gender, highest degree of education, taught subjects (other than mathematics) and school grades of the teachers and the two questions reported below.

Q1- *To what extent did the Covid-19 pandemic situation change the way you used educational resources compared to how you use them now?*

Q7- Please, *describe how the Covid-19 pandemic situation has changed the way you used educational resources compared to how you use them now.*

Q1 is a closed-ended questions and the answers were collected by using Likert scales. Q7 is an open-ended question and the answers were qualitatively analysed. All other demographic questions are closed-ended questions. All closed-ended questions were quantitatively analysed by using *k-means* clustering method.

3 Data Analysis and Results

Data coming from closed-ended questions in the questionnaire were quantitatively analysed by using Cluster Analysis (ClA) method [26]. ClA aims at grouping the elements of a set in different non-overlapping clusters, that can be analysed to deduct their distinctive characteristics and to point out similarities and differences between them. Particularly, in this study, we used a non-hierarchical clustering method, called k-means [27], as it allows researchers to individuate clusters that are also easily represented in Cartesian graphical form.

The answers were coded by using a binary scheme. Each teacher was identified by an array composed of components 1 and 0, resuming the answers given by him/her in the questionnaire. For the sake of simplicity here we refer to the use of a two-level coding, where 1 means that a given answer was used and 0 means that it was not used by a student.

Table 1. An example of data matrix. The N teachers and the M answers are denoted as T_1, T_2,…,T_N., and as A_1, A_2,…,A_M, respectively.

Answers	Teachers			
	T_1	T_2	…	T_N
A_1	0	0	…	0
A_2	1	0	…	1
A_3	1	…	…	…
A_4	0	…	…	…
A_5	1	…	…	…
…	0	…	…	…
A_M	0	1	…	0

For example, let us say that teacher T_1 used answers A_2, A_3 and A_5 to respond to the questionnaire questions. Therefore, column T_1 in Table 1 contains the binary digit 1

in the three cells corresponding to these answers, while all the other cells will be filled with 0.

All data elaborations were performed by using custom code written in *C* language and MATLAB by one of the authors.

In order to find the number q of clusters that best partitions our sample, the mean value of the Silhouette function S [28] was calculated for different numbers of clusters. We found that the best partition of our sample was achieved by choosing $q = 4$ clusters ($<s(4)> = 0.69$). The obtained mean value is higher than 0.6, indicating that reasonable cluster structures have been found [29].

Once the appropriate partition of sample has been found, each cluster was characterized. To do this we took into account the answers most frequently given by the teachers for each cluster, which according to Springuel et al. [30] can be called the "prominent" answers.

Figure 1 shows the solution obtained by applying the k-means method. It shows the four clusters that best partition our data set and the related centroids. Each point in this Cartesian plane represents a teacher and is placed in a given cluster because it is more similar to the teachers in the same cluster than the ones in the other clusters of Fig. 1 [31, 32].

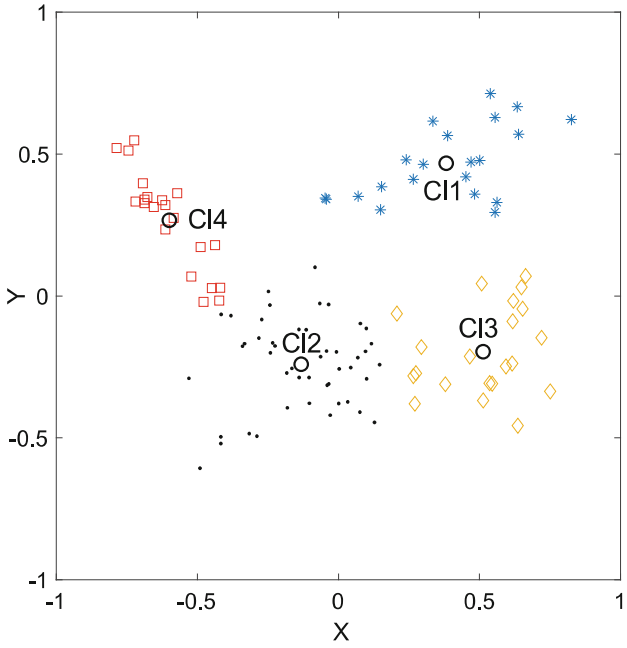

Fig. 1. K-means graph. Each point in this Cartesian plane represents a student. Points labelled Cl1, Cl2, Cl3 and Cl4 are the centroids.

To the values reported on the axes X and Y it is not assigned a specific meaning. Only the distances between each couple of teachers are relevant and represent the dissimilarity between each couple of teachers with respect the answers given to the questionnaire.

It is worth noting that some points may be placed at the boundaries of different clusters. The k-means method classifies these teachers in a specific cluster and associates them the behaviour obtained by the most frequent answers in the cluster. However, those points may actually represent teachers that exhibit mixed behaviours, involving

characteristics of the neighbouring clusters. In particular, this happens for some points in Cl2 cluster and some other in Cl3 and Cl4 clusters.

The k-means method should, therefore, be understood as giving global-type information, and must not be considered as a way to study the characteristics of each element in the data sample in detail that could be obtained referring to a qualitative analysis. We are still working in the direction of a qualitative analysis to further detail our results.

4 Discussion

In this section, we discuss the results obtained by the clustering analysis further detailed by a qualitative analysis of the answers related to question Q7.

Table 1 summarizes the answers most frequently given by the teachers in each cluster (i.e. the components of the related centroids) [32, 33]. It follows the coding used in the Appendix. The number of students in the clusters is also shown.

Table 2. The answers most frequently used by the teachers in the questionnaire and the number of teachers for each cluster. The answers are shown by means of the coding reported in the Appendix.

Cluster	Cl1	Cl2	Cl3	C14
Most frequently given answers	Q1.d, Q2.a, Q3.f-g-h, Q4.b, Q5.d, Q6.b	Q1.d, Q2.a, Q3.d-e, Q4.b, Q5.b, Q6.d-e	Q1.b, Q2.a, Q3.g-h-i, Q4.c, Q5.b, Q6.d-c	Q1.c-d, Q2.a, Q3.m, Q4.c, Q5.b, Q6.b
Number of teachers	21	47	21	21

The k-means analysis allowed us to find four clusters that are represented by the four centroids, which describe the prevalent behaviour of the teachers in the clusters (Table 2).

Upon examination, teachers in cluster Cl1 appear to be young Turkish teachers (age 25–29) from 6th, 7th and in part 8th grades, almost female. These 21 teachers in the Cl1 cluster show a clear behaviour that is significantly different from the other teachers in the sample. They appear to be aware (fourth level on 6 of a Likert scale) that the Covid-19 pandemic explicitly asked teachers for a change in the use of resources. In replying to Q7, they also highlighted that this change requires a perspective change in teaching, as discussed by Pepin et al. [14]. They clearly state that Covid-19 strongly influenced them, changing their use of resources. They strongly refer to a "shift" from text resources (e.g. textbooks, syllabi, websites), to digital curriculum resources (e.g. e-textbooks, educational platforms), and other material resources (e.g. calculators, digital instructional technology).

The centroid strategies of Cl2, show different teachers' behaviours in Q1, with more detail in the answers to question Q7. Cl2 cluster represents the biggest group of teachers (47 teachers) not culturally homogeneous in which it is possible to find teachers from Norway, the Czech Republic and, albeit to a small extent, Slovakia. Cl2 appears to

represent "old experienced" teachers (age 40–59), almost from 4th, and 5th grades, almost female. They appear to be aware (at the same level as Cl1) of the effect of the Covid-19 pandemic on the use of resources. In this case, they also reply to the questionnaire highlighting the significance of the changing process regarding the use of teaching resources. In replying to the Q7 question, they underlined in what ways the Covid-19 pandemic changed the way they used resources. In some cases, they refer to a new use of digital curriculum resources (e.g. e-textbooks, educational platforms) or other material resources as digital instructional technology for teaching (e.g. for preparing lessons, and assessments). However, some other teachers appear still anchored to the traditional logic of resource use. Some teachers refer to classical text resources (e.g. textbooks, syllabi) as one of the most useful resources for teaching.

The clusters represented by centroid Cl3 and Cl4 have the same numerosity as Cl1. (21 teachers for each one).

Cl3 is composed of "mixed experienced" teachers (age 30–49), almost from 7th, 8th and 9th grades, almost female. Cl3 cluster, as the Cl2 one represents a group of teachers not culturally homogeneous in which it is possible to find teachers from Italy and in small part from Slovakia.

The most given answers of Cl3, show a strongly different teacher behaviour on the Q1, detailed by the qualitative analysis of the Q7 question. These teachers appear aware of the effect of the Covid-19 pandemic on their teaching on level 2 of the Likert scale. They reply to Q1 highlighting a not significant change of resources in the pre and post Covid-19 times. Analysing their reply to the Q7 question, they appear more "conservative" than all the other colleagues from different countries in Cl1 and Cl2. It appears very clear that for them (especially for the Italian teachers) the classical printed version of textbooks and all the classical text resources remain the most useful resource for teaching even after Covid-19.

Very few teachers in Cl3 refer in the questionnaire to a strong change in the daily use of digital curriculum resources or digital instructional technology for teaching. This result screeches (and surprised us) with the data related to their degree of education that is higher than the teachers in the Cl1 and Cl2 clusters.

The cluster Cl4 is made of 20 young Czech teachers (age 25–29) from the last grade (13th), almost female. Cl4 teachers appear moderately aware of the effect of the Covid-19 pandemic on their use of resources. Analysing Q7 answers it is possible to de-tailed this data. Some Czech teachers refer to a new use of digital curriculum resources or digital instructional technology for teaching, useful for them in preparing lessons or helping students in a classroom or, finally for the student's assessments. Some other teachers appear still anchored (even if less than the Cl2 and Cl3 teachers) to classical text resources (e.g. textbooks, syllabi) as useful resource for teaching.

By also analysing the data related to Q7, the most used resources before Covid-19 were textbooks and discussions with colleagues. After Covid-19 time, some Czech teachers (some similar behaviour was found in cluster Cl2 about Slovak teachers) frequently use digital resources (such as GeoGebra, WolframAlpha, etc.) and professional online platforms for teachers. Other typical/classical resources remained the same after the Covid-19 situation.

5 Conclusion

Some researchers (e.g., [34]) highlight an increase in the use of technology and new software environments during the Covid-19 pandemic. In this contribution, we discuss a pilot study carried out during the 2020–21 academic year by the Consortium of the MaTeK Horizon 2020 project concerning the effects of the Covid-19 pandemic on the use of teaching resources in mathematics. Quantitative and qualitative methods were used to analyse the answers given to a questionnaire by a set of teachers. We only refer to a subset of questions in the questionnaire designed in the context of the MaTeK Horizon 2020 project. In particular, we analysed the answers related to the demographic questions such as age, gender, teaching experience, the highest degree of education, taught subjects (other than mathematics) at School and the two questions reported below.

Q1- *To what extent did the Covid-19 pandemic situation change the way you used educational resources compared to how you use them now?*

Q7- Please, *describe how the Covid-19 pandemic situation has changed the way you used educational resources compared to how you use them now.*

Q1 is a closed-ended question and the answers were collected by using Likert scales. Q7 is an open-ended question and the answers were analysed using a qualitative analysis. All other demographic questions are closed-ended questions. All closed-ended questions were quantitatively analysed by using K-means clustering.

Young teachers appear to be more open to changing their teaching than the "older" ones. We observed that young Check and Turkish teachers are aware that the Covid-19 pandemic explicitly asked them for a change in the use of resources and that this change also requires a perspective change in teaching. In many cases in Q7 answers, they strongly refer to a "shift" from text resources (e.g., textbooks, syllabi, websites) to digital curriculum resources (e.g., e-textbooks, educational platforms) and other kinds of resources (e.g. calculators, digital instructional technology). The "Older" teachers in our sample are aware of the impact of the Covid-19 pandemic on student learning. However, their use of teaching resources was not always strongly influenced by that. Italian and Slovak teachers in Q7 answers highlighted such a kind of behaviour much more than the teachers from other countries.

We think relevant some results regarding teachers with a high degree of education (Master, mainly Italians and Slovaks) independent of their age. They are aware of the impact of the Covid-19 pandemic on student learning, but still do not feel significant daily use of digital curriculum resources or digital instructional technology for teaching [35], sticking with the use of old-fashioned resources, like textbooks.

Turkish teachers are all grouped in a single cluster, showing a remarkable cultural homogeneity concerning the use of teaching resources. The same happens for almost all Czech teachers in Cl4. Italian teachers exhibit similar behaviour, being included in a single cluster, which also contains some Slovak teachers. The remaining part of Slovak teachers is in another cluster, together with Norwegian and a few Czech ones.

It is worth noting that Czech teachers exhibit mixed behaviours concerning the use of resources in teaching due to the Covid-19 pandemic. They recognize the importance of updating the resources, due to the pandemic emergency. In some cases, replying to Q7 they appear still anchored to the traditional use of resources. These results deserve more deepening and will be an object of further study, also by the Consortium.

Some more conclusions can be inferred using a closer analysis of the single answers given by the teachers to the questionnaire Q7 question. A preliminary result of such a kind of analysis seems to highlight that the majority of teachers feel the need to change their use of teaching resources. However, they find hard to do it in their everyday teaching coming from 4th and 5th grades. These results also deserve deepening and will be the object of further analysis, mainly by using further qualitative methods of data analysis.

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Appendix

Q1 – To what extent did the covid-19 situation change how you used to use resources and how you use them now?

a- 1 – Not at all
b- 2
c- 3
d- 4
e- 5
f- 6 – To a great deal
g- No answer

Q2 – What is your gender?

a- Female
b- Male
c- Prefer not to say

Q3 – Please indicate the grade level(s) you are teaching mathematics this year (2021–22) – You may select more than one option:

a- 1st Grade
b- 2nd Grade
c- 3rd Grade
d- 4th Grade
e- 5th Grade
f- 6th Grade
g- 7th Grade
h- 8th Grade
i- 9th Grade
j- 10th Grade
k- 11th Grade

l- 12th Grade
m- 13th Grade

Q4 – What is the highest degree of education you have completed?

a- High School
b- Bachelors
c- Masters
d- Ph.D.
e- No answer

Q5 – What subjects other than mathematics do you teach?

a- Science related subjects (chemistry, biology, physics)
b- Social Studies related subjects (examples)
c- Arts or humanities (examples)
d- No answer

Q6 – What is your age?

a- Under 25
b- 25–29
c- 30–39
d- 40–49
e- 50–59
f- 60+

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