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Exploring the statistical practices in classroom: STEM teachers' experiences using dynamic data analysis technology.

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In the 21st century, schools have been increasingly expected to raise students prepared for a world of quantities and uncertainty. As statistical practices become an important skill for every individual, researchers and educators work on ways to translate the methodologies of professional statisticians in the teaching and learning environments. Technological tools are helpful in translating statistical investigations into the classroom. The purpose of our research is to understand teachers' experiences about integrating statistical practices into their STEM lesson plans by using LabStar, a dynamic data collection and data analysis device. Findings were investigated under four categories: personal development, in-class implementation, views about the mobile application and the tool, and statistical investigation environment. Future research was recommended to investigate teachers' professional development opportunities to integrate meaningful statistical practices in their lesson plans.

Keywords: Statistics education, statistical investigation, dynamic data analysis technology.

Introduction

In the Big Data era being competent in making data driven decisions in all aspects of daily life is inevitable. Many decisions in politics, economics and social sciences are based on thorough analysis of data. The omnipresence of data requires individuals with strong analytical and reasoning skills who can base their decisions on their inferences beyond the data in the way that professional statisticians do (Frischemeier, 2020). However, international reports point out the lack of individuals, who demonstrate necessary skills to cope with Big Data even at the tertiary level (Manyika et. al., 2011; Puang-Ngern, Bilgin, Kyng, 2017). From this point, practice of statistics became a crucial element to integrate in primary and secondary school curricula.

In 21st century, schools have been increasingly expected to raise students prepared for a world of quantities and uncertainty. With the availability of data from variety of sources and in a variety of formats students are required to manage the complexities to reach data driven conclusions (Makar & Rubin, 2009). Statistics, therefore, has become an essential element of school mathematics curricula of many countries (e.g., Australian Curriculum, Assessment and Reporting Authority, 2015; Common Core State Standards Initiative, 2010; Ministry of National Education, 2018).

As statistical practices become an important skill for every individual, researchers and educators work on ways to translate the methodologies of professional statisticians in the teaching and learning environments. Statistics education is becoming an agenda across many levels of schooling. Debates about how to help students gain an understanding about statistics requires us to think about the nature of statistics. Statistics is about carrying out statistical investigations on a specific statistical question to understand a phenomenon. Statistical investigations are based on exploring the variation, by

engaging data collection, data representation, data reduction, level of certainty and informal inference practices (Watson et al., 2018).

Statistical investigation is recommended to be the focus of the statistics teaching-learning activities in classroom contexts. The parts of the investigation process have been also included in mathematics curricula starting from elementary grades. As the practices of statistical investigation become a part in mathematics curriculum, the role of the teachers comes forth. Teachers are expected to design authentic contexts where students can engage in data collection, analysis, and informal inference processes. Research also underlines the importance of teacher knowledge on statistics and statistical thinking to design effective learning experiences for their students (Rodrigues & de Ponte, 2020).

Technological tools are helpful in translating statistical investigations into classroom. Dynamic technologies that allow students to experiment with data collection and analysis techniques were started to be researched in terms of the opportunities they provide for statistical practices (Meletiou-Mavrotheris et al., 2008).

Based on this rationale the purpose of our research is to understand teachers' experiences about integrating statistical investigation practices into their STEM lesson plans by using LabStar, a dynamic data collection and data analysis device. The main statistical aim for teachers was to encourage them use data as they teach different concepts in different disciplines. With the help of statistical investigations within the lesson plans students were expected to collect, analyze, and interpret data to make sense of the concepts taught. Teachers were provided with educational videos about integration of statistical investigations into STEM lesson plans and the use of the LabStar device. After watching all the videos teachers implemented the STEM lesson plans, designed with authentic statistical investigation tasks. Our aim is to explore the lived experiences of teachers about the implementation of these lesson plans. Our research questions are:

- How STEM teachers contextualize statistics and mathematics into daily life problems using STEM integration?
- How STEM teachers perceive their roles in terms of integrating statistical investigations in STEM lesson plans?
- How STEM teachers evaluate the mobile application, LabStar device, and educational videos in terms of designing and implementing statistical investigations in STEM lessons?

Methodology

The research used a phenomenological method among qualitative research designs. The study group is four STEM teachers who used statistical investigation practices in their classrooms during 2020-2021 Spring Semester. T1 was a middle grades mathematics teacher, T2 and T3 middle grades science teachers, and T4 was a high school physics teacher. All teachers were competent in developing and implementing STEM lesson plans. However, they did not use statistical practices in their STEM lesson plans before. Only T1, as a mathematics teacher, implemented mathematics lesson plans focusing on statistical concepts (i.e. mean, median, range) and procedures (i.e creating and interpreting bar graphs). Teachers were aged between 30-40 years. They implemented STEM lesson plans integrated with statistical investigation in various grades and with different disciplines in the center of the lesson plan. They used LabStar as a dynamic data analysis technology. LabStar is a

dynamic data collection and analysis device developed with pedagogical purposes. In each lesson plan LabStar is used for the data collection and/or data analysis to create a context for discussion on the collected data. LabStar was developed within a research grant received from Bahçeşehir University, Turkey. The device collects the following continuous data through its sensors: distance, ambient temperature, ambient humidity, air pressure, altitude, ambient light, acceleration, and sound intensity. Students can collect data in any location about different variables that can be associated with the curriculum and teachers' learning objectives. With the LabStar mobile application both collected data and data accessed through open resources can also be analyzed (Please see fig. 1).

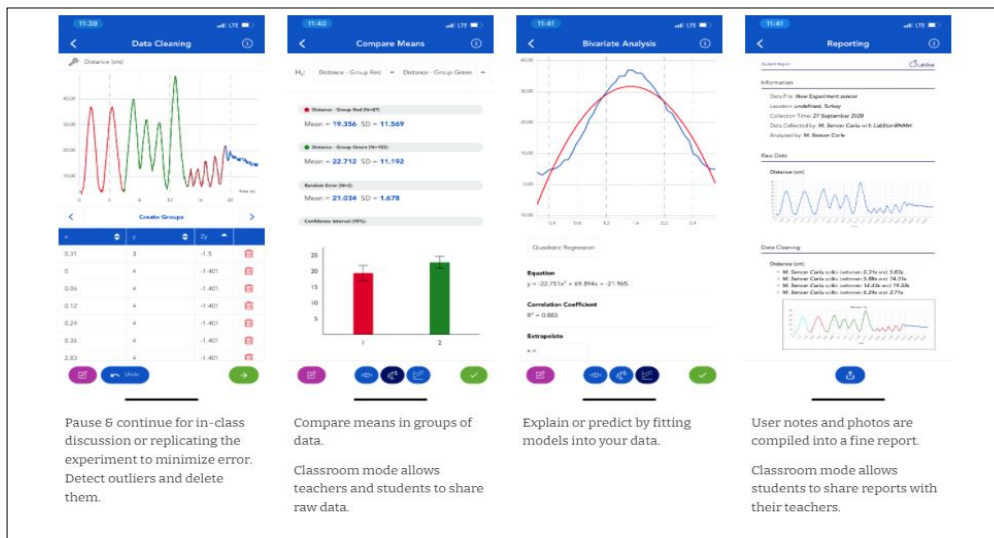


Figure 1: Screenshots from LabStar mobile application

All teachers and students had the LabStar mobile application, one of them (T4) had both the LabStar device and the mobile application. Teachers used data from open resources to analyze in their in-class implementations. Before the implementation they were provided with training videos regarding ways of using dynamic data analysis technology in their STEM lesson plans. In the lesson plan of T4, as an example, LabStar was used to create a student-centered, collaborative learning environment to allow students to work on real data and experience the practical aspects of statistics. In the lessons, the students collected data on sounds by using sound sensors. When they collected the data, the students simultaneously saw the decibel and amplitude change over time. By getting immediate feedback, it is possible to engage with real-world data and build an understanding about its meaning.

For data collection we conducted face-to-face interviews with the teachers. To ensure a prolonged relationship, interviews lasted at least 60 min. Audit groups were formed within the research group and member check processes were planned to ensure trustworthiness. Researchers are also using peer-debriefing during data collection and analysis phases. STEM lesson plans and field notes of the teachers were used as data sources to ensure triangulation in data collection. For data analysis, interviews were transcribed, and thematic analysis was conducted by using constant comparative method. First, codes were defined by reading the transcripts. Codes were used to generate overarching themes to answer research questions. The codes and themes were reviewed with the

coders and intercoder agreement was ensured. Lesson plans of teachers and lesson artifacts were analyzed to support the findings from interview data.

Findings

Regarding the first and second research questions statistical investigation environment and in-class implementation themes has emerged.

Statistical Investigation Environment

The teachers used open resource data or collected data via LabStar device in their statistical investigations. For the open resource data, they chose current topics such as covid-19, health, and environmental problems (carbon emissions, mucilage, etc.). T4, who used the LabStar device collected sound intensity data to discuss about physical concepts related with sound. The teachers from different disciplines have different expectations about the statistical terms that the students must know and express in a statistical investigation environment.

It is crucial to be able to read the graphs, where is the peak, what is the increment this month, being able to comment, creating a cause-and-effect relationship is important for science. Mathematical interpretation, peak point, outliers. I believe that LabStar application is related to mathematics at most. (T2)

The students do not know how to read the graphs, they cannot even read tables. They have learnt how to do it; I believe that that is the significant contribution. (T3)

The teachers claimed that STEM integration made observing statistical terms easy.

In the topic waves, there are fundamental notions. Frequency, amplitude, and wavelength. You can create a sinus wave, you can observe the wavelength, then we can measure it. We talked about range and modes, we created 2-3 waves, x wave and y wave then we compared them. At first, they talked about their image, then we compared them as data. (T4)

Some students were not interested in terms related to statistics. When teachers were asked if the students asked about statistical terms, T2 said “No, they did not ask. In 6th and 7th grades the activities would be more efficient. However, since the total number of lessons are less in 5th grades, it limits us.” T1 added that, in online environment, only the students who are passionate about mathematics asked, but we did not have a whole-class discussion. Since the number of curious students were low, they contacted us through direct messages. (T1)

In-class Implementation

This theme has emerged as the teachers expressed their experiences about the application of statistical investigations within a STEM lesson plan. A problem occurred because of the mismatch between the current grade’s curricula and the statistical terms in the tool. T1 claimed that “Some terms were troublesome since they did not fit to my class”. T2 added that “In my opinion it was not suitable for 5th graders, the terms mode, median in the graphs”. T1 further explained that: “The students didn’t know the terms and their meanings since the terms do not fit to fifth grade’s curriculum. They did not understand it because they did not learn it, and I did not pre-teach the terms.”

Some teachers had problems because of the students' technological skills being insufficient. T1 claimed "Some students found it hard to transfer data to an Excel sheet", She further said "At first they found it hard to create a table. There were students who did not know the shortcuts".

The teachers who had the mobile application but not the LabStar device claimed that they could have reached to more students if they had the device to collect real time data. Some teachers observed that some students were interested in the lesson:

There were many students who were interested in the lesson. There was data related to basketball, it drew the attention of male students. If the topics were different there could be different things. But I received positive reactions, some students asked if they could collect and analyze another data. (T2)

Regarding the third research question teachers' personal development and their views about mobile application and LabStar device themes came forth.

Personal Development

This theme has emerged as the participants mentioned about the training they have received and research they have done before and/or during applying a STEM activity in the class. All teachers expressed that the educational videos that they have watched before attending to the classes, helped them to learn and grasp the nature of the application before introducing the software to the students. One of the teachers, T1, commented that "With the help of the videos, especially the fourth one, we were able to lead the students in the right direction". T2 added that: "The videos were sufficient, I received STEM education last year, I knew nothing. In a year I learnt about STEM education and some of the questions were given to us that are in the videos."

Furthermore, some of the teachers had to get help from various resources because they felt that they did not have sufficient knowledge.

I am a science teacher, when I was studying on it, I got help from my husband who is a mathematician, (I asked about) upper quartile, lower quartile etc. I taught students with the information I got from him too. I also got tremendous help from the educational videos. (T3)

This view also showed that teachers also had an opportunity to discover knowledge related to other disciplines. A teacher had sufficient technological knowledge and even integrated STEM education to work with a software simultaneously.

I thought about what I could do, I set up a meeting with the students from 9th and 10th grades. A student said that we should test its (LabStar's) accuracy. We tested it and it was accurate. We conducted two experiments, firstly we created sound waves and measured its decibel. We have a software called Scratch; we created the sound waves then integrated it with LabStar. The data were almost equal. We used it to compare the sound waves, their wavelengths. I found it usable for advancing in physics. It is a nice software (T4).

The teachers started their lessons with introductory activities to motivate students. T1 stated "We asked the students about number of cases of covid-19. Then we led them to the relevant website.". T2 added "I asked the properties of microscopic life forms. With the feedback I have received, I mentioned about the bacteria then gave the table". Although T2 did not ask anything before the lesson, she let the students explore by themselves. This allowed the students learn by discovery.

I did not ask anything, I let them do experiments because I was experimenting too. When I asked what do you see, they told me that the wave is increasing, I asked how a wave can increase? Is it on the direction x or y? Then we got data, but now they tell numbers instead. Are they increasing or decreasing? We call them data. As the waves increase, the numbers increase, what do we call it? Wavelength. (T4)

Some teachers worked as a group to put out the lesson plan.

We worked as a group. I usually build interdisciplinary relations with mathematics, but I always get help from the biology. We do gas pressure, sound waves, they are all about biology. There were machines in STEM laboratory, I used the distance sensor there. (T4)

The teachers explained that they plan to apply their knowledge into their other lessons too.

Maybe it is not possible to apply it to all topics, since physics, chemistry and biology are different. But for velocity, race, order of the velocity, density of a matter, there can be data and it can be commented on. I think that it could be integrated depending on the area. (T2)

T4 also asserted that, “I will use it to explain illumination density. I have the topic movement on 10th grade, location, distance, translocation, I will use graphs. It is fun to make students active in 9th and 10th grades.”

Views about the mobile application and the LabStar device

This theme has emerged as the teachers stated their views about the mobile application and the tool that they have used to carry out their STEM lesson plans.

Another challenge was born because of the language of the application being English. This was a common problem amongst all teachers. T1 stated “The only problem was the application being in English, it could be in Turkish. If they don’t know English, they need to use translation”. Some schools did not receive the LabStar device, but they only had the mobile application. The teachers believe that they need the device itself.

It would be better if we had the tool. For instance, in a 7th grade, I have conducted a lesson about darker colors absorbing light thus being colder. I used heat and light sensor simultaneously to observe the graph. It was a brilliant lesson. I did not have such fun in any lesson before. So, it would be better if we had the data collection tool. (T3)

T2 claimed that. “It is vague for 5th graders, for a fifth grader, the tool being here and the process of collecting the data is necessary. It needs to be concrete”. There were some problems that originated from the application and technology use. Overall, the teachers were satisfied with the experience they had with LabStar. T2 claimed “The teachers can use LabStar easily and create STEM lesson plans.”, T4 added “LabStar can analyze data, it is accurate and fun”.

Discussion

Based on the findings we can conclude that mathematics teacher made use of the LabStar mobile application to directly teach statistical concepts. The teachers from other disciplines used the mobile application and the LabStar device to bring current issues related with their disciplines into the classroom environment. Although they had some difficulties, the teachers reported that by seeing the

graphs live, students grasp both the concepts related to their disciplines and statistical concepts in a fun and interactive way. This may be because in most cases formal statistics teaching leaves students in a confused state as most of the time they are not able to apply the theoretical knowledge into real life (Bakker et al., 2017), whereas the fun factor comes into play with the real life integration activities. Teachers from the disciplines other than mathematics used statistical investigations to work on scientific concepts in detail with their students. This enabled them to integrate mathematics into their STEM lesson plans. Even though context integration should be used to teach STEM (Kertil & Gurel, 2016), the teachers most of the time failed at integration of STEM with other disciplines, especially mathematics, they mostly worked on their own disciplines. Therefore, creating statistical investigation environments was evaluated to be essential in terms of integration of mathematics into other STEM disciplines (Anderson & Li, 2020).

In terms of how teachers contextualize mathematics and statistics in the STEM lesson plans we found that interpreting graphs, basic statistical concepts, and procedures were the topics that teachers focused on. With the help of the mobile application and the device they had the opportunity to discuss about statistical concepts in various disciplines. Teachers also reported that they had hard time to interpret the statistical terms, and they found the statistical terms discussed beyond the level of students. The reason for this might be that both mathematics and science curricula in Turkey do not emphasize the importance of data and doing statistics to make sense of the concepts. However, starting from mathematics curricula, more and more countries intended to include data science to foster statistical investigations in the classroom (e.g, 2022 revision of the Mathematics Framework, the California Department of Education).

Teachers evaluated their role in creating statistical investigation environments, mostly, as finding the data source, and explaining the meaning of statistical concepts. Parallel to the embraced role, the teachers reported that they have dealt with problems that arise from the statistical terms. Regarding this problem, increasing students' agency and discussing the meaning of statistical terms together with the students throughout the statistical investigation process might be recommended. Teachers also reported that they improved themselves in terms of statistics terms and procedures by seeking help from other teachers. This can be evaluated as an indication of that the teachers want to improve themselves to integrate statistical investigations into their disciplines. They were content about the trainings they received, but they are also ready to transfer this experience into other concepts and topics within their disciplines by learning more. Future research was recommended to investigate teachers' professional development opportunities to integrate meaningful statistical practices in their lesson plans.

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