Examining the opinions of mathematics teacher candidates on the effectiveness of coding activities in the teaching-learning process

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The aim of this paper, is to reveal pre-service mathematics teachers' views on STEM education and coding activities. Research was conducted with 28 pre-service mathematics teachers studying at a mathematics education department in Turkey. There were two sources for data: the lesson plans analysed using the content analysis technique and the opinions of the participants which were collected through the questionnaire. The findings, were obtained through the views of the participants indicated that coding activities supported the students in terms of algorithmic thinking ($n = 19$) and that they provided the opportunity to learn mathematics with gaming ($n = 14$). In addition, participants stated that the workshops were needed to develop knowledge and awareness of technological-pedagogical content knowledge in order to increase the effectiveness of coding activities.

Keywords: STEM education; Coding; Teacher training

Introduction

Coding, which is defined as a computer language used to develop applications that establish human-to-human and human-to-machine communication within a system and organization, is stated that students should be equipped with the 21st century skills (European Commission, 2014). In the many curricula worldwide, there is particular attention given to develop coding skill, with the evidence of its influence on the skills of logical thinking and problem solving (Balanskat & Engelhardt, 2014).

Coding is a natural component of STEM education, as it necessitates the use of algorithmic thinking and designing skills. There is also evidence that the skill of coding contributes to the learning of mathematics (Aydın & Derin, 2018). For example, it was used to enhance the understanding of the concepts of applied mathematics such as algorithm, iteration and variable. Students learn such concepts better by turning mathematical ideas to games and animations (Gadanidis, 2015). Lewis and Shah's (2012) study provided evidence that coding has a positive impact on their summative test results.

In Turkey, the technology component of STEM is generally put into practice in the form of a coding activity and most of the STEM applications in Turkish schools include a coding component. A superficial look at the perception of STEM in the Turkish practice, shows that STEM activities are perceived to be equivalent to coding activities. At this point, we need to make a distinction between a 'coding activity' and 'coding as part of a STEM activity'. We believe that an activity based solely on coding without a STEM context cannot be considered as a STEM activity, since there is no need for the integrated knowledge for the solution of a problem.

Conceptual Framework

The literature indicates two different STEM classroom perspectives: content and context integration (Roehrig, Moore, Wang & Park, 2012). In the content integration, the areas of STEM are perceived as a single discipline (Breiner, Johnson, Harkness & Koehler, 2012). In Turkey, this approach was met with caution by some of the leading academics in the areas of science and mathematics education (especially the latter one), because of the perceived threat to the identity of each of the STEM areas (Aydın & Derin, 2018). In the context integration, one of the STEM areas is in the centre and at least one of the other three are in the periphery (Roehrig, Moore, Wang & Park, 2012). This is defined as the knowledge of the other discipline needed by teachers to help teach in his/her own area of teaching. A mathematics teacher needs to have a knowledge of how to 'code' within the context of a mathematics problem. This leads to the integration of technological pedagogical content knowledge (TPACK) and mathematical content knowledge (MCK). In this study, we are adopting a context integration: what seems a pure coding problem has a mathematical basis. So we consider the intersection of the coding knowledge and the mathematical background knowledge that makes it possible to code.

Aim of the study

This particular work is part of a bigger project supported by the Scientific Research Project Committee at Marmara University. Our wider focus, as defined in that study was to investigate whether or not a STEM integration is necessary for the Turkish educational system considering the structure of the curriculum in science and mathematics education and the lack of research in these areas and if so, in what ways, the integration can be made. In this particular study, we pay attention to the role of coding activities within this integration process. The aim of this paper is to reveal pre-service mathematics teachers' views on STEM education and coding activities. The research question of this study was formulated as: what is the opinion of the pre-service mathematics teachers about the effectiveness of coding activities in the learning-teaching process?

Method

We used a case study design as the research method to evaluate the process of the participants in a specific learning environment in depth. This research was conducted with 28 pre-service mathematics teachers studying at a mathematics education department in Turkey on a voluntary basis. Participants are selected from among the pre-service teachers by purposeful sampling, who took the STEM education course. During the autumn semester of the 2017-2018 academic year, the participants were faced with modelling activities under the "Problem Solving with STEM Education" selective course in the mathematics laboratory. This is considered as an opportunity to investigate our research question.

STEM education course

During STEM education course participants learned how to code with programming software tools, such as Mblock, Scratch and Microbit. These programs allow the users to control their robots' movements by dragging and dropping preloaded commands. The users can turn their codes into real effects and, as a result, programming becomes visible in the physical world. A problem-based approach was used throughout the course. Students are encouraged to solve the problems given in activity sheets using mathematical modelling in the first phase of the course. In the second part of the course engineering problems were given using FischerTech engineering sets, then coding programs were introduced by using the programming software of Scratch, MBlock and Microbit. The robotic training sets and activities, which were used in STEM environments by the following FischerTech engineering sets guide books, are as follows: Impeller and gear system (*Static sets*), Bridge Problem (*Static sets*), Crane Problem (*Dynamic sets*), Ferris Wheel Problem (*Dynamic sets*) and Wind Rose Tribunes Problem (*Robotic sets*).

Data collection process

There were two sources for data: the first source of data is from the lesson plans which were analysed with respect to the three pre-defined themes such as content strands, targeted skills and content integration types. Findings from the lesson plans were reported by using descriptive statistics. The second source of data is the opinions of the participants, which were collected through the questionnaire. Excerpts from participants' writings were used to support the trends revealed from the lesson plans. The data came from the questionnaire which was collected as part of formative assessments of the course in STEM education. The activities in the STEM course presented a fruitful opportunity in that regard. In order to answer the research question, STEM education and mathematics-based lesson plans prepared by the participants are the main data collection tools of the study. The lesson plans developed in this context were evaluated according to content analysis. In addition, some of the participants were selected by means of purposeful sampling technique and the points that were taken into consideration during the preparation of the lesson plans were analysed more deeply.

Findings

The participants prepared a lesson plan to apply the tasks they developed for a content strand at secondary school level and expressed the mathematical skills they aimed to develop in these strands. The findings of the study were obtained through content analysis of the lesson plans and interview findings gathered with the participants selected from the purposeful sampling. We will report the findings of the study under three headings which were used in the content analysis.

Use of tasks with respect to four content strands

There are four content strands in the Turkish mathematics curriculum at secondary school level and these are algebra, geometry, numbers and statistics. The findings of the study showed that the participants developed the tasks for coding with the geometry strand the most frequently (71%). Another area of learning, which was later used more frequently in the geometry strand, was algebra (21%). It was noted that only one participant developed coding activity in the strands of statistics and numbers (Figure 1).

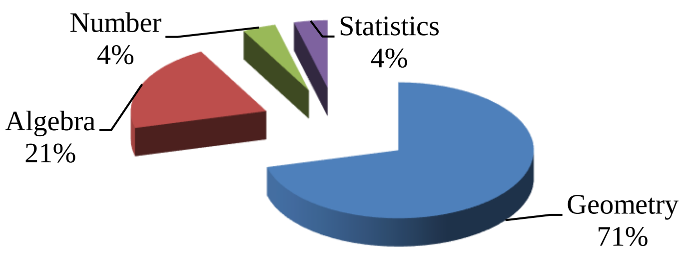

Figure 1: Percentages of use of the four strands

It has been observed that, in the geometry strand, codes are written as an algorithm for drawing of the solid objects and especially to turn a shape around an axis to obtain a new shape. In the algebra strand, that coding activities are mostly used for exploring the relational changes in the variables.

Use of tasks in terms of targeted skills

As a result of the content analysis of the lesson plans, it was determined that the mathematical skills aimed to be developed with related coding activities were algorithmic thinking, visualization, logic, problem solving and reasoning. Approximately two thirds of the participants stated that students could develop their algorithmic thinking skills through coding tasks (68%). Almost half of the participants described their coding activities as a means of visualization that can be embodied in algebraic expressions (43%) (Table 1).

Table 1: Distribution of tasks in terms of targeted skills

Mathematical skills	Frequency	%
Algorithmic thinking	19	68
Visualization	12	43
Logic	8	29
Problem solving	8	29
Procedure	6	21

As can be seen from the quotation below, the participants who pointed out the ability of visualization stated that the activities were compatible with the learning levels of Piaget (transition from the abstract world to the concrete world) (Aydın & Derin, 2018), and this understanding indicated that a visualization argument could be used in the transition period from coding to abstract.

> ***Participants-2:*** Especially in the process of transition to algebraic expressions, a coding activity will be useful to show the students what kind of a real world model is behind mathematics.

When Participant-2 explained why she used this activity, she stated the following: “*Here, this program helps the student to visually perceive and better understand the solid geometric figures. Prism can be made in desired size and shape and different prisms are comparable by using this coding activity.”*

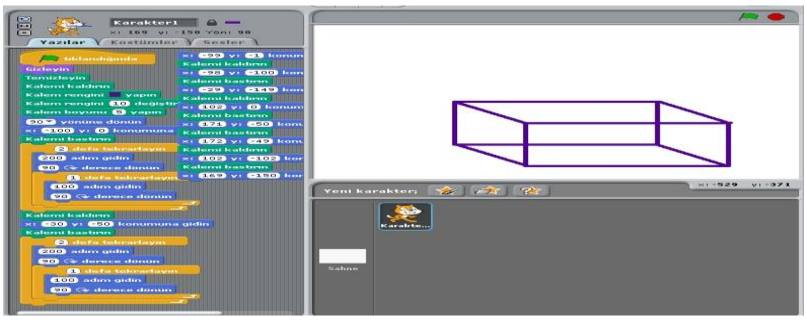

Figure 2: Coding activity of Participant-2’s with Mblock

Use of content integration types

When the activities are evaluated according to the type of integration, it is determined that the contents are based on coding program based, STEM disciplines-oriented or software-oriented outputs. Although there are contents based on science, mathematics and design skills in the course which participants attended, only one third of the activities developed were designed in accordance with the integrated nature of the STEM disciplines. It was observed (57%) that it is often necessary to use a programming language in the mathematical solution of real-life problems. The proportion of activities focusing on the integrated skills of the STEM disciplines was only 32%. In the remaining activities, the outputs that require the solution of a new problem situation through the Geogebra software have been emphasized (11%).

Table 2: Distribution of content integration types

Content integration types	Frequency	%
Programming-based	16	57
STEM-based	9	32
Software-based	3	11

The most striking point for the limitation of coding activities in STEM-based themes is the difficulty in finding the appropriate activity for each discipline. The following is a quotation from a participant that exemplifies the above argument.

> ***Participant-5:*** Trying to embed the mathematical acquisitions within the activities can be quite difficult. In particular, developing such activities for each mathematical concept can adversely affect usefulness.

Discussion and Conclusions

In the study findings, it is interesting that the students more often produce activities that can be used in the field of geometry. It is known that the content of the geometry course is below 25% in the secondary in the Turkish school mathematics program. However, students in our study used such activities more often. One of the reasons for this finding can be that the two problems which require coding in transformation geometry were asked in the high school entrance exam in recent years. The fact that the previous examples emphasized the area of geometry may have prompted the participants to prefer the area of geometry more. In fact, pattern models that require algorithmic thinking in algebra content can also be used frequently at secondary school mathematics, but it is observed that pre-service teachers do not give importance to the types of activities that require skills in this sense.

Another noteworthy finding is that the objectives of this study are the integration of participants with content that can be used in the process of coding mathematics in the context of STEM activity, while participants focus more on the contents that lack the design and science disciplines and require the use of technology in mathematics education. There may be two reasons for this. Firstly, the conclusions of the interview results showed that the participants were first faced with integrated STEM training and therefore they preferred the fields (technology-mathematics) that were close to them in STEM education. The second implication is that the popular agenda of STEM approach, programming and coding seemed to attract the attention of the participants.

According to pre-service mathematics teachers, coding activities particularly supported the students in terms of algorithmic thinking. Pre-service mathematics teachers also stated that these activities provided the opportunity to learn mathematics by playing games. In addition, the results of the study showed that the participants' awareness about how to use coding activities in mathematics education is low. In this context, it is recommended to focus on the processes of developing activities appropriate to different subjects and different mathematical skills that participants expressed as limitations.

Acknowledgments

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References

Aydın, E., & Derin, G. (2018). STEM ve matematik eğitimi (STEM and mathematics Education). In A.K. Kirkiç, & E. Aydin (Eds). *Merhaba STEM: Yenilikçi Bir Öğretim Yaklaşımı*, (pp. 27-38). Konya: Eğitim Yayınevi.

Balanskat, A., & Engelhardt, K. (2014). *Computing our future: Computer programming and coding - Priorities, school curricula and initiatives across Europe. European Schoolnet.* Retrieved from http://www.eun.org/resources /detail?publicationID=481.

Breiner, M. J., Johnson, C. C., Harkness, S. S., & Koehler, C. M. (2012) What is STEM? A discussion about conceptions of STEM in education and partnerships, *School Science and Mathematics*, *112*(1), 234-243.

European Commission (2014). *Coding - the 21st century skill.* Retrieved from https://ec.europa.eu/digital-single-market/coding-21st-century-skill.

Gadanidis, G. (2015). Coding as a Trojan horse for mathematics education reform. *Journal of Computers in Mathematics and Science Teaching*, *34*(2), 155-173. Waynesville, NC USA: Association for the Advancement of Computing in Education (AACE). Retrieved from https://www.learntechlib.org /primary/p/147419/.

Lewis, C. M., & Shah, N. (2012). Building upon and enriching grade four mathematics standards with programming curriculum. *Proceedings of the 43rd ACM technical symposium on Computer Science Education*, (pp. 57-62). North Carolina University: USA.

Roehrig, G. H., Moore, T. J., Wang, H. H., & Park, M. S. (2012). *Is adding the E enough?: investigating the Impact of K-12 engineering standards on the implementation of STEM Integration.* (Unpublished doctoral dissertation). Purdue University, USA.