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A Comparative Study between 2009, 2013 and 2018 Lower-Secondary Mathematics Education Programmes on the Use of Material and Technology

***Tuba Gökçek, ** Tuğba Baran Kaya**

Abstract. The study aims to compare lower-secondary mathematics education programmes (5-8th Grades) between the years of 2009, 2013, and 2018 in terms of the use of programme material and technology. The study is conducted through document analysis, the documents of which are compiled from lower-secondary mathematics education programmes of the concerned years. It explores the types, and the extent, of tangible teaching materials and technologies used in those programmes by examining learning outcomes and explanations drawn from them. The study evidently shows that the 2009 mathematics education programme has the largest number and diversity of materials in comparison to other programmes due to the high number of learning outcomes and concrete examples of activities used. In the 2013 and 2018 programmes, there is less focus on teaching materials and technologies as the main focus in those programmes lies at the issues such as teaching outcomes and short explanations. Henceforth, it remains to be teachers' responsibility to decide how to teach majority of the aimed outcomes as well as how to use teaching materials and technologies. Whilst the 2013 and 2018 programmes predominantly use such papers as dotted, isometric, and grid papers that facilitate the teaching of mathematics, the 2009 programme additionally use such materials that can be found in everyday life as magnifying glass, play dough, rope, beads, etc. and other materials namely centuriated cards and geometry boards. Moreover, given the explanations of learning outcomes, the 2009 programme suggests to use dynamic software for geometry more explicitly than the 2013 and 2018 programmes do. Evident shows that the 2009 education programme is more advanced than the other two considering the continual suggestion of the use of other teaching materials and technologies and the suggestion of diversity of teaching materials and technologies at large.

Keywords. Lower-secondary mathematics education programme, use of tangible teaching materials, use of teaching technologies.

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Education programme is a mechanism of learning lives that comprises all teaching activities of a course-subject planned to be delivered to pupils in and out of school (Demirel, 2009) and that provides a guideline on how to conduct those teaching activities (Melanlıoğlu, 2008). Mathematics education programme is defined as a plan in which pupils are provided with not only general experiences but also specific experiences that are designed to help them meet certain mathematical objectives (Remillard and Heck, 2014). This plan duly encompasses teaching materials. With teaching materials, Remillard and Heck (2014) refer to all sources that are designed to supplement, or complement, the teaching. Those include textbooks, guidebooks, activity books for mathematical explanations and all other teaching technologies. In fact, these sources have a foundational importance for the teaching of mathematics in education system (Eisner, 1987).

Turkey has given special attention to the use of tangible teaching materials as one of the sources of mathematics education programmes since the 2005 mathematics education programme, which was designed based on the constructivist approach and enforced (İskenderoğlu, Türk and İskenderoğlu, 2016). Studies since 2005 have shown that the use of tangible teaching materials are highly effective in the teaching of mathematics (Bahadır and Demir, 2017; Bozkurt and Polat, 2011; Demir, 2019; Gürbüz, 2006; Kutluca and Akın, 2013; Şengül and Körükcü, 2012). Whilst it seems effective to use tangible materials, it is also important that teachers need to be able to select and/or develop such materials to use them effectively (Özdemir, 2008). Therefore, it is of primary significance that education programme properly guides teachers and that it includes tangible teaching materials for such intangible course-subjects as mathematics that needs materialisation.

Teaching technologies, which is another source of an education programme, provide a number of advantages to pupils in the current context, let alone all humanity. Therefore, it has recently been one of the most significant teaching-learning methods (Önal and Çakır, 2016). Some of the aspects that need to be taken into consideration for the use of those technologies are the use of calculator, dynamic mathematics/geometry software, spreadsheet software, and other sources developed for the teaching of mathematics, namely websites, animation, etc. Those other sources also include the effective use of internet to access such sources as relevant online information, videos, and applications that need to be used in order to make mathematical subjects comprehensible (Turkish Ministry of National Education [MoNE], 2013). Whist it is not desired that pupils use calculators as an immediate recourse for all calculations, its use when necessary is well-supported. More problems can be solved in a shorter time using calculators and the time saved can be spent on developing deeper conceptual understanding, critical thinking and problem solving skills (Waits and Demana 2000). Also, another teaching technology, which is dynamic geometry software, has recently begun to be used in lower-secondary mathematics education programmes with the development of information technologies (Vatansever, 2007). Dynamic geometry software enables pupils to make geometrical and analytical-geometrical shapes, to drag those shapes, and to make measurements. Whenever those shapes are modified, those modifications can also be measured. Moreover, this software can be used in the teaching of transformational geometry (Güven and Karataş, 2003). Considering the literature on dynamic geometry, it is evident that this software helps pupils to explore the links between mathematical concepts and renders learning experience more amusing (Kutluca and Zengin, 2011).

In addition to calculator and dynamic geometry software, the teaching of mathematics can use the aforementioned sources such as spreadsheet software, websites, animations, etc. and the aforementioned information and communication technologies such as maths-related online information, video, application, etc. However, there still remains certain questions about which, and to what extent, information and communication technologies ought to be used and are recommended in the 2009, 2013, and 2018 lower-secondary mathematics education programmes, particularly given the impact of rapid improvement in technology.

The constant transformation of information in the contemporary world paves the way to transformations in education programmes as well. Since the design of the 2005 mathematics education programme adopting the constructivist approach, there have been several modifications on curriculum (in the years of 2005, 2006, 2009, 2013, 2015, 2017 and 2018). The majority of the studies conducted in this 15-year period is consisted of studies investigating teachers’ perspectives on the implementation of those programmes (Akkaya, 2008; Bal and Artut, 2013; Budak and Okur, 2012). The studies comparing programmes predominantly compare and contrast programmes’ approaches and philosophies and learning fields and outcomes (Delil and Güleş, 2007; Şen, 2017). Yet, there are not any studies examining the extent to which there is a specific emphasis on the use of materials and technology-supported teaching in those modified education programmes. This prompts the question whether or not teaching materials and technologies transform along with the transformation of education programmes. Hence, this study aims to compare the 2009, 2013, and 2018 mathematics education programmes in terms of their teaching materials and the recommended technologies.

Method

The study is conducted through document analysis, the documents of which are compiled from lower-secondary mathematics education programmes of the years of 2009, 2013, and 2018. It explores the types, and the extent, of tangible teaching materials and technologies used in those programmes by examining learning outcomes and explanations drawn from them.

As known, the national education system in Turkey has been transformed into 4+4+4 system within the 2012-2013 academic year. The 4+4+4 system refers to a four-year primary education, followed by a four-year lower-secondary education, and completed with a four-year upper-secondary education. That is, Grade 5 that had been in primary education until 2009 has started to be counted as Grade 1 in lower-secondary education as of 2012. Therefore, during this comparative study, primary mathematics education programme is utilised for the evaluation of Grade 5 of the 2009 mathematics education programme.

Initially, research documents are accessed via the official website of the Board of Education affiliated with the Turkish Ministry of National Education. The documents used in the study are as follows:

- ✓ Primary Mathematics Education, Education Programme for Grades between 6 and 8 (MoNE, 2009)
- ✓ Primary Mathematics Education, Education Programme for Grades between 1 and 5 (MoNE, 2009)
- ✓ Lower-Secondary Mathematics Education, Education Programme for Grades 5-6-7-8 (MoNE, 2013)
- ✓ Mathematics Education Programme (Primary and Lower-Secondary Education, Grades 1, 2, 3, 4, 5, 6, 7 and 8) (MoNE, 2018)

The study explores the types of tangible teaching materials and technologies that are used in education programmes by thoroughly examining each learning outcome, activity sample and explanation. Moreover, each frequency and learning sub-field are noted and reflected onto findings. This study undertakes the comparison based on these data. As a result of the data analysis, the concrete materials in the three programs were classified as mathematics materials, materials from everyday life and papers supplementary to the teaching of mathematics and concrete models.

Instructional technologies are divided into four as calculators, dynamic geometry software, spreadsheet software and information and communication technologies.

Following the examination of programmes, such expressions as "suitable models for…" are used in the explanations of learning outcomes. The majority of those expressions refer to visual models. They are well-presented in the learning outcomes and explanations presented in Figure 1 and Figure 2.

M.6.2.1.3. Explain the meaning of simple algebraic expressions.

At this level, studies on understanding algebraic expressions in the form of $4a, \frac{a}{5}, \frac{2+a}{5}$ *are included.*

For example $a+a+a+a=4a$, $2b=b+b$.

As exemplified below, studies are done with suitable models as well as procedural-based applications such as $\frac{3+c}{5}=\frac{3}{5}+\frac{c}{5}, \frac{d}{5}=\frac{1}{5}.d$

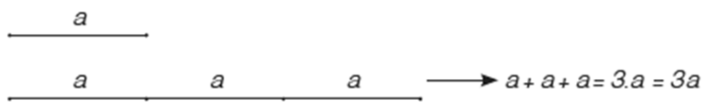

Figure 1. A Sample of Intangible Models in Education Programmes.

Figure 1 uses the model of numerical axis that is presented in the explanation of learning outcome of "…explains simple algebraic expressions" in the 2018 education programme. That is, there is no use of any models.

8.3.1.2. Relates the length of the third side of a triangle to the sum or difference of the two side lengths.

- *Activities to be carried out using concrete models can be included. Studies on understanding triangle inequality can be included with appropriate computer software.*

Figure 2. A Sample of Recommendation for the Use of Tangible Models in Education Programmes.

Figure 2 uses the expression of "tangible model" as seen in the learning outcome of "It relates the sum, or difference, of the length of two sides of a triangle with the length of its third side". If the expression of tangible material is used in the learning outcome, or if any of the tangible materials are explicitly mentioned, their frequency is noted for the use in this study.

Results

This section is split into two and presents the findings of this comparative study on the use of tangible teaching materials and technologies in the 2009, 2013, and 2018 Lower-Secondary Mathematics Education Programmes.

The Comparison of Tangible Teaching Materials Recommended in 2009, 2013, and 2018 Lower-Secondary Mathematics Education Programmes

In this section, the concrete materials recommended for the outcomes in each of the three programs are presented in the form of separate MAXQDA maps. The 2009 program contains materials that are more in number and more diverse. Therefore, one map for each grade level was provided to present the findings in a more understandable way. However, concrete materials in the other two programs are shown on a map, each. Firstly, Figure 3 shows tangible teaching materials and frequencies in the 2009 Lower-Secondary Mathematics Education Programme for Grade 5.

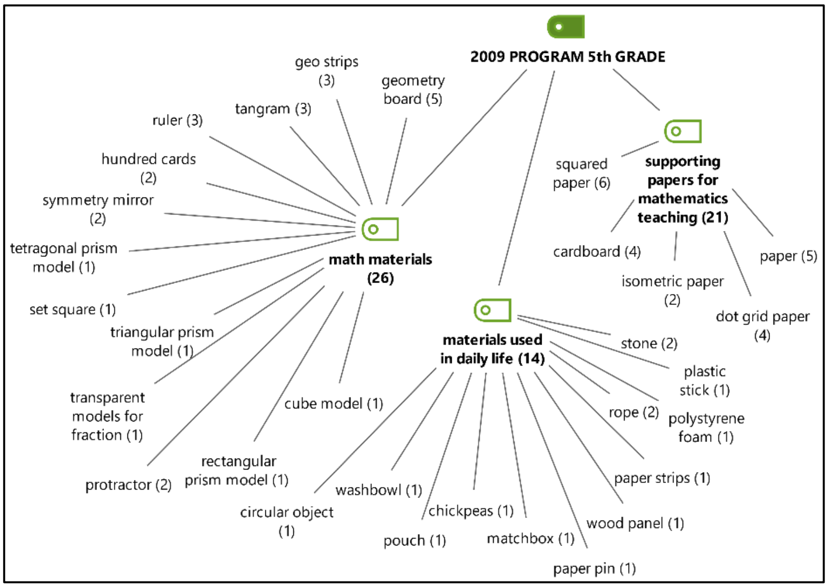

Figure 3. Tangible Teaching Materials used in the 2009 Lower-Secondary Mathematics Education Programme for Grade 5.

Having examined the 2009 programme, it is evident that the programme predominantly contains teaching activities and frequently addresses the tangible teaching materials to be used in those activities. In fact, multiple tangible materials are used in various learning outcomes. Figure 3 shows that among all teaching materials recommended for Grade 5, it is mathematical materials that are more predominantly used. 26 of 61 teaching materials are consisted of such materials as geometry board, symmetry mirror, etc.

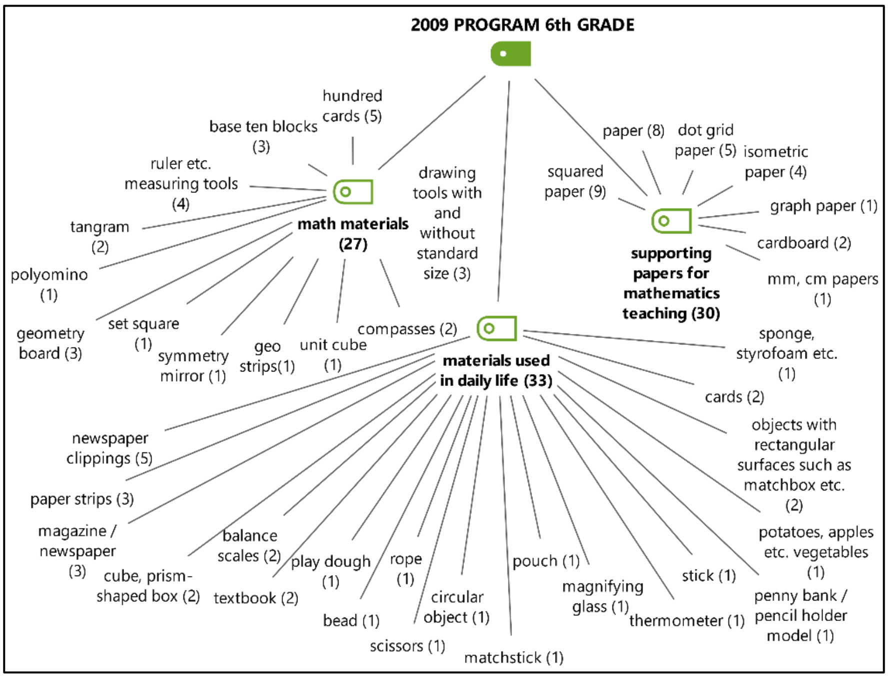

Figure 4. Tangible Teaching Materials used in the 2009 Lower-Secondary Mathematics Education Programme for Grade 6.

Figure 4 demonstrates that tangible teaching materials for Grade 6 is more numerous and diverse (f=90) than for Grade 5. Mathematical materials, materials from everyday life and papers supplementary to the teaching of mathematics have similar quantity. However, it is evident that such materials from everyday life as newspaper clipping and scales are more predominantly used in the 2009 Lower-Secondary Mathematics Education Programme for Grade 6 than Grade 5.

The study shows that the majority of tangible teaching materials is in the 2009 Lower-Secondary Mathematics Education Programme for Grade 7 (f=105). Particularly, it is found that papers supplementary to the teaching of mathematics (e.g. dotted, isometric, and grid papers) are strongly recommended to use in Grade 7. Moreover, as Figure 5 demonstrates, such mathematical tools that may facilitate the teaching of geometry as geometry board, compass, ruler, drawing tools are often recommended in the programme.

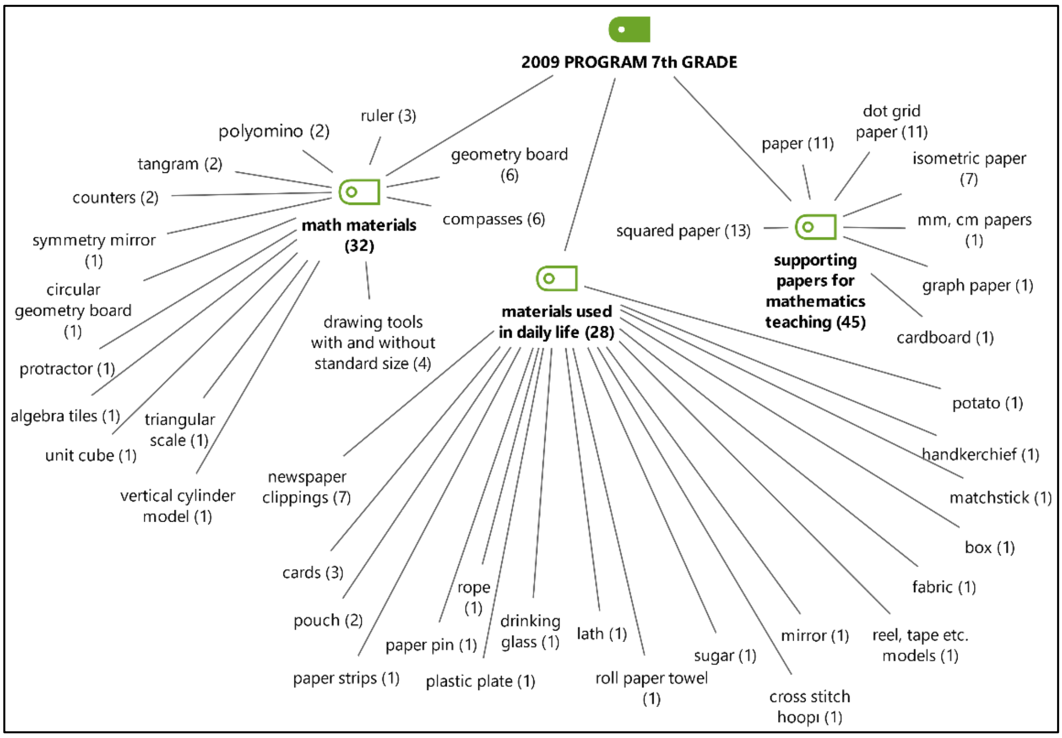

Figure 5. Tangible Teaching Materials used in the 2009 Lower-Secondary Mathematics Education Programme for Grade 7.

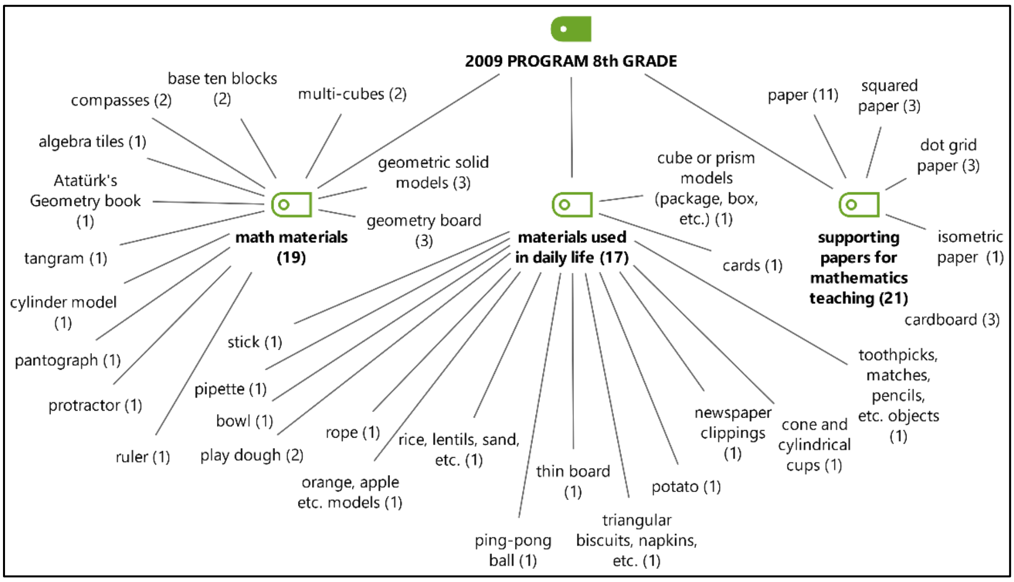

Figure 6. Tangible Teaching Materials used in the 2009 Lower-Secondary Mathematics Education Programme for Grade 8.

The lowest number of tangible teaching materials, which is 57, in the 2009 mathematics education programme is within the programme for Grade 8. In comparison to Grade 6 and Grade 7, Grade 8 has less teaching materials in both quantity and diversity. In fact, Grade 8 uses papers supplementary to the teaching of mathematics and other mathematical materials more densely than materials from everyday life.

As shown in the findings above, the most common use of materials is in Grade 7. Considering material diversity, such widely used materials from everyday life as magazines, newspapers, cardboard box, rope, pins, etc. are used in every level of grade. It is of particular importance that such materials from everyday life are predominantly in use in Grade 6. In the activity samples and explanations of some of the learning outcomes, there are examples of materials from everyday life. For instance, it is suggested in three learning outcomes to use rectangular prism and in two learning outcomes square prism for the mathematics education programme in Grade 5. It is suggested in one of the learning outcomes, which is the outcome of "It measures the volume of a geometrical object with an unstandardised unit", to use cardboard box and cube sugar box to exemplify rectangular prism and cube sugar to exemplify square prism. Overviewing the 2009 programme at large, the use of papers supplementary to the teaching of mathematics such as isometric and grid papers supersedes the use of materials from everyday life and other mathematical materials. Furthermore, teaching tools and equipment to be used in 2009 for Grade 1-5 and Grade 6-8 are presented with their visuals.

Figure 7 below provides the tangible teaching materials stated in the learning outcomes and explanations of the 2013 programme with their frequencies.

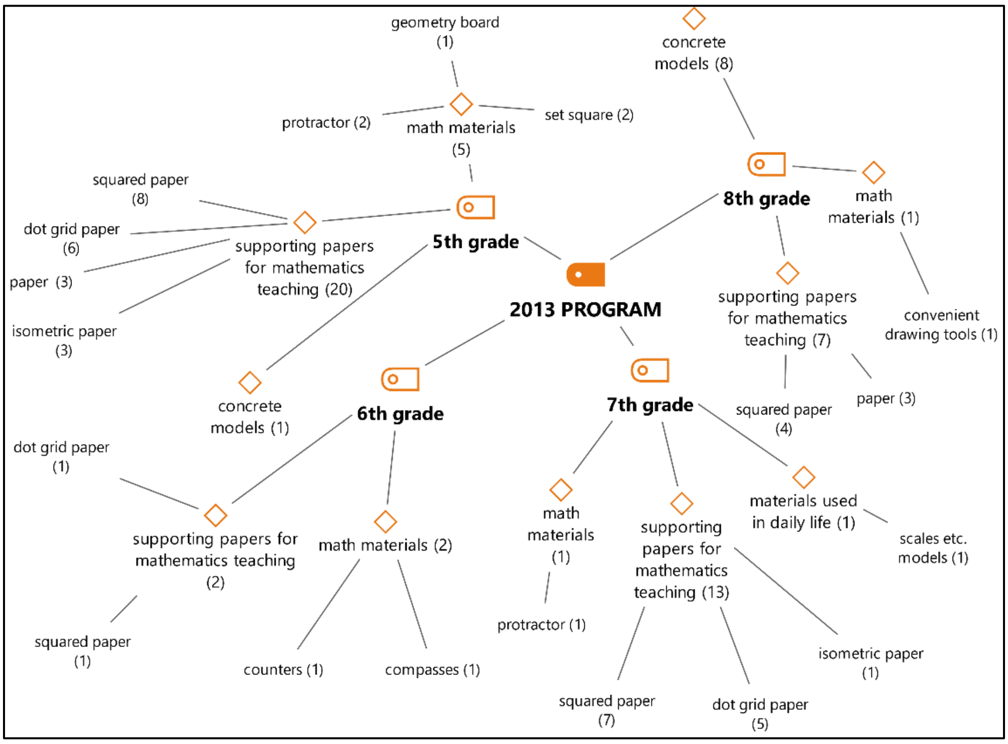

Figure 7. Tangible Teaching Materials used in the 2013 Lower-Secondary Mathematics Education Programme.

Considering Figure 7, it is evident that the most common use of tangible materials in the 2013 programme is in Grade 5 whereas the least common use of those materials is in Grade 6 with the use of four materials only. The vast majority of the recommended materials for Grade 5 is consisted of supplementary papers for the teaching of mathematics. 13 materials of 15 tangible teaching materials recommended for Grade 7 too are supplementary papers for the teaching of mathematics. Whilst there is no use of tangible models for Grade 6 and 7, it is evident that there is one model used in Grade 5 and eight models for Grade 8. There is no explanation regarding the tangible models in the programme. Yet, it is of particular importance that there is one material from everyday life (i.e. scales and other equilibria) used only in Grade 7.

Figure 8 presents tangible teaching materials stated in learning outcomes and explanations of the 2018 programme.

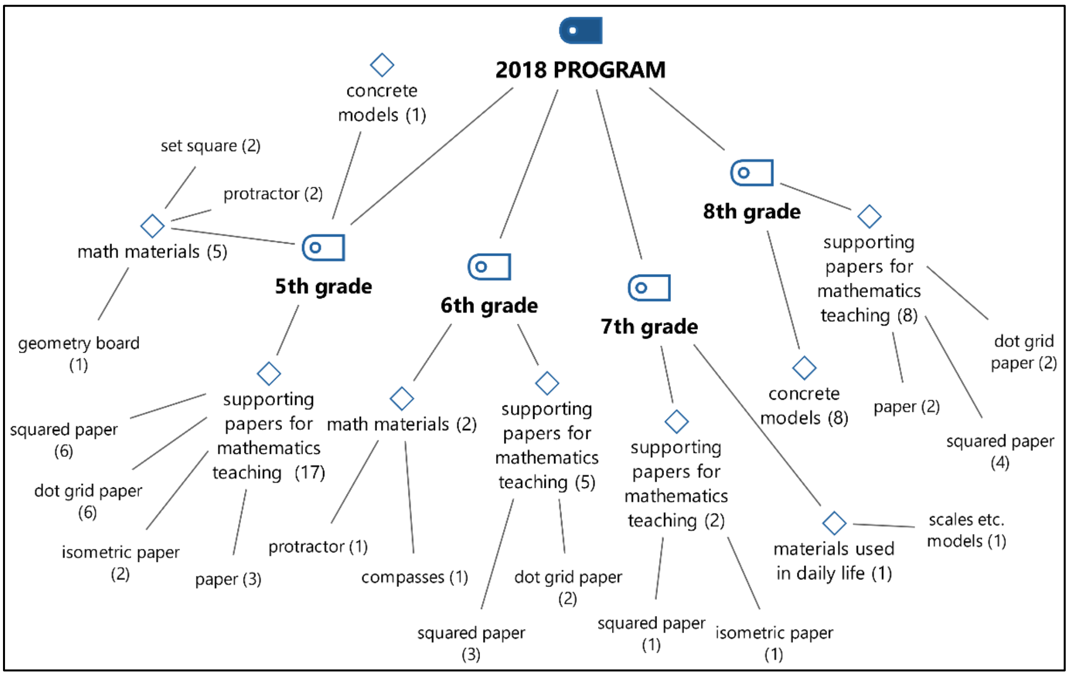

Figure 8. Tangible Teaching Materials used in the 2018 Lower-Secondary Mathematics Education Programme.

As seen in Figure 8, the most common use of tangible materials is in Grade 5 with 23 materials in total whereas the least common use of those materials is in Grade 7 with only three. Considering the recommended tangible materials, it is seen that there is quite a low number of tangible materials in the programme, among which the key materials are mainly papers supplementary to the teaching of mathematics such as grid papers, dotted papers, and so forth. In the 2013 programme, nine tangible teaching materials are used, eight of which are for Grade 8.

When comparing tangible teaching materials for the 2009, 2013, and 2018 programmes, it is explored that the majority of materials both in frequency and in diversity remains in the 2009 programme. Also, the total number of materials in the 2013 programme is higher than in the 2018 programme. That is, the number of the recommended tangible materials have gradually diminished. In addition, the 2009 programme comprises more materials from everyday life than the 2013 and 2018 programmes do, whilst the latter two have nearly no materials at all from everyday life. Instead, they mainly have papers supplementary to the teaching of mathematics. The below section will present the findings with regards to the teaching of such mathematical subjects that require the use of teaching materials in different years.

Table 1.

The use of tangible teaching materials in all three education programmes for Grade 5

Course-Subjects	2009	2013	2018
Polygons/Triangles and Quadrangles	+	+	+
Area Measurement	+	+	+
Geometrical Objects	+	+	+
Fractions	-	-	-
Decimal Notation	-	-	-
Percentages	-	-	-
Basic Geometrical Concepts and Constructions	+	+	+
Data Collection and Assessment	+	-	-

In Table 1, those indicated with "+" refer to the use of at least one tangible material in a given subject, and those indicated with "-" refer to the use of no tangible materials in a given subject.

Considering Grade 5, it is shown that there are tangible teaching materials in each of the three education programmes as stated in the learning outcomes of the subjects such as basic geometrical concepts and constructions, triangles and quadrangles, area measurement, and geometrical objects. However, there are not any tangible materials in any of the three education programmes for the subjects namely fractions, decimal notation, and percentages.

Table 2.

The use of tangible teaching materials in all three education programmes for Grade 6

Course-subjects	2009	2013	2018
Geometrical Objects	+	+	+
Area Measurement	+	+	+
Natural Numbers	+	-	-
Whole Numbers	+	+	-
Fractions	+	-	-
Decimal Fractions	+	-	-
Percentages	+	None*	None
Lines, Line Segments and Rays	+	None	None
Angles	+	-	+
Polygons	+	None	None
Congruence and Similarity	+	None	None
Transformational Geometry	+	None	None
Length Measurement	+	None	None
Volumetric Measurement	+	-	-
Patterns and Relationships	+	-	None
Equilibrium and Equation	+	None	None
Multipliers and Factors	+	-	-
Circles	None	+	+
Sets	-	None	-

*This subject is not taken part in the related grade level.

Considering Table 2, it is evident that there are tangible teaching materials merely used for area measurement and geometrical objects in each of the education programmes for Grade 6. Having looked at which types of materials recommended in which education programmes for the teaching of area measurement in Grade 6, it is found that matchbox, eraser, grid papers or graph papers, and quadratic sets are recommended in the 2009 education programme. Papers supplementary to the teaching of mathematics such as dotted or grid papers are mainly recommended in the 2013 and 2018 education programmes. There is a similar trend for other years in the said programmes.

Moreover, there is at least one tangible teaching material for nearly all of the course-subjects for Grade 6 in the 2009 programme whereas the recommendation of tangible materials in the 2013 and 2018 is less than the 2009 programme.

Table 3.

The use of tangible teaching materials in all three education programmes for Grade 7

Course-subjects	**2009**	**2013**	**2018**
Operations with Whole Numbers	+	-	-
Equilibrium and Equation	+	+	+
Displays of Objects from Different Sides	+	+	+
Rational Numbers	+	-	-
Operations with Rational Numbers	-	-	-
Ratio and Proportion	+	-	-
Percentages	-	-	-
Algebraic Expressions	+	None	-
Lines and Angles	+	+	-
Polygons	+	-	-
Circles and Circular Regions	+	-	-
Data Processing/Analysis	-	-	-
Transformational Geometry	+	+	None
Congruence and Similarity	+	None	None
Angle Measurement	+	None	None
Tetragonal Areas	+	-	-
Patterns and Relationships	+	None	-
Geometrical Objects	+	None	None

As seen in Table 3, there is at least one tangible teaching material for such course-subjects as equilibrium and equation, and displays of objects from different sides in each of the three education programmes whereas there are more materials for other course-subjects in the 2009 education programme. For instance, for the course-subject of rational numbers, none of the four learning outcomes of the 2018 programme, none of the four learning outcomes of the 2013 programme, and two of the three learning outcomes of the 2009 programme have tangible teaching materials. The tangible materials recommended in the 2009 (e.g. cards, symmetry mirror, calculator) are considered as useful materials as they are cost-effective, more accessible, and uncomplicated materials. In addition, the learning outcomes of the 2009 programme explain how to use those materials recommended.

Table 4.

The use of tangible teaching materials in all three education programmes for Grade 8

Course-subjects	**2009**	**2013**	**2018**
Square Roots	+	-	-
Real Numbers	+	-	-
Triangles	+	+	+
Geometrical Objects	+	+	+
Patterns and Embroidery	+	None	None
Projection	+	None	None
Algebraic Expressions	+	-	-
Inequalities	-	-	-
Equation	+	-	-
Simple Probability	None	-	-
Transformational Geometry	+	+	+
Congruence and Similarity	None	+	+
Data Organisation/Assessment/Interpretation	+	-	-
Multipliers and Factors	None	-	-
Exponential Notation	-	-	-
Probability Calculations (Combination, Permutation)	-	None	None
Types of Probability	-	None	None

Table 4 shows that it is the 2009 education programme which has the majority of tangible teaching materials used in Grade 8. Each of the education programmes regarding such course-subjects as triangles, geometrical objects, and algebraic expressions has at least one tangible material. The course-subjects which do not use tangible teaching materials in the 2009 education programme are inequalities, exponential notation, probability calculations, and types of probability. Apart from these four course-subjects, there is at least one tangible teaching material in all other course-subjects demonstrated in Table 4. There are tangible materials in five of six learning outcomes in the 2013 education programme for the course-subject of transformational geometry. It is suggested in all of those six outcomes to use standardised grid and dotted papers to undertake activities. In the 2009 programme, however, it is suggested to use such materials from everyday life as mirror and books in addition to the aforementioned materials. For instance, it is aimed to teach rotation to pupils in Grade 7 by using potato print. Yet, the 2018 lower-secondary mathematics education does not comprise rotation as an aim.

Comparison of the 2009, 2013 and 2018 Lower-Secondary Mathematics Education Programmes In Terms of the Use Of Teaching Technologies

First of all, which technologies are used in which program are listed below.

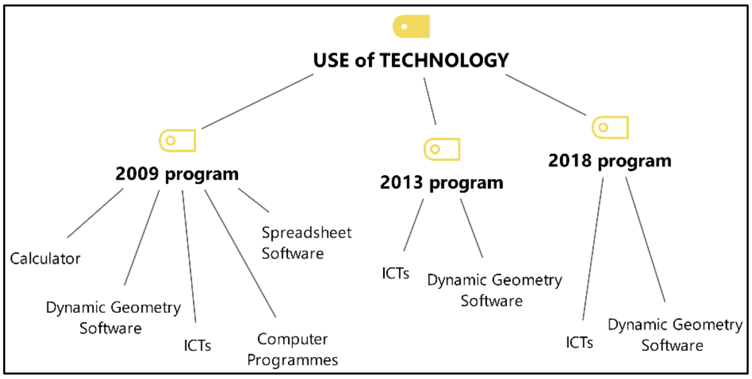

Figure 9. Technologies Used in Education Programs.

As seen in Figure 9, while only ICT and dynamic geometry software were included in the 2013 and 2018 programs, the use of more types of technology was suggested in the 2009 program.

Having examined the concerned programmes, it is explored that the 2009 and 2013 programmes recommend to use calculators and dynamic geometry software in the introductory part of the program. Despite this, the use of a calculator was recommended in the outcomes of the 2009 program, while not recommended in the outcomes of the 2013 program. Besides, the 2018 programme does not recommend the use of calculator anywhere. Instead, it mainly recommends dynamic geometry software. Table 5 below presents the numbers of learning outcomes comprising the recommendation of dynamic geometry software in accordance with levels of grade.

Table 5.

Numbers of Learning Outcomes recommending Dynamic Geometry Software in the Lower-Secondary Mathematics Education Programmes

Level of Grade	**Programmes**		
	2009	**2013**	**2018**
Grade 5	-	3	2
Grade 6	3	1	1
Grade 7	6	3	1
Grade 8	2	1	3
Total	11	8	7

In Table 5, it is shown that there are no recommendations in any of the learning outcomes for Grade 5 to use dynamic geometry software in the primary mathematics education programme for Grades 1 to 5. However, the title of "5.6. The use of technology must be effective" states that dynamic geometry software can also be used in the teaching of mathematics. The 2009 programme emphasises the use of dynamic geometry software relatively more than other programmes, despite that it is not used in Grade 5. Whilst the 2009 education programme recommends the use of dynamic geometry software for six learning outcomes in Grade 7, the 2018 makes the same recommendation for only one learning outcome. The 2013 and 2018 education programmes recommend the use of dynamic geometry software within the explanation of "Activities shall be undertaken through dynamic geometry software" whereas the 2009 programme recommends it within the explanation of "Dynamic geometry software may be used". Some of the explanations of learning outcomes provide the aim within the use of dynamic geometry software. For instance, the following two are examples of those explanations: "Dynamic geometry software shall be used to measure the relationship between the central angle and inscribed angles" and "Dynamic geometry software shall be used to construct polygons".

Table 6 below demonstrates some of the learning sub-fields for which dynamic geometry software are recommended to use.

Table 6.

Learning Sub-fields in the Lower-Secondary Mathematics Education Programme in which Dynamic Geometry Software is used

Grade	**Programmes**		
	2009	**2013**	**2018**
Grade 5	-	-Triangles and Quadrangles -Geometrical Objects	-Basic Geometrical Concepts and Constructions -Geometrical Objects
Grade 6	-Polygons, -Congruence and Similarity -Transformational Geometry	-Geometrical Objects and Volumetric measurement	-Geometrical Objects
Grade 7	-Polygons - Congruence and Similarity -Circles and Circular Regions -Transformational Geometry	-Lines and Angles -Transformational Geometry	-Lines and Angles
Grade 8	-Triangles -Transformational Geometry	-Triangles	-Triangles -Transformational Geometry

Table 6 above demonstrates that all of the learning outcomes recommending the use of dynamic geometry software in the 2009 lower-secondary mathematics education programme are in the sub-fields of the learning field of "Geometry". Recommendations in the use of dynamic geometry software are made in the learning field of "Geometry and Testing" in the other two programmes.

Comparing the 2009, 2013 and 2018 programmes in terms of the use of calculator, it is found that the use of calculator is recommended in the 2009 programme for some of the learning outcomes. Table 7 below demonstrates the number of learning outcomes and sub-fields of those learning outcomes recommending the use of calculator.

Table 7.

Numbers of Learning Outcomes and their Sub-Fields in the 2009 Education Programme in which calculators are recommended.

Level of Grade	**Number of Learning Outcomes**	**Learning Sub-Fields**
Grade 5	4	- Addition with Natural Numbers - Subtraction with Natural Numbers - Division with Natural Numbers - Circumference
Grade 6	4	- Natural Numbers - Decimal Fractions - Patterns and Relationships
Grade 7	2	- Rational Numbers - Ratio and Proportion
Grade 8	3	- Exponential Numbers - Area Measurement on Triangles - Triangles
Total	13	

Considering Table 7, whilst the learning outcomes for the learning field of "Numbers" are more predominant (f=10) in the 2009 lower-secondary mathematics education programme, it is also found that the use of calculator is recommended for a learning outcome in each of those learning fields in that programme, namely "Algebra", "Geometry", and "Testing". Calculator is used for calculation of trigonometrical ratio of angles, the display of "+/-" and square-root, the indication of incorrect result for incorrect sequence of operations, and the identification of root numbers on numerical axis.

In Table 7, the use of calculator is merely examined in the 2009 mathematics education programme because there are no direct recommendations for the use of calculators for any other learning outcomes in other years' programmes. Even though it is stated in the 2013 programme that calculator is an important tool in the teaching of mathematics, there are no direct recommendations for the learning outcomes of the programme. The use of calculators is recommended neither in the explanations nor in the learning outcomes of the 2018 programme.

Calculators are recommended in the 2009 programme both in the explanations of learning outcomes and in some of the course plan samples. For instance, the use of calculator is not recommended in the explanation of the learning outcome of "It explains the relationship between square numbers and their square roots with models and identifies their square roots". Yet, the use of calculator is recommended in a course plan suggested for this learning outcome to identify the approximate value of $\sqrt{11}$.

Moreover, in addition to dynamic geometry software and calculators, the 2009 programme recommends to utilise 'computer programmes' for the identification and comparison of different representations of the same data for the learning outcome of "It displays and interprets data with relevant statistical representations". Similarly, the 2009 programme suggests to use 'spreadsheet software' for the teaching of three learning outcomes.

Considering the three programmes examined in this study, there are certain learning outcomes in which relevant information and communication technologies (ICTs) are recommended without stating which ICTs will be used and how. That is, it is teachers' responsibility to make the decision on whether ICTs will be used or, if so, which ICTs will be used. This recommendation is mentioned only once in the 2009 programme whereas it is made multiple times in the 2013 and 2018 programmes. Table 8 demonstrates the results of comparison between levels of years for those two programmes.

Table 8.

Numbers of Learning Outcomes comprising ICTs in the 2013 and 2018 Lower-Secondary Mathematics Education Programmes

Level of Grade	**Programmes**	
	2013	**2018**
Grade 5	2	2
Grade 6	1	1
Grade 7	4	4
Grade 8	11	8
Total	18	15

As shown in Table 8, there are equal numbers of learning outcomes recommending the use of ICTs for Grades 5, 6, and 7 in the 2013 and 2018 programmes. Considering those learning outcomes, there seems to be learning outcomes comprising the same course-subject. For instance, the expression of "There may be interactive activities with the use of relevant ICTs" is identically used for the learning outcome of "*It develops surface of rectangular prism and determines whether different surface developments are of the concerned rectangular prism or not*" in the 2013 education programme and for the learning outcome of "*It develops surface of rectangular prism and determines whether different surface developments are of the concerned rectangular prism or not*" in the 2018 education programme. There are 11 learning outcomes for Grade 8 in the 2013 education programme and eight outcomes for the 2018 programme. The expression of "There may be activities to identify triangular inequalities with relevant computer software" is used for the learning outcome of "*It relates the addition or subtraction of the length of two sides of a triangle with the length of its third side*" both in the 2013 and in the 2018 education programme. Table 9 below shows the learning sub-fields recommending the use of ICTs.

Table 9.

Learning Sub-Fields using ICTs in the 2013 and 2018 Lower-Secondary Mathematics Education Programmes

Level of Grade	**Programmes**	
	2013	**2018**
Grade 5	-Geometrical Objects -Generation of Research Questions, Data Collection, Organisation and Display	-Geometrical Objects -Data Collection and Assessment
Grade 6	-Geometrical Objects and Volumetric Measurement	-Geometrical Objects
Grade 7	-Displays of Objects from Different Sides -Generation of Research Questions, Data Collection, Organisation, Assessment and Interpretation	-Data Analysis -Displays of Objects from Different Sides
Grade 8	-Linear Equations -Transformational Geometry -Congruence and Similarity -Geometrical Objects -Data Organisation, Assessment and Interpretation	-Linear Equations -Geometrical Objects -Congruence and Similarity

Table 9 shows that the learning sub-fields recommending the use of relevant ICTs are the fields of Geometry and Testing, and Data Processing. It is explored that the learning outcome of "*It explains the slope of a line with models, and relates linear equations and graphs with the slope*", which recommends the use of relevant ICTs, is the only learning outcome in the learning field of "Algebra" under the learning sub-field of "Linear Equations". It is of particular importance that there are no recommendations for the use of ICTs in any of the learning outcomes of such fields as "Probability" and "Numbers and Operations".

Discussion and Conclusion

This section will present the conclusions drawn from this study examining the 2009, 2013, and 2018 lower-secondary mathematics education programmes in terms of the use of tangible teaching materials and information and communication technologies. It also provides suggestions based on the conclusions.

Following on Şen's (2017) research, despite that the use of tangible materials is a common feature of all three programmes, the 2009 mathematics education programme has more numerous and more diverse tangible materials in comparison to the other two programmes. According to the findings of this study, this derives from the fact that there are activity samples and that there are high numbers of learning outcomes. Particularly, it is evident that there are a large number of materials for Grade 6 and 7. Given that it is evidently shown in many studies that the use of tangible materials is highly effective in the teaching of mathematics (Bozkurt and Akalın, 2010; Kutluca and Akın, 2013; Körükcü, 2008; Manches, O'Malley and Benford, 2010), it can be argued that the 2009 programme is one of those effective programmes in that aspect. Moreover, the 2009 programme is a programme that comprises detailed explanations of learning outcomes and descriptions in which phase, and how, materials will be used. Within the 2013 and 2018 programmes, merely teaching (not learning) outcomes and short explanations are provided, and hence the use of materials and technologies are of a less concern for studies. As a result of this, the decision how to teach most of the teaching outcomes and how to use materials and technologies mainly remains with teachers. However, many studies suggest that materials are not as effective as anticipated if teachers do not know how to use them (Bozkurt and Şahin, 2013; Çakıroğlu and Yıldız, 2007; Fidan, 2008; Stein and Bovalino, 2001). Similarly, Brown, McNeil and Glenberg (2009) also argue that teachers may mistakenly select inappropriate materials if the responsibility is solely given to them.

Although it is not imperative to use tangible materials in the teaching of mathematics, it is accepted as a useful strategy for students (Baroody, 1989). Therefore, it can be argued that teachers are far from being encouraged to use materials when there is a reduction in recommendations for the use of materials in the 2013 and 2018 lower-secondary mathematics education programmes. Even though there is an effect of 10% alleviation of the 2018 programme compared to the 2013 programme and of 25% of the 2013 compared to the 2009 programme resulting in this situation (Şen, 2017), it can be suggested that another reason precipitating this situation is the change within levels of years for certain learning sub-fields. For instance, whilst the learning sub-field of

"Congruence and Similarity" was previously taught in Grade 6 and 7, it is taught in Grade 8 in the 2013 and 2018 programmes. Nevertheless, there is a reduction in the recommendations for the use of tangible materials in those two programmes in comparison to the 2009 programme. Henceforth, it can be argued that both programmes are less encouraging for teachers to use materials in comparison to the 2009 programme.

Considering the education programmes compared, the 2013 and 2018 programmes mostly recommend such models as dotted papers, purposive models, and grid papers whereas the 2009 additionally recommends such models from everyday life as magnifiers, play dough, ropes, and beams. Given that mathematics is taught in order to equip pupils to develop concepts based on their everyday life (Karakuş, 2015), the 2009 education programme stands out among all three. Furthermore, the 2009 mathematics education programme frequently recommends such materials to be used as symmetry mirror, geometrical stripes, geometry board, base ten blocks, counting scales, tangrams, and algebra tiles. The 2013 and 2018 programmes less frequently recommend these materials. Though, it is known that the use of mathematical materials so much better equips pupils as to use their creativity in order for them to better comprehend mathematical concepts (Furner and Worrell, 2017).

This study compares the 2009, 2013, and 2018 lower-secondary mathematics education programmes in terms of not only the use of tangible teaching materials but also the use of teaching technologies. All three programmes aim to equip pupils with the necessary skills to effectively use information technologies. In so doing, three types of technology use are suggested within the learning outcomes of all three programmes. Those include "dynamic geometry software", "calculators", and "relevant information and communication technologies". In addition, only the 2009 program included spreadsheet software. Considering the dynamic geometry software, it is found in the learning outcomes that the 2009 programme recommends the use of the said software more frequently than the 2013 and 2018 programmes. Dynamic geometry software is recommended for some of the learning sub-fields under the learning field of geometry in the 2009 programme, and under the learning fields of geometry and testing in the other two programmes. As Cantürk Günhan and Açan (2016) unearth in their meta-analysis focusing on the findings of studies between the years of 2005 and 2016 looking at the use of dynamic geometry software in Turkey, the use of the said software is effective in pupils' geometrical attainment. Henceforth, it is of particular importance that there is a reduction in the learning outcomes of the 2013 and 2018 programmes recommending the use of dynamic geometry software compared to the 2009 programme, even though the opposite has been anticipated.

Recommendations

Considering the recommendations for the use of calculator in all three programmes, it is found that the use of calculator is not mentioned at all in the 2018 education programme whereas it is only mentioned in the explanations of the 2013 programme as an effective tool for the teaching of mathematics without being recommended. The 2009 programme, on the other hand, predominantly recommends the use of calculator for mainly the learning field of "Numbers" in general, and of "Algebra", "Geometry", and "Testing" in particular. In those learning fields, some crucial issues are specifically underlined. Those include the calculation of trigonometrical ratio of angles, the display of "+/-" and square-root, the indication of incorrect result for incorrect sequence of operations, and the identification of root numbers on numerical axis. Indeed, calculator is a teaching material that ought to be used in, and is recommended for, a wide range of levels of education, from kindergarten to university (NCTM, 2000). It is worth noting that such an important and easily accessible material as calculator is not mentioned at all in the 2018 programme that is still in operation.

The 2013 and 2018 programmes recommend not only the use of dynamic geometry software and calculators but also of "relevant ICTs". The way to select and use those materials, without the information on how to use them, will be teachers' responsibility. Yet, it is known that if technologies are used in the educational settings without being organised prior to their use, they are likely to generate some problems (Doğru and Aydın, 2017; Göktaş, Yıldırım and Yıldırım, 2008). Moreover, it is disputable whether or not teachers are sufficiently competent to use teaching technologies in their classes, given that there are certain studies demonstrating that teachers and teacher students in Turkey do not feel competent in the use of those technologies (Mete, 2008; Pamuk, Ülken and Dilek, 2012; Tatlı and Akbulut, 2017) and that they find their skills on average to be able to use them (Kara, 2011).

Having looked at the frequency of recommendations for the use of teaching materials and technologies and at the diversity of those materials and technologies, the research findings evidence that the 2009 mathematics education programme, which is the earliest programme, is more effective than the other two. The 2009 programme aims to equip pupils to self-sufficiently learn what is aimed in those learning outcomes, instead of pushing them to memorise the given knowledge. Following on this objective, it is suggested for future education programmes that teachers need to be clearly instructed with regards to the purpose within the use of tangible materials and information technologies, and the know-how of their use. This may enable teachers of mathematics, who are expected to follow the instructions provided within education programmes, to use materials and information technologies more often. Also, it may be useful to situate mathematics, which has a central importance in everyday life, at future education programmes by supplementing it with such tangible materials from everyday life that are frequently used and easily accessible. Teachers of mathematics can benefit from in-service training in order to be equipped with necessary skills to use tangible materials and information technologies, currently used in the 2018 lower-secondary mathematics education programme. Additionally, the content of the module of *Teaching Technologies* given in the current undergraduate degree programmes of primary mathematics education can be enhanced, and more information can be given to teacher students with regards to teaching technologies and implementations that are used in current education programmes.

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